NASA Tech Briefs

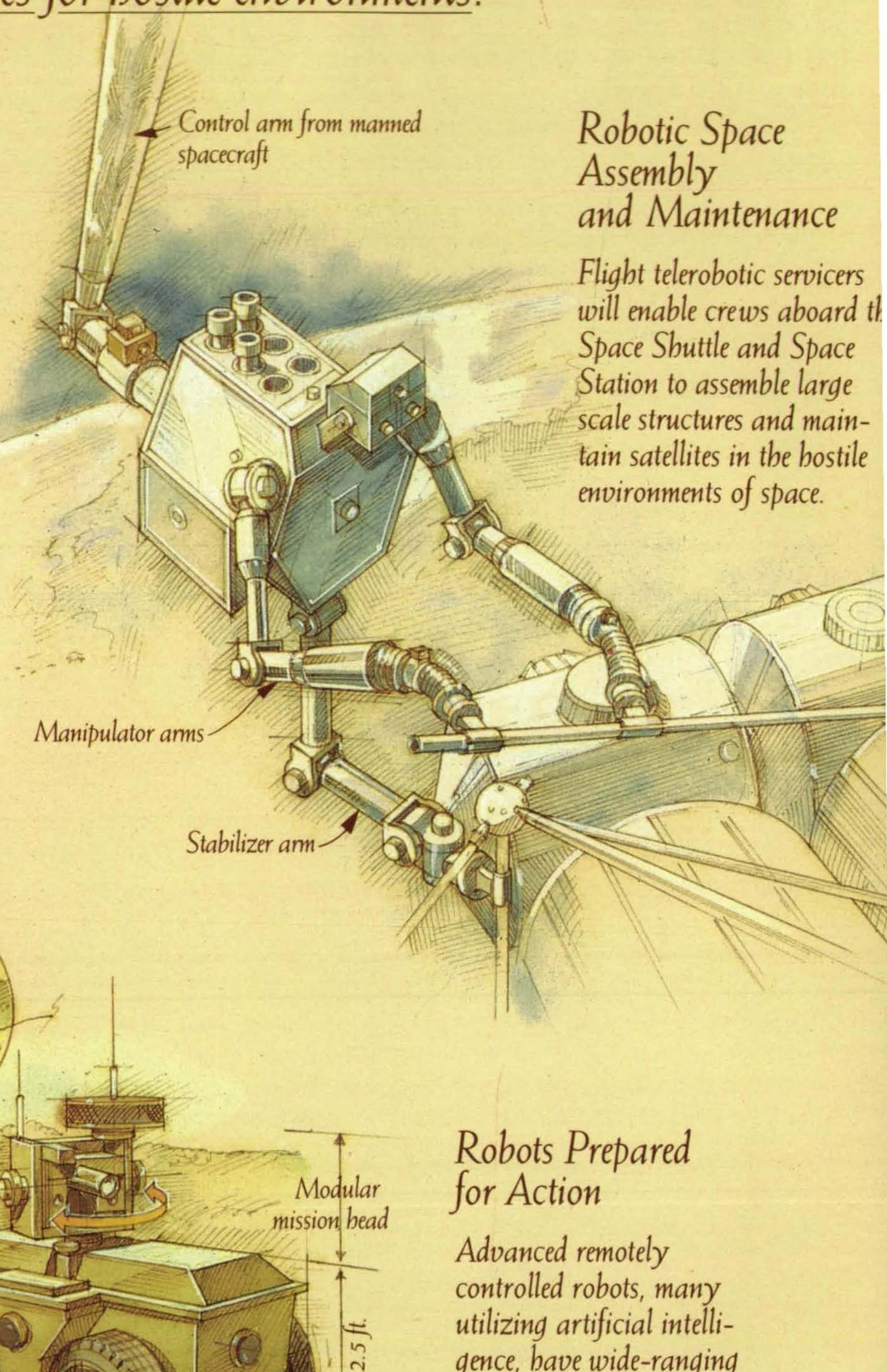
Transferring Technology to
American Industry and Government

October 1988
Volume 12 Number 9

The Evolution of "Smart" Materials

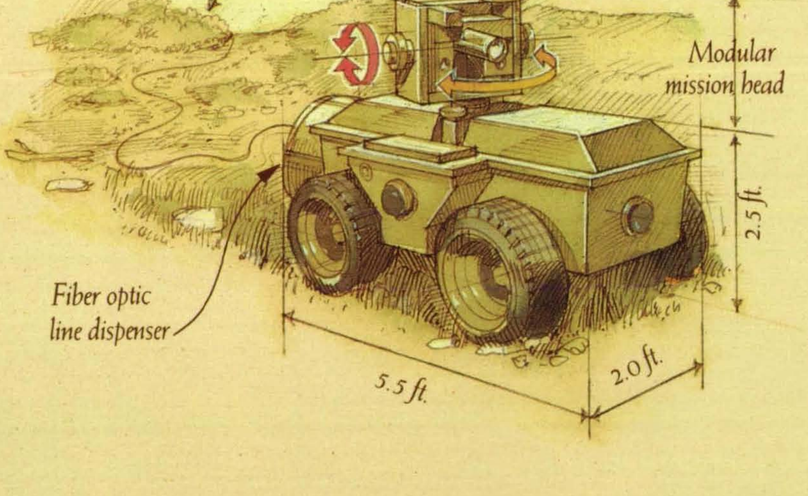
High-technology machines for hostile environments.

On the ground, in the air, in space, beneath the sea – wherever hostile or hazardous conditions exist, new generations of independently functioning, "intelligent" machines are being created to assist man's performance in these adverse situations. Many of these machines, including autonomous and remotely controlled land vehicles, aircraft, spacecraft and submersibles, will rely heavily on advanced technologies in artificial intelligence and robotics being developed at Martin Marietta.



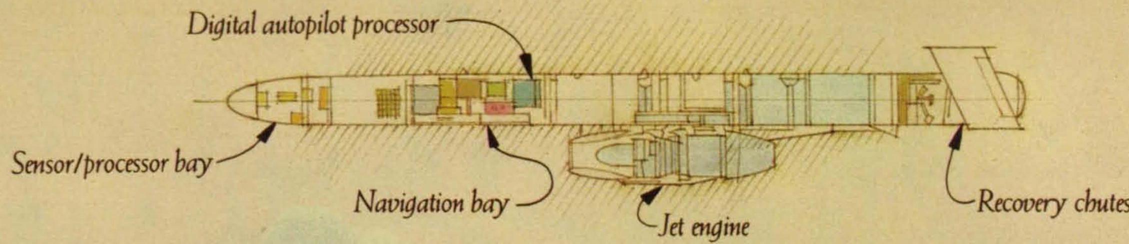
Robotic Space Assembly and Maintenance

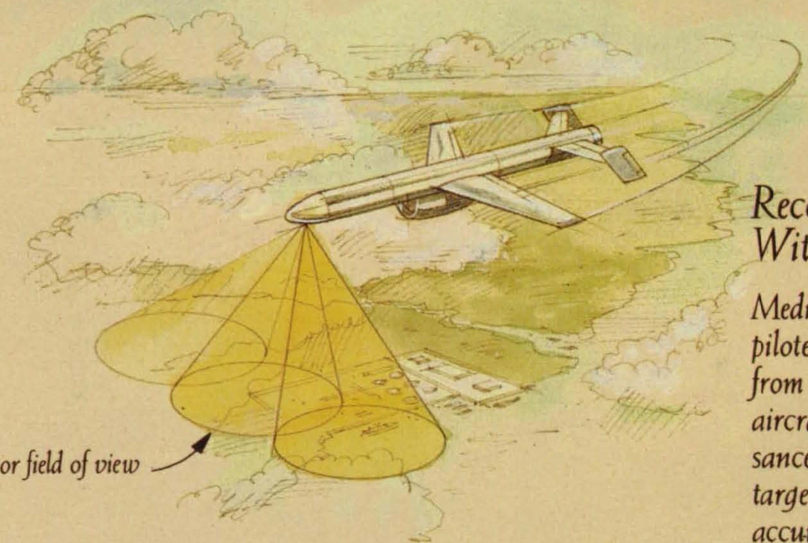
Flight telerobotic servicers will enable crews aboard th Space Shuttle and Space Station to assemble large scale structures and maintain satellites in the hostile environments of space.



Robots Prepared for Action

Advanced remotely controlled robots, many utilizing artificial intelligence, have wide-ranging military applications. Vehicles for reconnaissance, target designation, weapons platforms, resupply and medical evacuation will improve troop survivability and provide force multipliers for battlefields of the future.



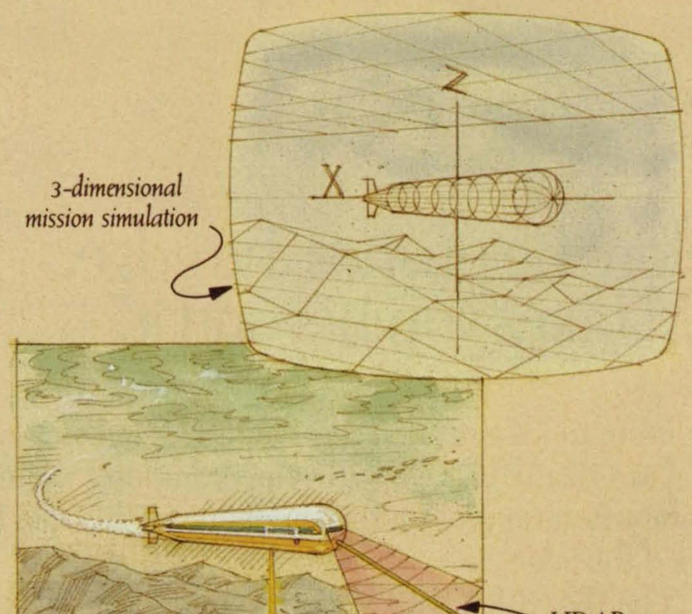


Reconnaissance Without Risk

Medium-range, remotely piloted aircraft launched from the ground or other aircraft will fly reconnaissance missions and identify targets with pinpoint accuracy.

A "MUST" for Testing Underwater Technology

The Mobile Undersea Systems Test Laboratory – MUST – is an unmanned submersible to test autonomous underwater vehicle technologies and systems under sea environment conditions. Funded by Martin Marietta, MUST will demonstrate and prove sensor technology and signal processing to aid undersea navigation, seabed surveys and reconnaissance.



MUST autonomous testing

MASTERMINDING TOMORROW'S TECHNOLOGIES

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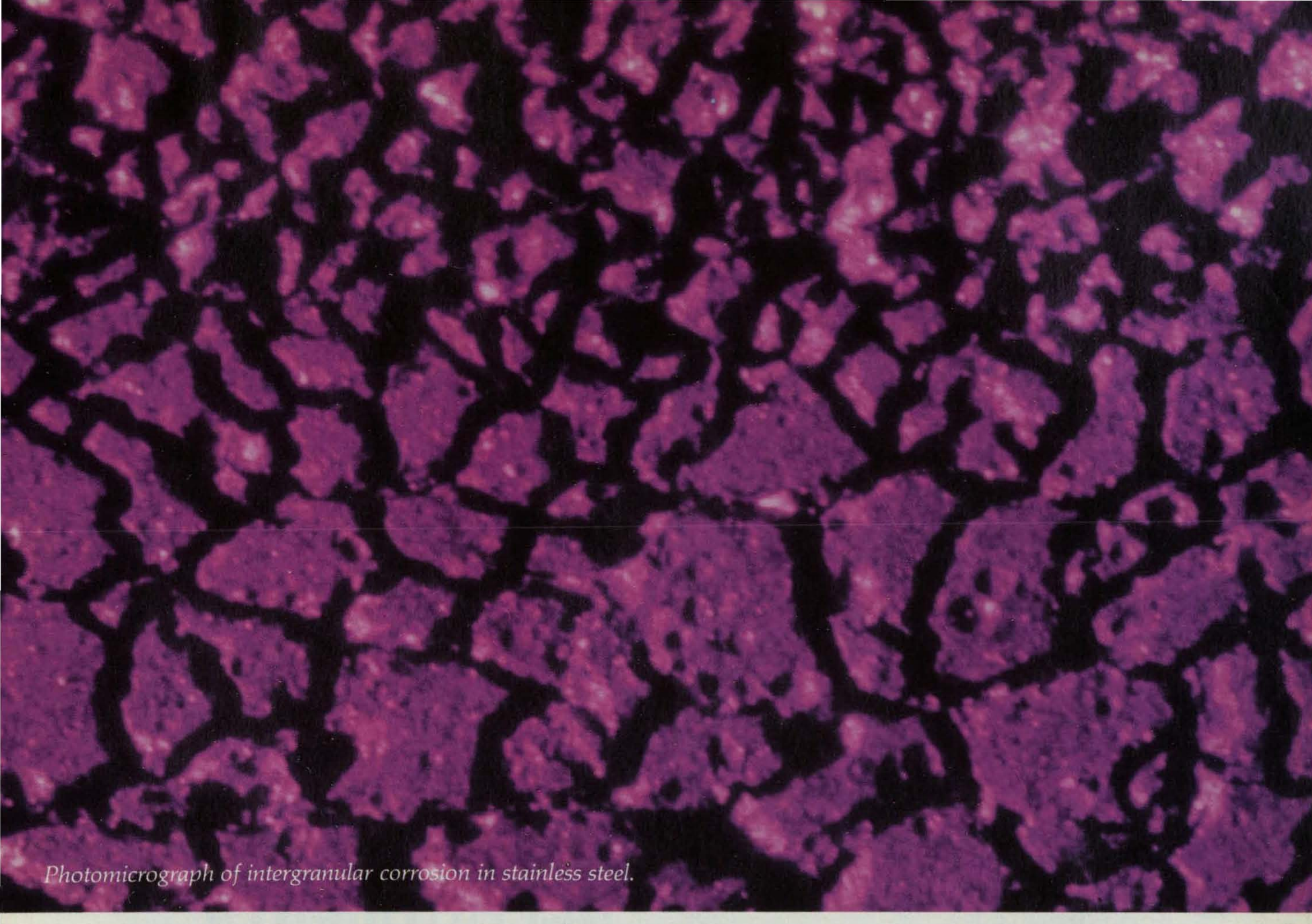
IBM. The Bigger Picture


Photomicrograph of intergranular corrosion in stainless steel.

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Acid Corrosion		✓				✓	✓	✓	✓	
Alkali Corrosion	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Salt Corrosion	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Chloride Stress-Corrosion Cracking	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
High Temperature Corrosion			✓	✓	✓	✓	✓			✓
Pitting					✓	✓	✓	✓	✓	

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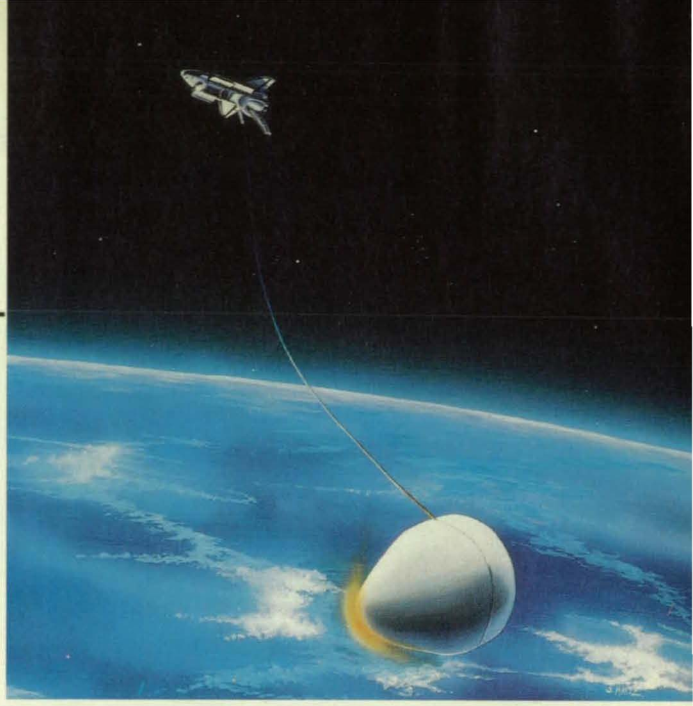
NASA Tech Briefs
National Aeronautics and
Space Administration

OCTOBER 1988
Volume 12 Number 9

SPECIAL FEATURES

TECHNICAL SECTION



Sensor-embedded "smart" structures could play an important role in future space research projects such as the Shuttle Tethered Aerothermodynamic Research Facility (pictured above), which will study the interaction of the atmosphere with satellites at hypersonic speeds. Fiber optic sensors embedded in the tether would offer a cost-effective way to monitor the line's health and performance. See page 20. *(Photo courtesy NASA)*

DEPARTMENTS

On The Cover: A microscopic view of ceramic fibers used as reinforcement in composite materials. This month's feature story describes the evolution of a new species of composite that will make structures inherently "smart." Turn to page 20. *(Photo courtesy the Carborundum Company, Niagara Falls, NY)*

A high school honor student and a plastics industry engineer will attend the U.S. Space Camp as winners in NASA Tech Briefs' 1988 Letter Writing Contest. A special contest section begins on page 9. *(Photo courtesy U.S. Space Camp)*

ABP BPA

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POSTMASTER: please send address changes to NASA Tech Briefs, 41 E. 42nd Street, Suite 921, New York, NY 10017-5391.

NASA Tech Briefs

National Aeronautics and Space Administration

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Published by .... **Associated Business Publications**
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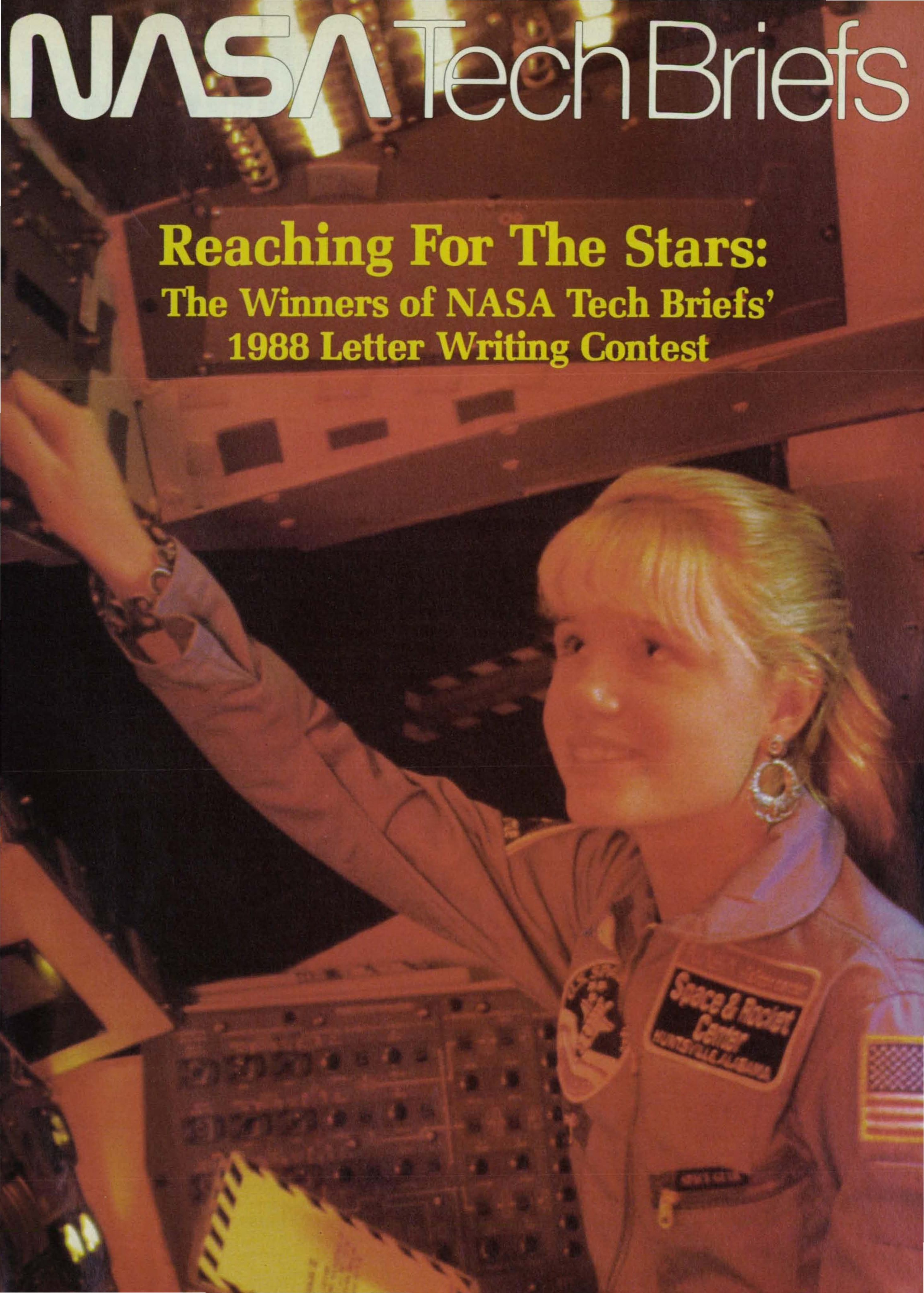
NASA Tech Briefs

Reaching For The Stars:
The Winners of NASA Tech Briefs' 1988 Letter Writing Contest



Editorial Notebook

An Overwhelming Response

The quantity and quality of your messages to your elected representatives have been overwhelming. Five hundred and seventy-three people wrote approximately 1000 letters to politicians from President of the United States on down. They have been eloquent, inspiring, and touching. They are all winners. Every one.

From the first week the letters started pouring in, I have wondered how I had the temerity to say that we would select the winning entries. I plead temporary insanity. After you read the following letters, I think you'll agree that only a madman would have offered to say one is better than another. All of the letters are winners, and choosing among them was extremely difficult for us. I wish we had enough space to print every letter and enough money to give every entrant a stay at the U.S. Space Camp and a complete set of the NTB:BASE software library. We have, however, printed Scott Wahlstrom's grand prize winning letter and Robert Price's second prize winning letter, as well as the letters of the five merit winners, who will each receive one NTB:BASE category of their choice. All other entrants will receive certificates of honor, and you'll find excerpts from many of their letters on the following pages.

The contest brought us a few pleasant surprises. Since NASA Tech Briefs is not exactly easy reading for the general public, we didn't expect the contest to be picked up by the consumer media, but it was. And in my infinite wisdom and prescience I never dreamed that children would enter the contest, but they did.

We received so many excellent letters from children that we established a separate category for children's letters, and are awarding a second Space Camp scholarship to 13-year-old Christine Keys for an extraordinarily well-written and informed letter.

We are sending copies of this section of the magazine to each congressman on the Hill, as well as to Vice President Bush, Governor Dukakis, and the consumer media.

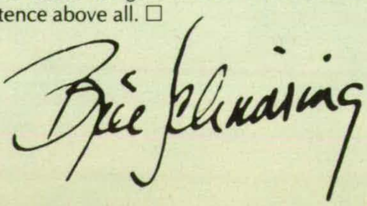
Persistence Pays Off

As I began writing this column, I was given an article from the Chicago Tribune. It says in part, "The tragic fate of the Challenger Space Shuttle, rather than dampening enthusiasm for the nation's space program, has resulted in a massive reaffirmation of support according to a landmark survey by researchers at Northern Illinois University. . . The ongoing three-year survey also found that Americans want a space program run by civilians, they want their astronauts to be the first to explore other worlds, and they are willing to pay for it. . . Fully half of the American people changed their attitudes about funding the space program. The support was extraordinary. They felt we should spend more."

And so we should. The public feels it, your letters prove it. The economic arguments alone are beyond refute. But the best salesperson in the world with the best products only makes a sale when he or she makes a call. We have to make calls on our public servants to sell the benefits of the space exploration process. Your letters do that well.

We will succeed if we remember that these letters are not an end in themselves but part of what must be the on-going process of building relationships with our elected representatives. Since most eligible Americans don't bother to vote, it's probably reasonable to assume that fewer still have ever written or called their representatives, let alone made personal visits to their offices. And they want to see us.

If each of us makes one personal visit a year to our elected representatives, and we each write a quarterly letter with suggestions and comments on their positions and voting records (hopefully more positive than negative), we will prevail. Our initiative and our persistence today will determine the future for generations. Initiative and persistence. . . but persistence above all. □



The Awards:

Grand Prize Winner

Scott A. Wahlstrom, Shrewsbury, MA

Scott Wahlstrom, 26, is Quality Manager for the Holden Plastics Corporation in Worcester, MA. He holds a B.S. degree in Mechanical Engineering from Worcester Polytechnic Institute. Mr. Wahlstrom is married and has a one-year-old daughter.

Dear Congressman Early,

I am writing to express my support for continued funding of NASA and a strong national space program.

This nation is at a critical juncture in history. We are faced with a staggering budget deficit which will not easily be dispensed with. The political winds favor budget cuts wherever possible. We must, however, resist the temptation to sacrifice investment in the future in an effort to return to fiscal responsibility. The space program is one area where budget cuts today will produce crippling fallout for decades.

World economics has brought about the demise of many of our heavy industries. Steel, textiles, all kinds of labor-intensive manufacturing are moving offshore to less costly labor markets. Our high technology industry is strong, but still the trade balance is against us. If the United States is not going to export technology in the future, what will it export? What will our economic future be based on? We are a rich nation getting poorer. We must reverse this trend!

Historically, space expenditures have been tiny compared to the economic benefits they spawn. Ask yourself: Where would this nation be today without the spinoff technology created by the Apollo program? Computer and electronic technology are two major areas matured by the moon missions. The descendants of that technology now form the foundation of our economy. Each year this technology produces many times the original expenditure on the entire program in jobs and industry. Had we not proceeded with Apollo, what would fill the vacuum left by our flagging heavy industry?

Support for our manned space program is a matter of historical necessity. The past has shown us that a power which fails to invest in the future eventually stagnates and dies. Reductions in our standard of living and trade losses due to overseas competition show that the process is already at work. We must invest before the damage becomes so great that recovery is all but impossible. There is still time, but not much.

There are many worthy areas where investment in our nation's future will pay handsome dividends. It is solid fact, however, that the space program is among the best. Every dollar spent today will be returned many times over in the coming years by creating the new technologies and industries to drive this nation into the next millennium. The payback will be in job and economic vitality versus welfare and sagging world position. We will create an environment of scientific exploration which will ensure that the United States remains the focus of future advances.

It was Benjamin Franklin who said that an ounce of prevention is worth a pound of cure. Today's investments in space will produce far more than this sixteen to one return. The choice is either to anticipate future need or to react to problems after they have developed. As a nation we, like all other things in nature, must continue to evolve or face eventual extinction. Now is the time to act. The path is clear.

Sincerely,

Scott A. Wahlstrom, Shrewsbury, MA

Excerpts from other Letters:

❝ Let my children remember not a recession or a war or some social unrest from the 1990's, but instead let them remember the magnificent national accomplishment of an American walking on Mars. ❞
—Dirk Nordling, Sykesville, MD

The Top Letters Supporting the U.S. Space Program

Second Prize Winner

Robert O. Price, San Clemente, CA

Robert Price is a technical editor and project manager for Envirosphere, a subsidiary of Ebasco Services Inc., Santa Ana, CA. A former NASA employee, Mr. Price was a member of the Voyager spacecraft design team at NASA's Jet Propulsion Laboratory. He graduated from Michigan State University with a B.S. degree in Zoology. Mr. Price is 37, married, and has two sons.

Dear Vice President Bush,

Are we Americans destined to become the Vikings and Portuguese of the 20th century?. . . to be remembered only as the bold, ambitious explorers and trailblazers of the space frontier who lost out, ultimately, to the more carefully conceived, precisely orchestrated expeditions of the Europeans, the Russians, and the Japanese?. . . our sole contribution to the ultimate human conquest and habitation of space, confined, in the final analysis, to a brief historical footnote and a few quaint and shiny relics accumulating lunar dust?

As you well know, the United States is embroiled in a new and different space race, a race not for political domination or global prestige but one which deals with commercial opportunity and economic competitiveness in a frontier that the American aerospace industry has pioneered during the last quarter century. That race, which is to transform the use of space from a scientific curiosity into a fertile and productive commercial environment, already has begun. Unfortunately, we are in danger of stumbling at the starting blocks.

Space represents the most rapidly growing market segment in the aerospace industry. Its market share has quadrupled in the last decade for a 16% growth rate, compared to 11.5% for the aerospace industry as a whole. This robustness translates into a huge opportunity for returns on resources invested in NASA-derived research and technology. Such investments and continued White House support are crutial because the new space race will be a marathon rather than a sprint.

In directing the President's Task Force on Regulatory Relief, you have shown the vision to promote and encourage the development of alternative fuels for energy independence and environmental protection. Our next chief executive must focus that same type of foresight and leadership on America's space program to ensure that the citizens of this country need not become dependent on foreign resources to reap the educational, employment, and economic benefits of this new industrial environment.

Sincerely,

Robert O. Price, San Clemente, CA

“Space is nothing less than the most promising new source of wealth that this country can take advantage of for its future growth. Even though space travel is still in its infancy, it has already produced multi-billion dollar industries such as communications and remote sensing satellites. Further advancement of the state of the art in space travel can produce even more tangible benefits to the United States. We can look forward to the prospect of manufacturing products in zero gravity that cannot be made on Earth and exploiting the natural resources of space, such as solar energy and valuable materials that can be mined on the moon.”
—Edward Barocela, St. Louis, MO

“Space offers new knowledge and unnumbered opportunities that America must grasp. We cannot afford to lose our hard-earned edge. The resolve and willingness to accept calculated risk is a cornerstone of America's greatness.”
—William F. Clapp, Stratham, NH

Merit Winner

Dear Vice President Bush,

Please speak out in favor of a strong civil space program. This effort transcends politics of the moment. It is something that needs to be done for and by our society, our nation, our species. As an American, I hope that America regains the lead in space. I also want the job done right, not nickled and dimed into compromises that affect its safety and ability to do the job. When NASA is given a goal and the tools to work with, it can and will do wonders. We must look beyond the next election to the long-term good of our nation. I believe it was Thomas Jefferson who said that civilization is denoted by its desire to make the future better than the present. Our forefathers built this country for the future. Don't we owe our children as much? If America lives only in the present, then the future will see us living in the past.

Of course it is important to end hunger and homelessness too, but there is no link between the two goals; one is not traded for the other except in the rhetoric of politics. I believe the public will accept this fact when pointed out in a clear statement. The sad truth is that you could cut NASA's budget to zero and not make one jot of difference in today's domestic problems. But by doing so we would create untold problems for the future of this nation vis-a-vis technological competitiveness, education, and employment—all of which impact our economy and, therefore, jobs. Perhaps our current problems stem in part from the diminished research dollars after the Apollo program was wound down. The moment our society stops working towards the future it is doomed to recede into the past.

Please take action immediately to help restore full funding to NASA in general and the Space Station in particular. It is the best investment this nation can ever make.

Sincerely,

Thomas A. Sullivan, Houston, TX

Merit Winner

Senator Warner,

I am writing this letter on a personal computer. I am looking at the screen through gas permeable contact lenses. I am employed in the telecommunications industry. My wife balances the checkbook with the help of a light-powered calculator (she has to do the balancing as even with the calculator my figures never add up). The toothpaste I use every day is packaged in a pressurized container which economically dispenses the product. The tires on my automobile and bicycles are reinforced with an aramid plastic fiber which allows increased mileage. Through the use of aluminum and plastic, my automobiles are lighter. Lighter vehicles use less gasoline. I use a seven and one-half foot fly rod to throw a number two flyline after native mountain rainbow trout. The rod weighs less than four ounces as it is made of a graphite composite fiber. The flyline could only be fabricated with new extrusion techniques and modern plastic materials.

By now you are probably asking yourself why you are reading this letter. I am writing to you to enlist your support for NASA and the space program. All of the products described above are direct or indirect benefits of the space program. Most people do not realize the enormous impact the space program has had in everyday life. Support for the program could be defended on these consumer grounds alone, but a greater reason exists for your support.

When Roald Amundsen reached the South Pole in 1911, the pole was known as the last place on Earth. Most great exploration of the Earth was completed on that December day. The heavens are the next frontier for men to dream of and strive to understand. Without a space program these dreams are earthbound. With a space program these dreams are limitless. The courage of Amundsen, Peary, Scott, and Shackleton can be found today. All we need is the vision to explore and the technology to reach for all that we can see. Your support of the space program can only encourage men to strive toward the next place off Earth.

Sincerely,

Lawrence Shield, Vinton, VA

“Our generation has an obligation to our society to push ahead with the exploration of the last frontier, the universe, for the same reasons Columbus sailed the Atlantic and our brave pioneers headed west.”
—Jeremy R. Burnham, La Crescenta, CA

Merit Winner

Dear Congressman Huckaby,

I'd like to let you know my thoughts on funding for NASA. I think that the best money we've spent in the last thirty years went for the technology used in space. Each of those dollars has saved many more dollars in work and waste by the use of plastics, alloys, microcomputers, and large-scale integrated circuits originally developed for NASA missions and adapted for all sorts of civilian and military uses.

We tend to take for granted the ease and lack of expense with which we can talk to each other by satellite and microwave relay, as well as the advances in medicine which improve not only our life expectancy but also the quality of our lives. These developments have either originated or been greatly sped along by NASA research. I'd like to share with you one of the instances in my own life where NASA research has made a big difference:

When I was almost four years old my father had a fatal heart attack at his work site. This happened a little over twenty-seven years ago and the medical technology of the time was simply incapable of saving his life. Ten years later my mother suffered a heart attack. Timely action with a cardiac defibrillator—a device made available to virtually every physician and paramedic because of advances in electronic and medical technology generated largely by NASA—saved her life. I know that I am not the only person who owes the life of a loved one to a NASA invention.

It would be a grave mistake to drastically cut NASA's funds in order to balance the budget. One might as well eat the seed corn during a bad year on the farm as hamper the cutting edge of American technology by short-changing NASA.

The fact is that we get double value for our NASA dollars. By observing and exploring space we gain the sort of abstract knowledge about the universe which will serve us well in the long run, and we learn how to overcome serious technical problems here on Earth, thus helping ourselves in the short run. For nearly thirty years NASA has provided the results-oriented technical research we need in order to keep up with technological progress in other countries around the world.

NASA is a positive way of dealing with the trade deficit—it constantly gives us technology which other countries will trade for. We can't hope to compete with less well-off countries in industries which depend on cheap labor, but we can sharpen the qualitative edge of American products on the world marketplace, and NASA has been helping in this way for a long time. Products which are among our most profitable national exports, such as computer technology and structural composite fibers for aircraft were developed in NASA laboratories. Every day more hard, practical ideas come from NASA shops, made in the USA and and ready for the world. As a technician with Louisiana Tech University's Center for Rehabilitation Science, I was priviledged to help assemble a handicapped driver assessment system which was recently shipped to Australia. This system is a prime example of the technology which NASA helped to generate and which is in such high demand around the world.

It is very important to have a working civil space program, for as we look to the asteroids and other nearby bodies for metal ores and other economic resources, NASA will serve as our long arm to reach out for the things we need. When one considers that a single sizable nickel-iron asteroid of the sort found between Mars and Jupiter could supply the world with high-grade ores for steel production for a century, and that it should be possible to procure from asteroids some rare metals that now are only obtainable from political trouble spots, it seems that looking out to space for our raw materials may not only be exciting but also the most sensible and economical way to deal with our difficulties in obtaining strategic raw materials.

I am not advocating that we starve anyone out to fund NASA. Less than one percent of the national budget is spent on space. For that expenditure we get the research which has made the United States the world leader in technology. When our fastest-growing export is technology, is it really a good idea to cut back funds for the government agency which helped in the progress we've made so far?

What we need now is new and better know-how—NASA's best product. NASA is as good an investment for the country as a set of tools or work clothes are for the working man, and for the same reason—it helps money come IN to the country.

I appreciate your time in reading this. Many thanks for helping us and good luck with the campaign.

Sincerely,

Vance P. Frickey, Ruston, LA

Merit Winner

Senator Bentsen,

I have noticed that during the 1988 Presidential campaign the future of America's civil space program has not been seriously debated. This area has both the potential to spark our country's imagination and economy or to drain the budget of critical research dollars. Considering your past efforts promoting the growth of Clear Lake and NASA's Johnson Space Center, I am sure you are aware of many of the issues surrounding the civil space program. I would like to reiterate the benefits proper administration of this program brings.

The most often cited reasons for space technology development are of short-term impact. Namely, an active space program creates new jobs and new technologies, with spinoffs eventually spurring other sectors of America's economy. Similarly, the international economy is lifted through technology transfers. America's role as a technological leader aids foreign relations and ignites patriotism in her citizens. The many economic opportunities of a strong space program have only just begun to be demonstrated. These benefits are necessary but not sufficient for the full commitment of the significant time and efforts required by a permanent space program.

Less tangible effects of space development will have the greater impact on the course of human history. Well publicized, successful research efforts create heroes who are well educated and socially responsible. The American dream is reinforced as people from different backgrounds work together to build and manage an ongoing space program. This gives youth reasons to stay in school and dreams to which they can dedicate themselves. An open research community promotes international information exchange and cooperation. The collective human psychology develops a one-world point of view as more people more often see the world from space, one small home in a vast, cold universe. People then begin to interact as planetary citizens, putting aside national differences for the sake of world concerns. Our advances will benefit all people, regardless of patriotism. We must contribute to the body of human knowledge and continuously extend our horizons. By avoiding space exploration as too costly or too dangerous, we are putting blinders on our intellect and stunting the growth of civilization. As with all great achievements, such as the building of the pyramids or the exploration of the New World, sacrifices must be made. Horribly greater would be the sacrifice of constraining humanity by the land and knowledge boundries we have yet to transcend.

Timely achievement of these goals can only occur with a serious governmental commitment to the civil space program. A military space program could contribute to many areas of space development, but would always suffer the downfalls of a closed research community, namely difficult technology transfer and the lack of international cooperation. The insight of the one-world view would be lost to these barriers. Though the private sector could provide a flexible research environment, by its nature it is incapable of financing projects with multi-year lag times between investment and profit. The hazards and sacrifices inherent in a technology industry such as space exploration and development would devastate any individual private effort. Further, the commitment needed must be geared to a long-term program. Project managers must have at their disposal a budget spanning the duration of the mission. We have seen repeatedly (eg: Skylab and the space shuttle) that short-term budgets only extend the time and costs of long-term engineering projects.

Therefore, in order to gain the monetary and philosophical benefits of an active space research and development effort, we must have a firm, long-term commitment to our civil space program. If directed correctly, such a program could ignite the economy and the imagination of all America. A partial commitment, on the other hand, will serve only to drain critical funds and talent away from other important research areas.

I urge you to address these issues during your campaign and emphasize their effect upon the future of our country.

Sincerely,

Shannon Powers, South Pasadena, CA

Excerpts from other Letters:

“ Most people don't know this, but NASA loves babies. They used their special skills to help my dad build a safe ambulatory fetal monitor. This will help mothers all over the world to keep bad things from happening to their babies. Please help NASA keep doing good things like this. ”

—Katie Baker (age 11), Spokane, WA

Merit Winner

Dear Senator Lugar,

Thirty years have gone by since I came to this country on the heels of Sputnik. I have seen American astronauts land on the moon and I took part in designing instruments for their missions. These were proud moments in the history of this great nation. With concern I saw the lead in technology, political vision, and educational excellence ever so slightly diminish to the point of second rate status. As I see now a younger generation enter their careers, I can't help but ask this question: What are we giving them to assure their children the continuation of a great nation?

It is with these thoughts in mind that I want to write to you at a time when decisions are being made by our political leaders which will have far-reaching consequences on our lives and, much more important, on the lives of our children and grandchildren. Technology has given us a much better life than our fathers and forefathers had. At times we paid a price for it and gallant and heroic men and women lost their lives. Most of the achievements we enjoy now were born when great visions were transformed into reality. It was the creation of NASA that helped in that transformation. We were all proud of the successes and still enjoy in many ways the dreams which came true.

As our political leaders found it wise to cut back on the expense for outer space research to address the problems of our society, less and less technical achievements were accomplished. Other countries took up the lead in many technical areas, but no satisfactory solutions were found for our social ills. I don't mean to suggest that technology is the all-encompassing solution for our problems, but without a strong leadership in space we are bound to lose the leadership in technology and with it one of the pillars for a strong nation.

With this letter I wish to put my voice in with those who want to assure a great future for this country. I believe this country can afford and continue to afford a strong space program under the leadership of NASA. I urge you to help restore this great institution to the level it once was. By doing so we will regain leadership in space, plant the seeds for innovation and technological excellence, and strengthen the basis for peace, freedom, and continued economic growth.

Respectfully yours,

Julius A. Loisch, Elkhart, IN

“ The reaches of space offer a literally limitless frontier. Once a vigorous space program opens this frontier, mankind will be able to satisfy its hunger for knowledge, its desire for challenge, and the upward tendencies of the human spirit. Without such a forward-looking program to open this frontier, the human race may stagnate and the many other earthly issues that compete at this moment with the space program for money and attention will, in the long run, matter not one whit. ”
—Curtis L. Katz, Chicago, IL

“ As a teacher of blind children and as a legally blind person, I have directly benefited from technological spinoffs. The new computer technology that is accessible to the handicapped and the many miniaturized audible devices are related to space research. ”
—Olivia Ferrante, Revere, MA

“ I feel that the American spirit is rejuvenated each time the Space Shuttle is launched into outer space. If the space program is not going forward, then we are not going at all. In the words of Claude Pepper, 'Life is like riding a bicycle. You don't fall off unless you stop peddling.' ”
—Wayne Spencer, Suffolk, VA

“ I love this country and refuse to believe that we cannot or will not compete in the space arena. The mandates of a superpower demand that we set and maintain a goal of a permanent presence in space. ”
—Lee St. Mary, Gardner, MA

Children's Prize Winner

Christine E. Keys, Scottsdale, AZ

13-year-old Christine Keys is a freshman at Horizon High School in Scottsdale, AZ. She is a member of the Junior National Honor Society. Her interests include aviation, space technology, geology, literature, and art.

Dear Vice President Bush,

As a 13-year-old girl interested in space, I am writing to ask for your support in continuing funding for NASA and the exploration of "The Last Frontier."

The United States is the leader in the space race and we must continue to maintain a strong space program. It benefits everyone in one way or another. For example, millions of jobs are provided by the program, and that's good for the economy. Manufacturing in weightlessness promises to produce new medicines and materials for the computer industry. We have already learned more about other planets and our own. Weather forecasting and communications have been improved. Unmanned spacecraft survey global conditions and assist in monitoring pollution and flood control, and even locate important mineral deposits. Our presence in space is also vital to the national security of our country.

The quality of our lives has been improved by advances made through the space program. Did you know that special wire used by dentists to make braces was originated by NASA? The reflective film that insulates windows is a spinoff from the space program. Space technology even helps out at a football game! A shock-absorbing padding developed for use in spacecraft is used inside helmets for greater protection. Our own symbol of freedom, the Statue of Liberty, benefited from a special coating that was applied to her interior to resist corrosion. This material was originally developed to protect equipment at Kennedy Space Center from damaging salt in the air.

As you can see, your support of the NASA budget is the best investment that can be made for the future of our country. Please support the space program. Thank you.

Sincerely,

Christine E. Keys, Scottsdale, AZ

“ I request that (Congress) draft legislation which would afford U.S. taxpayers the opportunity to contribute one dollar of their federal tax return (as is now possible for Presidential elections) to NASA in support of the U.S. space program. ”
—Joseph A. Resnick, Pittsburgh, PA

“ If we do not promote the space program and fund NASA, what will our children dream of? We have received a vast amount of knowledge and products from our being space-oriented. If we want to continue to grow, we must continue to GO. ”
—Debra Kroslowitz, Holly Hill, FL

“ In 1984 I was working on the refurbishing of Pad B when a scaffold fell and fractured my back. I have spent the last four years recovering from that accident and preparing for a new career...I have chosen the field of Public Relations...not only because of my disability, but also because I feel I have something to offer my country. My dream is to work for NASA, helping to make the public aware of the tremendous accomplishments of the American space program. ”
—Annette Hamilton, Titusville, FL
(from the cover letter accompanying her entry)

HONOR ROLL

These are the concerned citizens who participated in NASA Tech Briefs' 1988 Letter Writing Contest in support of NASA and the United States Space Program:

David E. Adams, Libertyville, IL ★ Jeremy Bahns Adams, Greeley, CO ★ John S. Adams, Houston, TX ★ Steven T. Adamy, Urbana, IL ★ Marina Rodrigues Aguiar, Boston, MA ★ Saeed Al-Dhaheri, Boston, MA ★ Mohammed Alhomeida, Boston, MA ★ Peter F. Aller, Plymouth Meeting, PA ★ Nasr Al-Sahhaf, Boston, MA ★ Aaron Anderer, Cupertino, CA ★ Leonard D. Andrews, Augusta, GA ★ Dawn Annibale, Richmond Hill, NY ★ Craig T. Apolinario, New Bedford, MA ★ Don Archiable, Naperville, IL ★ Gill Armour, San Diego, CA ★ Helen M. Asmus, Greeley, CO ★ Shari E. Asplund, San Gabriel, CA ★ Richard J. Aull, Santa Rosa, CA ★ William R. Avery, Mentor, OH ★ Leonard R. Babbitt, Greeley, CO ★ Steven N. Bailey, Houston, TX ★ D. A. Baker, M.D., Spokane, WA ★ Katie Baker, Spokane, WA ★ Dennis Baldridge, Bourbonnais, IL ★ Roger A. Baldwin, Greeley, CO ★ Greg Barasch, Utica, MI ★ Jenna Barasch, Utica, MI ★ Chris Barba, Glendale, NY ★ Jeffrey A. Barnes, Greeley, CO ★ Edward Barocela, St. Louis, MO ★ Mark P. Barrieau, Baldwinville, MA ★ R. L. Beck, St. Petersburg, FL ★ Robert B. Bedenbaugh, Prosperity, SC ★ Angel Bedford, Boston, MA ★ Cindy A. Beemer, Greeley, CO ★ Richard A. Behning, Greeley, CO ★ Clifton F. Bennett, Kirkland, WA ★ Joseph Berenbach, Boston, MA ★ G. Berg, Bellflower, CA ★ Steven Berkowitz, Olney, MD ★ Aaron C. Berning, Greeley, CO ★ Jacques Berque, Boston, MA ★ Kelly M. Bess, Vero Beach, FL ★ Daniel Blanchard Boston, MA ★ W. Paul Blase, Alexandria, VA ★ Kevin M. Blue, Greeley, CO ★ Joshua D. Boe, Greeley, CO ★ Burl Bolerjack, Sylmar, CA ★ Erinn May Bolin, Greeley, CO ★ Gary G. Bond, Ft. Walton Bch., FL ★ Gregory M. Bowen, Hagerstown, MD ★ John S. Bowers, Cooperstown, NY ★ Richard M. Breidenstein, Seabrook, TX ★ Natalie J. Brening, Greeley, CO ★ Randall A. Briggs, Boston, MA ★ Suzanne K. Bristol, Greeley, CO ★ Adam Brody, Mountain View, CA ★ Andrew M. Brown, Huntsville, AL ★ Ian A. Brown, Palo Alto, CA ★ Richard M. Brown, Parma, OH ★ Tim Brown, Anderson, SC ★ Ronald F. Brubaker, Jr., Altoona, PA ★ Robert S. Bruff, Westminister, MD ★ Francesco Brunelli, Boston, MA ★ Barbara-Gail Bryant, St. Petersburg, FL ★ Amy Bullock, Thousand Oaks, CA ★ Jeremy R. Burnham, La Crescenta, CA ★ SeUn Byun, Bayside, NY ★ Debra Lyn Carlisle, Greeley, CO ★ Robert M. Carnes, Sumter, SC ★ J. C. Carson, Honolulu, HI ★ Robert Casner, Kensington, CT ★ Anthony Castranova, Hamburg, NJ ★ Jeremy James Cavanagh, Boston, MA ★ Jim Cebula, Marion, OH ★ Lynn M. Champagne, Bakersfield, CA ★ Jason Chan, Troy, MI ★ Carissa Chatigny, Weatherford OK ★ Joy Check, Collingdale, PA ★ Timothy L. Check, Collingdale, PA ★ Amy L. Chen, Houston, TX ★ Menghuai Chen, Boston, MA ★ David Cherne, Petoskey, MI ★ Herve Chopin, Boston, MA ★ William F. Clapp, Stratham, NH ★ Chase Clapper, Biloxi, MS ★ Jan Clapper, Biloxi, MS ★ Eric V. Coleman, Las Cruces, NM ★ Christine Connor, Boston, MA ★ Heather Lynne Cook, Aberdeen, MD ★ B. J. Coplan, Jr., Monroeville, PA ★ Michael J. Coppi, Lompoc, CA ★ John Cornetto, Farmingville, NY ★ Jedediah P. Cornforth, Greeley, CO ★ Jessica Criss, Toms River, NJ ★ Terence P. Crochetiere, Southampton, MA ★ Raymond J. Cronise, Boston, MA ★ Cynthia H. Crosby, Charlottesville, VA ★ Alexander C. Crosman III, Columbia, MD ★ Larry L. Cunningham, Littleton, CO ★ Malissa K. Daniels, Greeley, CO ★ Michelle Daniels, Arcadia, FL ★ Katherine Rose Daues, Boston, MA ★ James E. Davidson, Houston, TX ★ Jessica Day, Greeley, CO ★ Jane Deakin, Boston, MA ★ Scott Ryan Debusk, Greeley, CO ★ Sheila L. Dekrey, Greeley, CO ★ Lucia R. Marcondes D'Elia, Boston, MA ★ John A. Dennison, Bowie, MD ★ Peter F. Dettelis, Colorado Springs, CO ★ Gabrielle Devine, Havertown, PA ★ Keith C. DeWitt, Hopwood, PA ★ Peter M. Diedrich, Boston, MA ★ Charles J. Divine, Trenton, NJ ★ Randy Dodge, Glendale, CA ★ Bryan Lee Dorman, Greeley, CO ★ Ricky Dorr, Delmar, DE ★ Graham Dorrington, Boston, MA ★ Reynolds O. Dorris, Memphis, TN ★ William A. Drake, Greeley, CO ★ Al Duester, Woods Hole, MA ★ Dwight C. Duke, Marshfield, VT ★ Linda S. Duke, Marshfield, VT ★ Patricia Dunn, Idabel, OK ★ Lee S. Durham, Lakewood, CA ★ Rolf J. Dutzmann, Laconia, NH ★ John J. Dykla, Chicago, IL ★ Russell C. Eberhart, Ph.D., Columbia, MD ★ Tanya Ecker, Stoughton, MA ★ Tina Ecker, City and State Unknown ★ Kenneth S. Edgett, Tempe, AZ ★ Bill Edmiston, Jr., Thousand Oaks, CA ★ Laura Edmiston, Thousand Oaks, CA ★ Molly Lea Effinger, Greeley, CO ★ Daniel J. Faingnaert, Monaca, PA ★ F. Autumn Fanale, Chicago, IL ★ Joshua D. Feldmesser, Columbia, MD ★ Shelly Felmly, Cuyahoga Falls, OH ★ Daniel Fenech, Ypsilanti, MI ★ Olivia Ferrante, Revere, MA ★ Richard Ferrari, East Granby, CT ★ David Fessler, Lima, OH ★ Thomas G. Fezatte, Green Bay, WI ★ Matthew J. Fisher, Greeley, CO ★ Jeffrey L. Fister, Highlands Ranch, CO ★ Paul Flament, Boston, MA ★ Felipe Flores-Amaya, Greenbelt, MD ★ David M. Flynn, Beaumont, TX ★ Brian Forbes, Lincoln Park, NJ ★ Rudolf Forster, Boston, MA ★ Richard Fournier, Boston, MA ★ David P. Fowler, Irving, TX ★ Bruce A. Fralick, Easton, PA ★ Darwin C. Franceschi, Aurora, CO ★ Brian Francis, Greeley, CO ★ Carl Frederick, Ithaca, NY ★ Katie Vanessa Freeman, Sacramento, CA ★ Richard Frenthway, Grand Rapids, MI ★ Vance P. Frickey, Ruston, LA ★ Thomas B. Friedman, Sn Luis Obispo, CA ★ Bobbie Jo Fries, Orlando, FL ★ Jeff Fueston, Blanchester, OH ★ Richard C. Fulljames, Bethel, CT ★ Susan S. Fulljames, Bethel, CT ★ George H. Garbe, Fairfax, VA ★ Gus Gardellini, Boston, MA ★ H. Maury Gatewood, Jr., Prince George, VA ★ Teraesa Gendron, San Antonio, TX ★ Michael S. Gerhart, Ulster Park, NY ★ Dr. M. Gerloff, St. Louis, MO ★ Jeanie Gieseler, St. Petersburg, FL ★ Barbara Gilmore, St. Louis, MO ★ Dane A. Glasgow, Edgewater, MD ★ Ed Gnifkowski, Waite Park, MN ★ Eli Goldberg, Potomac, MD ★ Eddie Goletz, Urbana, IL ★ Robert W. Gordon, Seattle, WA ★ Charles F. 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Jackson, Greeley, CO ★ Jacqueline James, Greeley, CO ★ James D. Janos, Bethany, WV ★ Nelson Jimenez, Stamford, CT ★ C. Eric Johnson, Arlington, TX ★ Heather Jones, Chesterton, IN ★ Stephen T. Jones, Idabel, OK ★ Akiyoshi Kabe, Boston, MA ★ Anthony Peter Kalcina, Boston, MA ★ Richard R. Kallay, Largo, FL ★ James R. Kallenbach, Janesville, WI ★ Laura Kallstrom, Foxboro, MA ★ Charles L. Karich, Greeley, CO ★ Terrence K. Karner, Addison, IL ★ Bruce F. Karow, Middleton, WI ★ Curtis L. Katz, Chicago, IL ★ Brian Kaufman, Queens Village, NY ★ Edmund R. Kaup, Mineola, TX ★ Bonnie Mellott Keefer, McConnellsburg, PA ★ Randolph I. Keefer, McConnellsburg, PA ★ Brian Scott Keller, Boston, MA ★ Joseph Francis Kennedy, Boston, MA ★ James L. Keyes, St. Joe, AR ★ Christine E. Keys, Scottsdale, AZ ★ Michelle Kindsfather, Greeley, CO ★ Mary Lou King, Memphis, TN ★ Roger King, Sandpoint, ID ★ Gene Kleiner, Longmont, CO ★ Sean T. Klimczak, Palm Harbor, FL ★

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May, Greeley, CO ★ Debra A. Mayer, Terrell, TX ★ David C. McCall, Nashville, TN ★ Richard E. McCormick, Cleveland, OH ★ Glen McCue, Tempe, AZ ★ Mark J. McGrath, Radcliff, KY ★ George W. McGuirk, Ocala, FL ★ Patrick L. McHargue, San Jose, CA ★ Stephanie McInerney, Louisville, KY ★ Glenn J. McPeters, Underhill, VT ★ Andrew J. Mejia, Greeley, CO ★ Frederick C. Menage, Lanham, MD ★ Cathy L. Meredith, Washington, PA ★ Mark A. Middlebusher, Fairhope, AL ★ Tohru Mitsuhashi, Boston, MA ★ Feda Mohammed, Union City, CA ★ Mike Monison, Westland, MI ★ Blake D. Montey, Greeley, CO ★ David Moore, Los Angeles, CA ★ Tom Morrison, Hesperia, CA ★ Richard A. Moss, M.D., Plymouth, MA ★ Meredith Murar, Bruswick, OH ★ John D. Mustain, Kenton, OH ★ Bret G. Naber, Greeley, CO ★ Carol Nain, Boston, MA ★ Susan Naramore, Wiggins, MS ★ Edward J. 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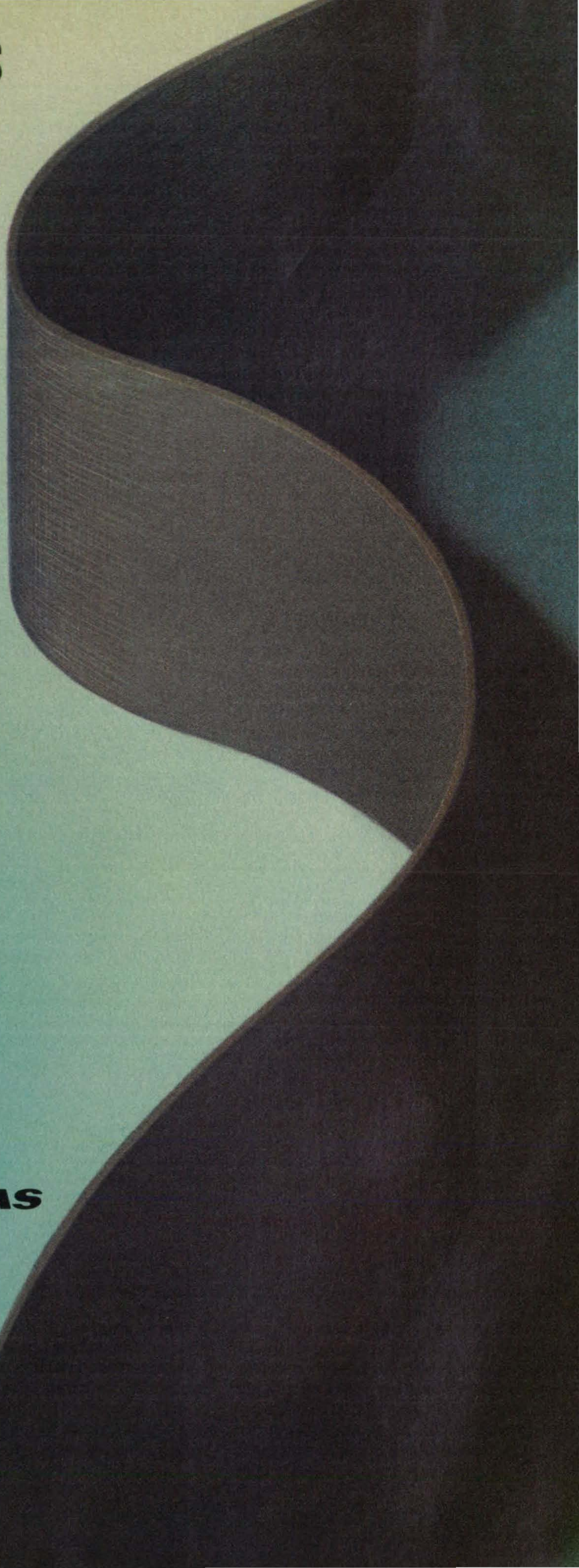
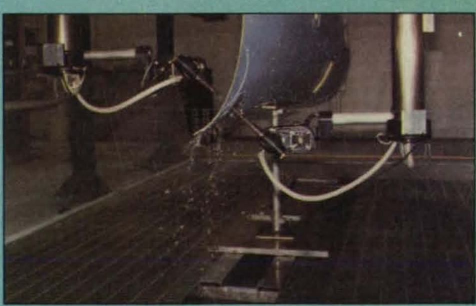
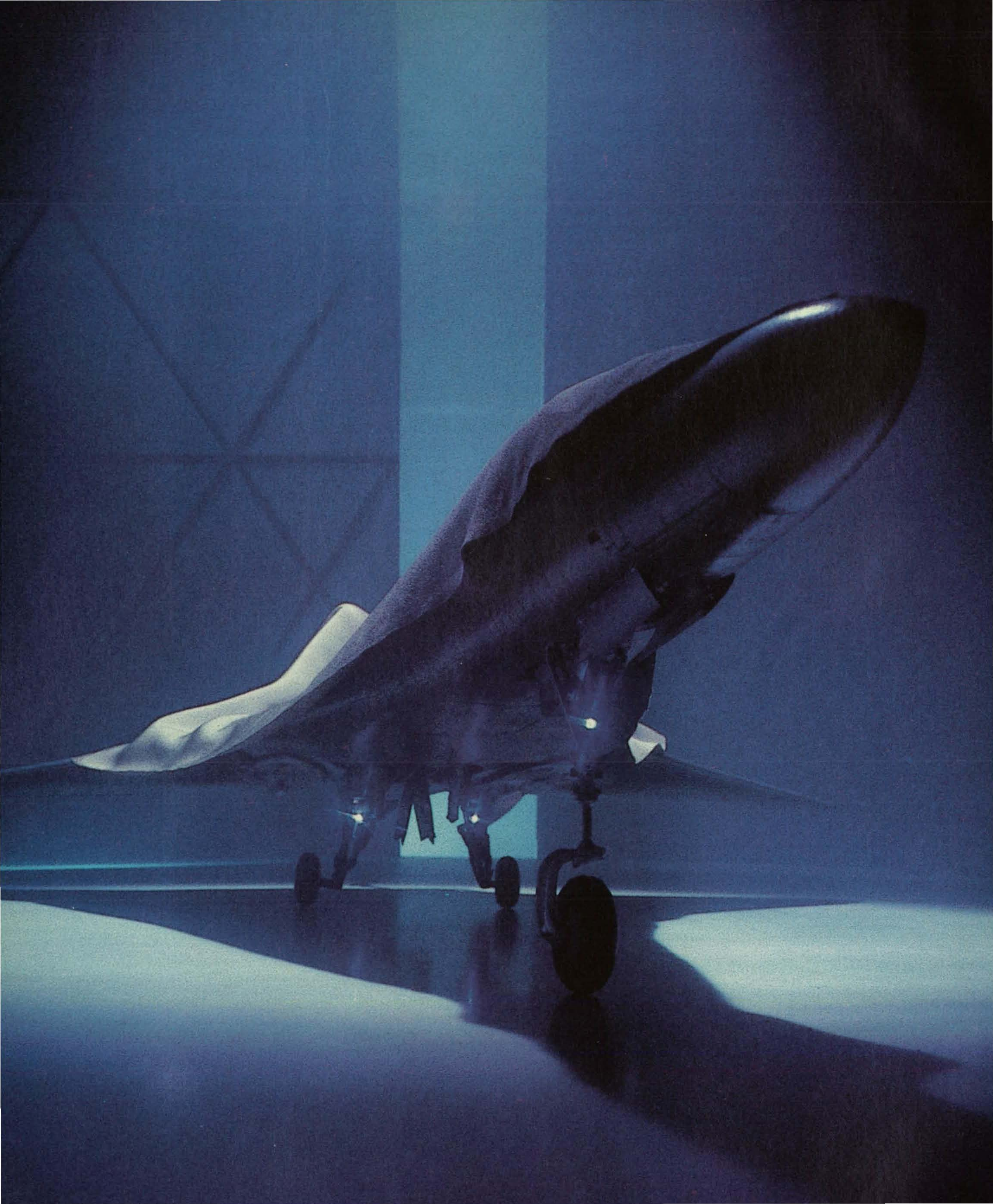






The Evolution of "Smart" Composite Materials

By Dr. Robert S. Rogowski, Dr. Joseph S. Heyman and Dr. Richard O. Claus

There is an interesting parallel between evolution in animals and in advanced materials. The evolution of most animal species has involved the integration of a highly developed nervous system—a network of sensors— with the biological structure. Pain sensors, for example, are crucial for survival and play a major role in "instant" education. The adage "once burned, lesson learned" has been an unfortunate part of every child's experience.

In the material science field, a new species of material is evolving which will be better equipped to survive in its environment than its predecessors. Engineers have developed strong, lightweight composites that mimic the properties of wood, nature's fiber-reinforced composite material. Now these materials are becoming "smart."

The smart materials concept is based on the integration of sensors with materials, so that the material has its own "nervous system," able to both sense and communicate with an outside intelligence. This technology offers a cost-efficient way to monitor the health and performance of structures both in space and on Earth. Presently, it would be difficult to monitor a huge space structure without a correspondingly huge investment. On Earth we can avoid this problem by over-designing the structure to the point that statistics are on our side, but we still have no way of predicting how the structure will perform for the remainder of its life. Striking examples of our failure to properly assess structural integrity are downed bridges on major highways and ruptured pipelines in nuclear power plants.

Applications of smart materials could touch everyone. Technology developed for the Space Station and aeronautical systems could be reapplied by the commercial sector to improve the safety and reliability of aging structures. Bridges may one day be monitored with sensor-embedded lines able to measure various forms of damage. Similar monitoring systems could be placed on dams, offshore platforms, storage tanks, pressure vessels—even your car.

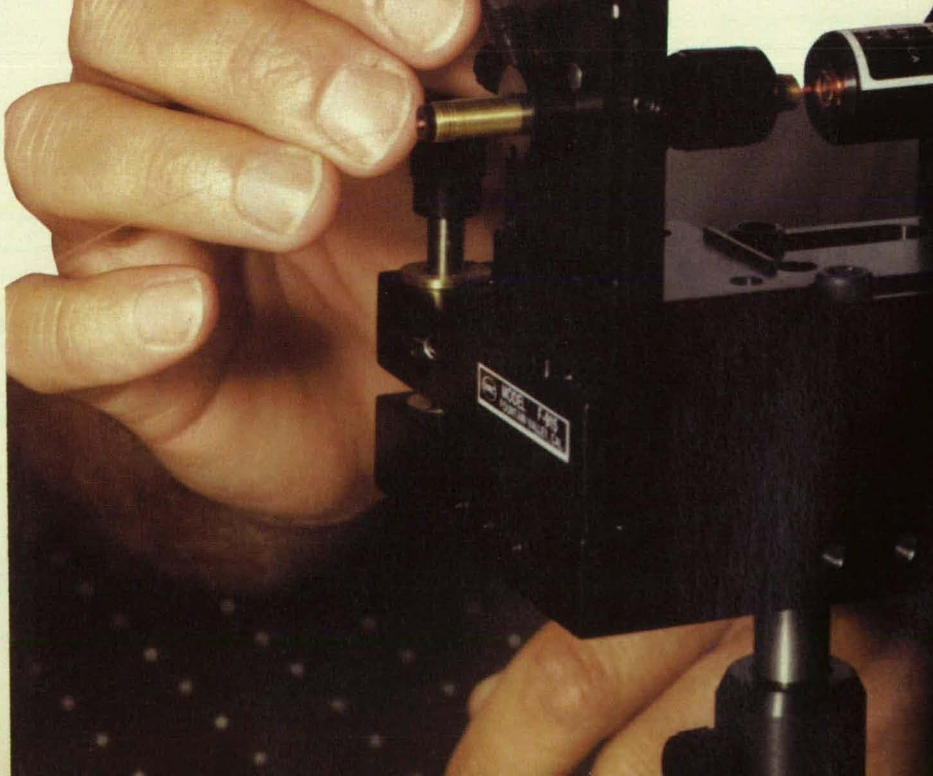
The sensors being examined for these applications can measure temperature, strain, impact energy, chemical activity, and electrical and magnetic fields, and include fiber optic, acoustic wave guide, and dielectric sensors. The development of integrated sensors relies on basic principles of physics and mechanics: first one must determine the critical structural properties and then decide which sensor technology is compatible with that structure.

Optical Fibers Light The Way

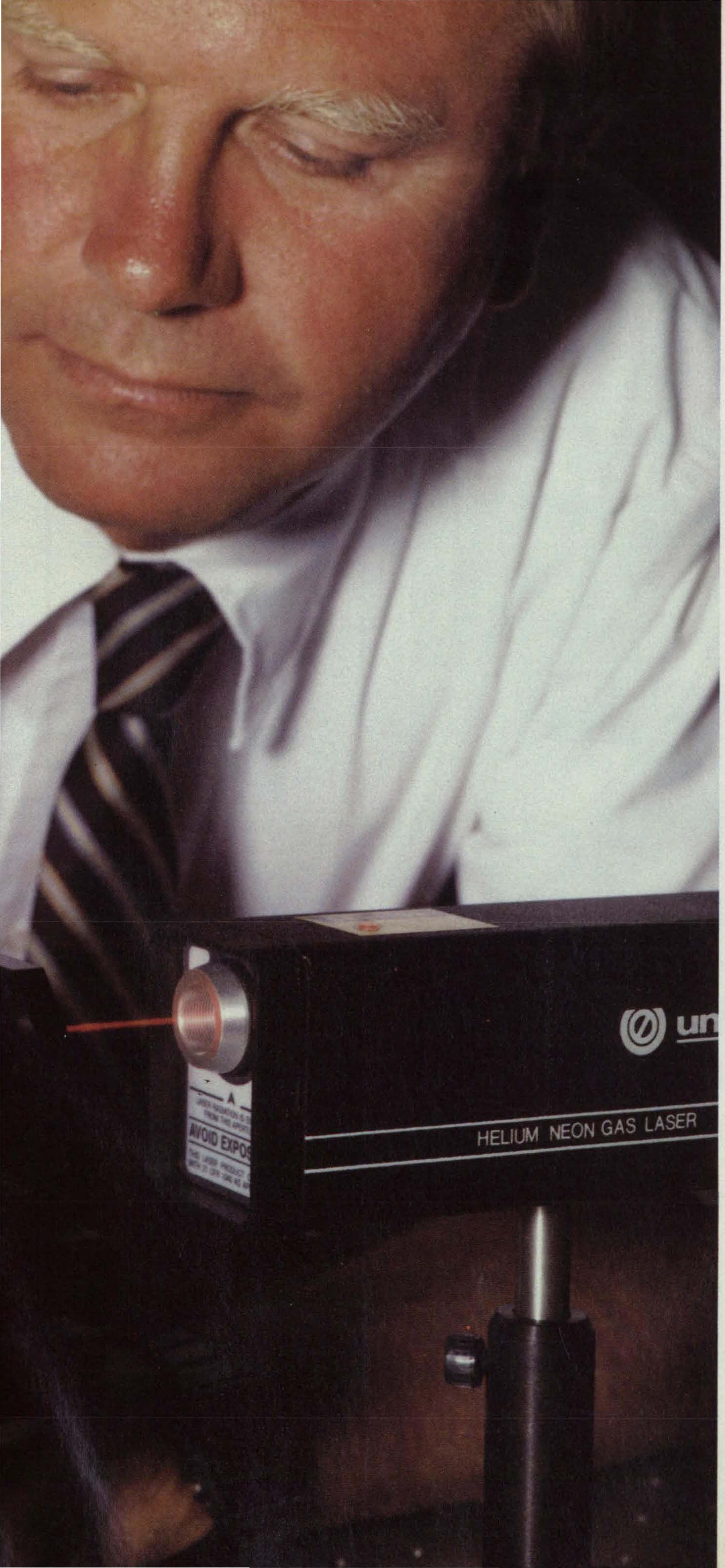
At NASA's Langley Research Center, we are developing in-situ fiber optic sensors for smart materials. Optical fibers offer many appealing characteristics for structural applications, including compatibility, versatility, sensitivity, unobtrusiveness, and low mass.

In monitoring structural integrity, one of the most important measurements is strain. We have measured both static and dynamic strain in test specimens using optical fibers. These were examined through techniques such as modal domain interference, optical time domain reflectometry, and an optical phase locked loop. In the latter, a voltage-controlled oscillator modulates a GaAlAs laser and provides a reference signal to a double balanced mixer. The laser radiation passes through a multimode optical fiber, is detected, amplified, and then mixed with the reference signal to generate an error voltage. The phases of the two signals are maintained at quadrature by feedback of the DC error voltage from the mixer to the oscillator. A filter removes the radio frequency component coming from the mixer. With this configuration, any change in the phase of the modulation is compensated by a change in the modulation frequency.

In one application, we used the op-



Dr. Robert Rogowski's research group at NASA Langley has measured strain in composite materials using laser-radiated optical fibers.



tical phase locked loop to measure dynamic strain in a cantilever beam fixed at one end. Both optical fiber and conventional resistance strain gauges were attached to a metal beam with a 0.6Hz fundamental vibration frequency. A Fourier transform of the signals from both devices indicated a prominent peak of 3.8 Hz, which is the frequency of the second mode.

We garnered similar results by interrogating the fiber with a modal domain sensor, which depends on the interference of several modes in a single mode fiber. If radiation from a He-Ne laser operating at 633 nm is launched into a single mode fiber at 840 nm, several modes will propagate in the fiber and various spatial patterns will emerge. Spatial filtering selects part of the pattern for detection. If the fiber is strained, the pattern changes and causes a change in signal amplitude at the detector.

Our group used the modal domain sensor to detect acoustic emission in a graphite/epoxy composite specimen. Acoustic emission can indicate damage from impact or excessive stress, which causes the material's fibers to break apart. The optical fiber picked up the stress wave generated in the composite and converted it to an optical signal.

One optical fiber can play a multiple sensor role. The fiber used to detect acoustic emission can also measure strain caused by the structure's natural vibration frequencies, and could provide feedback to a control system for damping vibrations in large flexible structures such as the Space Station.

Industry-Wide Research

Smart materials research is underway at several laboratories. Foster Miller is developing a fiber optic method for monitoring the curing of composites under a Small Business Innovative Research contract with NASA Langley. The method involves infrared transmitting fibers embedded in the composite and the use of a Fourier transform infrared spectrometer to monitor chemical changes which indicate the material's state of cure. Langley is also collaborating with the Air Force Astronautics Laboratory on a program for in-situ monitoring of strain and vibration in filament-wound graphite/epoxy tubes.

Many of the major aerospace manufacturers are developing smart composites. The Lockheed Missiles and Space Company has reported strain measurements in composites with embedded optical fibers and has created electrically conductive polymers for smart structure applications. McDonnell Douglas is applying its experience with fiber optic gyros to the development of composite monitoring systems, using Sagnac interferometers for strain sensing. Hercules Aerospace is investigating polarimetric techniques for strain measurement with embedded fibers. And United Technologies Research Center has fabricated a unique twin core fiber that can measure strain and temperature simultaneously in a composite structure.

An Intelligent Solution

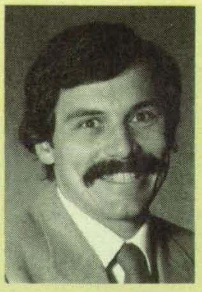
The evolution of smart materials is driven by necessity; certain requirements for space structure performance and reliability can only be met with new technology. Future deployment of space structures will require new kinds of sensors and actuators for active control of structural configuration. Conventional strain gauges and accelerometers are too cumbersome for use on these large structures and cannot provide the required accuracy.

Smart composites offer an intelligent solution. This new species of material promises to dramatically improve the performance, reliability, and safety of tomorrow's structures. □

About The Authors

Dr. Robert S. Rogowski is Group Leader for Fiber Optic Sensors in the Nondestructive Measurement Science Branch at NASA's Langley Research Center. He earned a PhD in Physical Chemistry at Michigan State University in 1968. Since then he has been engaged in research at Langley on fiber optic sensors, molecular spectroscopy, polymeric materials, and chemiluminescence sensors.

Dr. Joseph S. Heyman is Head of Langley's Nondestructive Measurement Science Branch. He received his PhD from Washington University in 1975. Dr. Heyman has been granted 21 patents in ultrasonics, sensors, measurement science, and instrumentation for NDE, industrial, and medical applications.



Dr. Richard O. Claus (PhD, Johns Hopkins, 1977) is Director of the Fiber and Electro-Optics Research Center at the Virginia Polytechnic Institute and State University. He is also a professor in the University's Department of Electrical Engineering, and has received five teaching awards in the last nine years. Dr. Claus is the author of more than 160 technical papers on fiber and related optics.

New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 26). NASA's patent-licensing program to encourage commercial development is described on page 26.

Noncontacting Inspection Heads for Robots

A remote inspection head for robots would include a variety of sensors housed in a compact assembly to monitor internal conditions of such complex equipment as turbines, pumps, motors, and generators. Signals from the sensors would be transmitted via fiber-optic cables to an electro-optical interface, converted to electrical signals, and sent to a computer for processing. (See page 36).

Controlling Vapor Pressure in Hanging-Drop Crystallization

A device helps to control the vapor pressure of water and of other solvents in the vicinity of a hanging drop of crystallizing enzyme or protein. With the help of the device, the rate of nucleation can be limited to decrease the number and increase the size of the crystals. Larger crystals are needed for x-ray diffraction studies of these macromolecules. (See page 57).

Radio-Frequency Strain Monitor

An RF strain monitor measures lengths of objects. Unlike other strain sensors, this device integrates the total strain over the total path length; which can be many meters or kilometers, a useful feature for monitoring such large structures as aircraft, bridges, and buildings. (See page 36).

Error-Tolerant Quasi-Paraboloidal Solar Concentrator

A solar concentrator with scalloped gores resembling a floppy umbrella would be easier to manufacture and to aim at the Sun than expensive paraboloidal reflectors. Computer analysis shows that the new design attains concentration ratios at least 18 times those of comparable paraboloidal reflectors. (See page 62).

This symbol appears next to technical briefs which describe inventions having potential commercial applications as new products. The process for developing a product from a NASA invention is described at the top of this page.

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We've outlined below NASA's TU Network—named the participants, described their services, and listed the individuals you can contact for more information relating to your specific needs. We encourage you to make use of the information, access, and applications services offered by NASA's Technology Utilization Network.

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You can contact NASA's network of Industrial Applications Centers (IACs) for assistance in solving a specific technical problem or meeting your information needs. The "user friendly" IACs are staffed by technology transfer experts who provide computerized information retrieval from one of the world's largest banks of technical data. Nearly 500 computerized data bases, ranging from NASA's own data base to Chemical Abstracts and INSPEC, are accessible through the ten IACs located throughout the nation. The IACs also offer technical consultation services and/or linkage with other experts in the field. You can obtain more information about these services by calling or writing the nearest IAC. User fees are charged for IAC information services.

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How You Can Access Technology Transfer Services At NASA Field Centers: **Technology Utilization Officers & Patent Counsels**—Each NASA Field Center has a Technology Utilization Officer (TUO) and a Patent Counsel to facilitate technology transfer between NASA and the private sector.

If you need further information about new technologies presented in *NASA Tech Briefs,* request the Technical Support Package (TSP). If a TSP is not available, you can contact the Technology Utilization Officer at the NASA Field Center that sponsored the research. He can arrange for assistance in applying the technology by putting you in touch with the people who developed it. If you want information about the patent status of a technology or are interested in licensing a NASA invention, contact the Patent Counsel at the NASA Field Center that sponsored the research. Refer to the NASA reference number at the end of the Tech Brief.

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Electronic Components and Circuits

Redundant Grounding Circuit for Arc Welding

Arc burns at loose ground connections are prevented.

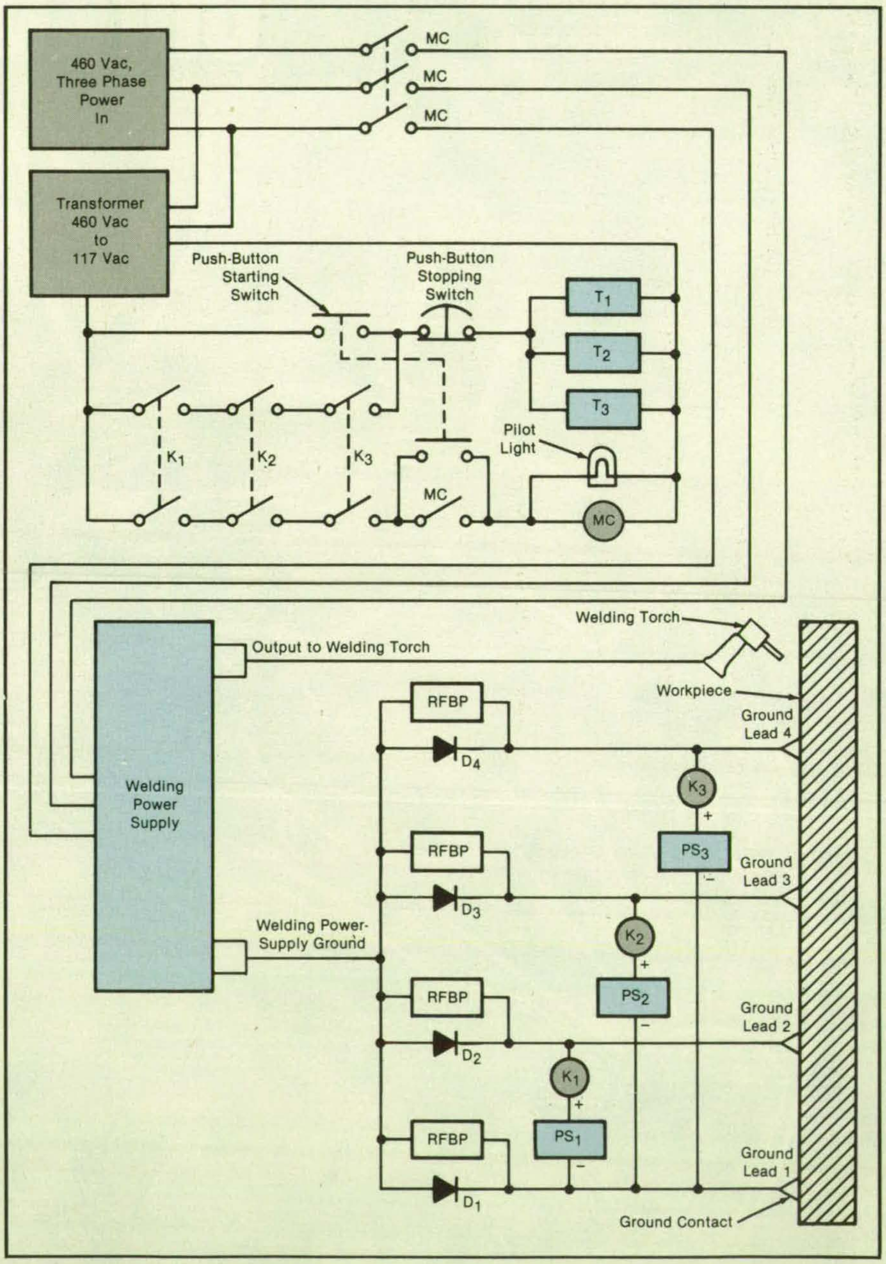
Marshall Space Flight Center, Alabama

A protective grounding scheme for an arc-welding power supply includes four ground leads to the workpiece and a circuit that automatically turns off the welding current if one or two of these ground leads becomes disconnected. The scheme prevents the burns and inadvertent welding that can occur where the full welding current passes through a single loose ground contact.

The protective circuit is an integral part of the welding power-supply control circuit (see figure). When the user presses the starting switch, power at 117 Vac is applied to the master control relay switch MC and to the primary windings of transformers T_1 through T_3. The transformers are parts of power supplies PS_1 through PS_3, which provide 24 Vdc to close control relay switches K_1 through K_3. As long as the stopping switch is not pressed and all the ground leads remain connected to the workpiece, all the relays remain energized, and switches K_1 through K_3 and MC remain closed; thus, the welding power supply remains on.

In normal operation, the welding current on the ground side flows to the workpiece through diodes D_1 through D_4 into ground leads 1 through 4, respectively. Each diode could carry the full 300-A welding current. Each diode is shunted by a radio-frequency bypass unit (RFBP), which consists of capacitors and varistors that carry the radio-frequency welding current used to start the arc.

If ground lead 1 becomes disconnected from the workpiece during operation, the welding and relay currents continue to flow in the other leads. But if lead 2, 3, or 4 loses contact with the workpiece, the current can no longer flow from PS_1, PS_2, or PS_3 to relay switch K_1, K_2, or K_3 respectively. In that case, the affected switch opens, turning off the power to all relays, including master control switch MC. When MC opens, the welding power supply is turned off.



Interlocking Relay Switches turn off the 460-Vac, three-phase input to the welding power supply if any of ground leads 2, 3, or 4 becomes disconnected from the workpiece.

This work was done by Richard K. Burley of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 100 on the TSP Request Card.*
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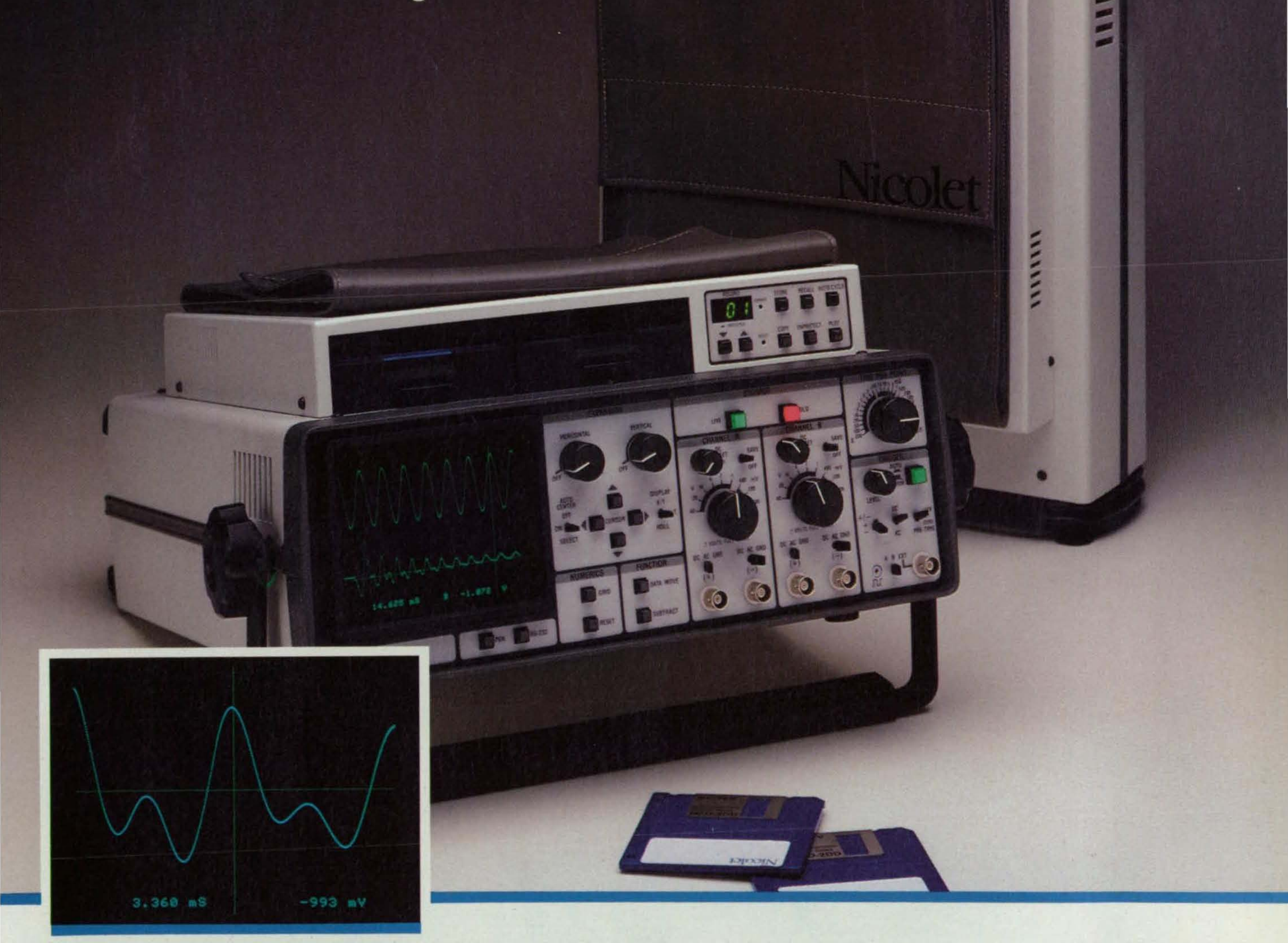

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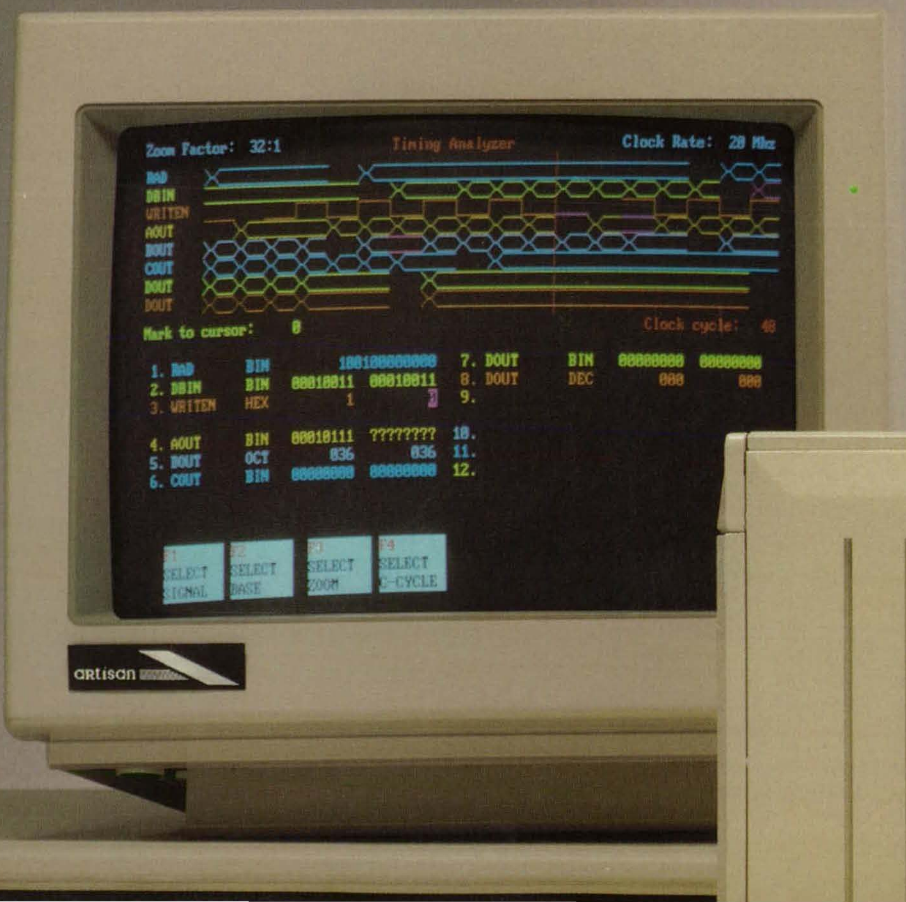

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Programmable Pulser

The user controls the number of clock pulses to prevent burnout.

Lewis Research Center,
Cleveland, Ohio

A new digital programmable pulser circuit can provide clock pulses in three formats: freely running, counted, and single pulse. It operates at frequencies up to 5 MHz, with no special consideration given to the layout of components or to terminations. The programmable pulser is an invaluable tool for initial verification or diagnosis of digital or digitally controlled circuitry.

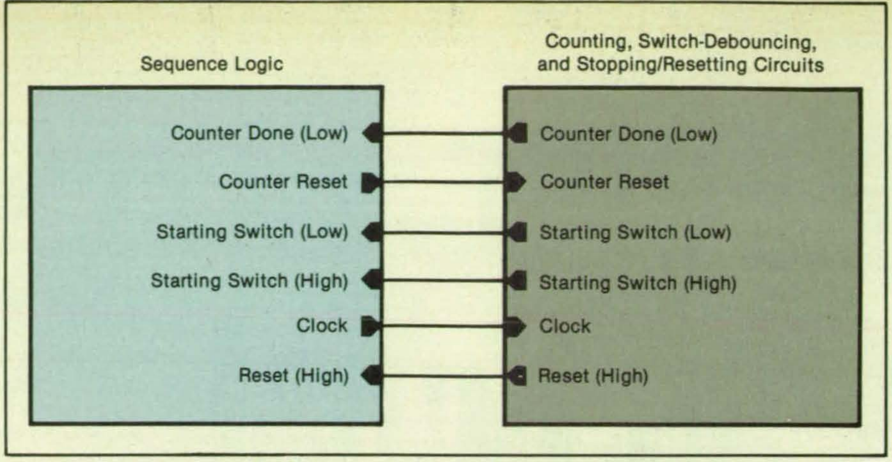


Figure 1. The **Programmable Pulser** consists of logic circuits connected to counter, switch-debouncing, and stopping/resetting circuits.

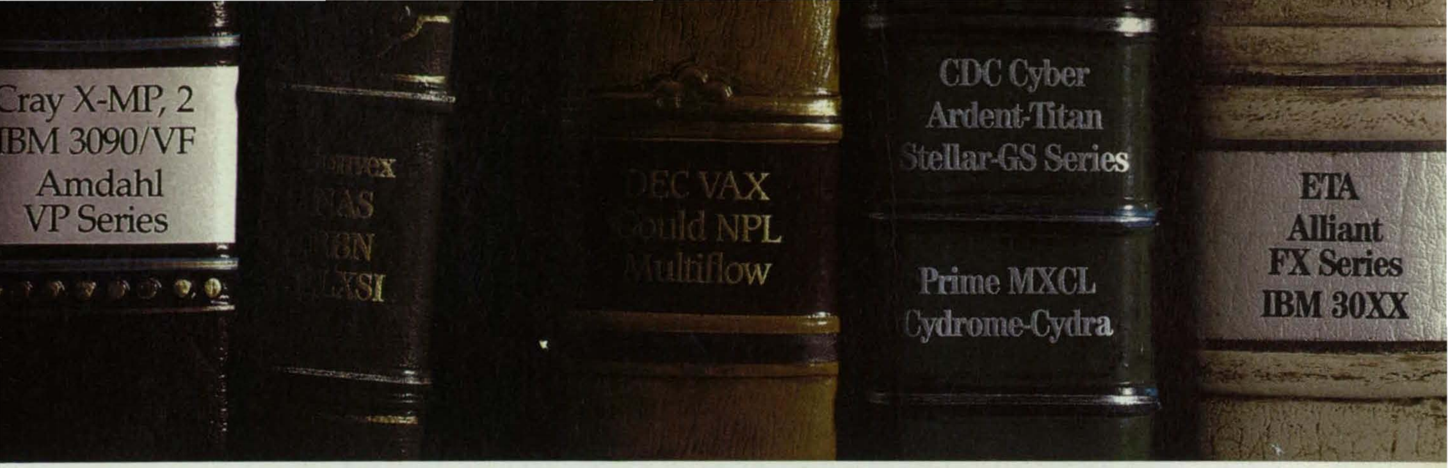
The programmable pulser (see Figure 1) is based on a sequential circuit that has four states and a binary counter with appropriate decoding logic. The number of programmable pulses can be increased beyond 127 by the addition of another counter and decoding logic. For very large pulse counts and/or very high frequencies, synchronous counters could be used in place of ripple counters to avoid errors caused by propagation delays.

The sequence logic includes the counter and decoding circuit illustrated in Figure 2. An external square-wave generator of the desired frequency is connected to the input. The user then sets a group of binary-weighted switches to select the desired number of clock pulses. In the configuration shown, the user can program a maximum of 127 pulses. If the user wants a single clock pulse, switch 2 is turned on. To obtain six clock pulses, switches 3 and 4 are turned on. Switch 1 allows the output to run freely.

The starting switch (not shown in Figure 2) must be pressed before any clock pulses will appear on the output. Multiple bursts of the programmed clock pulses can be obtained by repetitively pressing the starting switch. Because the sequential circuit is synchronous, the starting button must be depressed for at least one cycle of the input clock. When the stopping button is pressed, clock pulses at the output stop immediately, and the counter resets to zero.

The clock output is inhibited if an internal error occurs. Once an error occurs, the user must intervene to reset the circuit and reenable the clock output. Resetting is accomplished by pressing the stopping button. If desired, the stopping button can be wired in parallel with another circuit that turns on the power to ensure that the circuit is ready for operation.

The prototype of the circuit was used as



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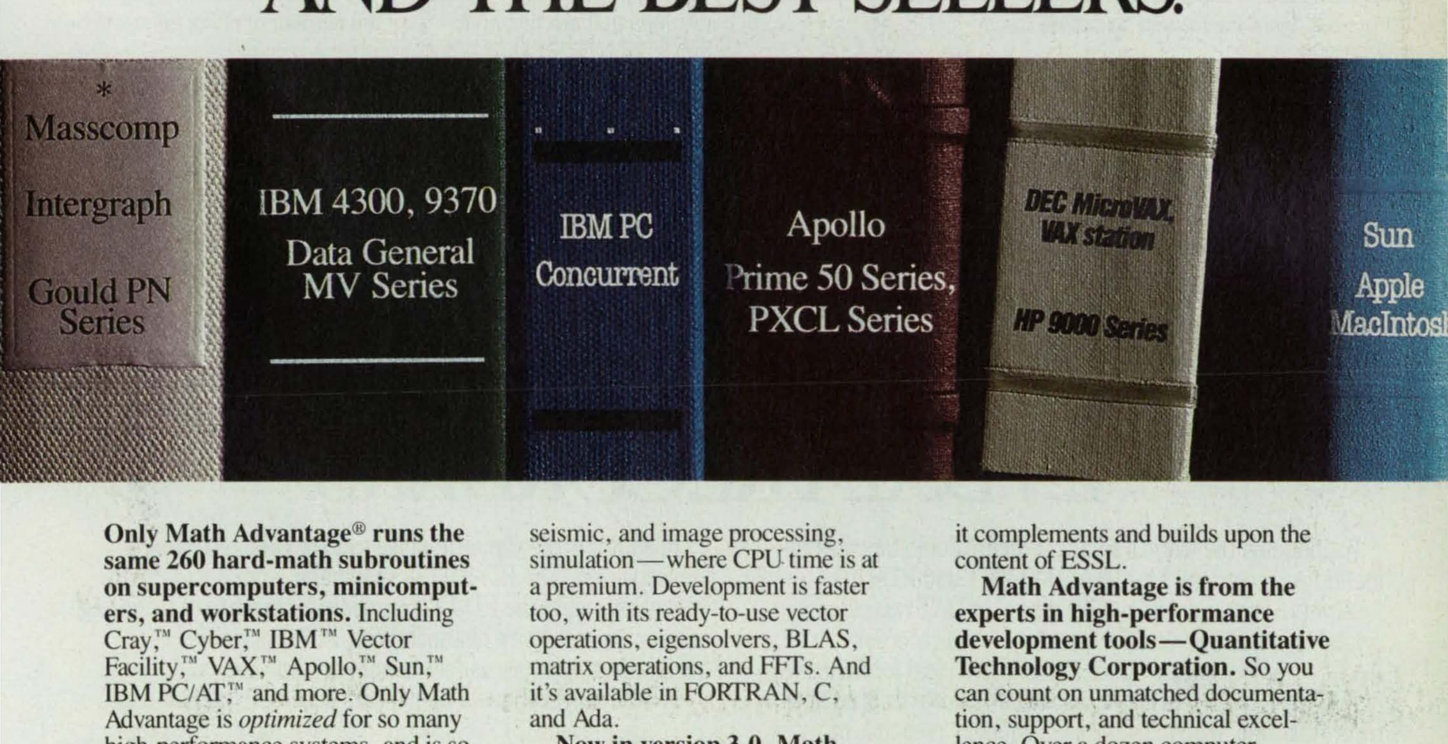

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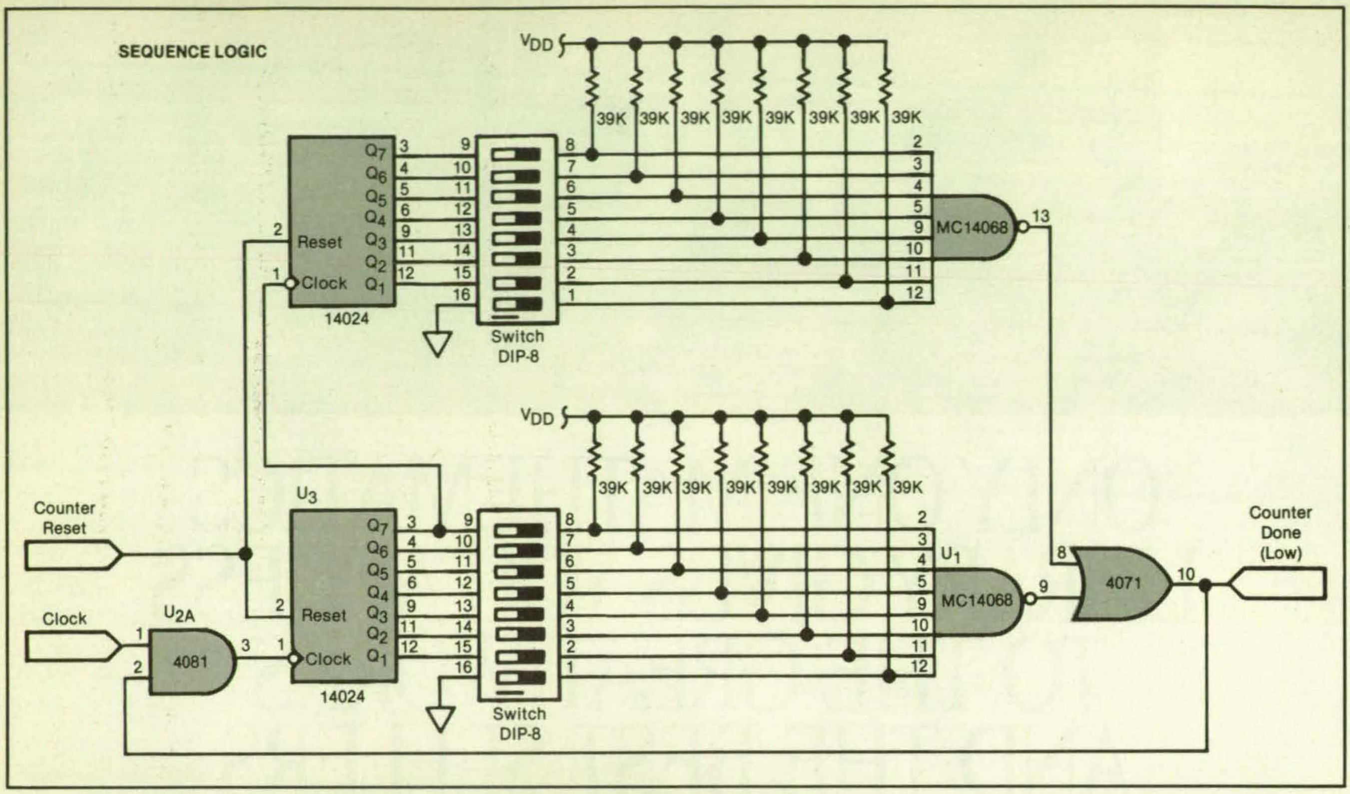


Figure 2. The **Counter and Decoding Circuit** includes binary-weighted switches that are thrown to select the number of clock pulses to be counted.

the master clock in a 20-kHz resonant inverter. With the pulser working in the counted-pulse mode, current and voltage anomalies in the inverter were detected without causing burnout of the components of the power circuitry during testing.

This work was done by Eric Baumann of **Lewis Research Center** *and Anthony Merolla of Sverdrup Technology Inc. For further information, Circle 75 on the TSP Request Card.*
LEW-14585

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Photogrammetry of a Parabolic Antenna

The surface is measured with an accuracy better than 10^{-5} times the diameter.

A report describes the use of advanced close-range photogrammetry to determine the deviations of a 34-m-diameter antenna main reflector and its subreflector from their nominal paraboloidal shapes. These measurements enabled the removal of linear offsets and angular misalignments of the subreflector, with a consequent increase of 4 percent in the aperture efficiency.

Adhesive-backed retroreflective targets 1 cm in diameter were installed on the two antenna reflectors. Back-to-back target pairs were also installed on brackets attached to the edge of the subreflector so that the photogrammetric determinations of the main reflector and the subreflector could be tied together: this is claimed to be the first use of back-to-back retroreflectors for such a purpose. A targeted 30-m low-expansion nickel/cast-iron alloy tape marked with targets was installed across the face of the main reflector to set the absolute scale.

A precise mobile photogrammetric camera was used to take pictures of the targets. Within each of 4 coordinate networks relative to the face of the antenna, the camera was placed at 6 to 10 positions chosen by a computerized optimization procedure to minimize the triangulation errors in the measured target coordinates. The photography required less than 1 hour in each coordinate network. The photographs were taken at night, using stroboscopic illumination, to avoid the thermal expansion of the antenna that would be caused by Sunlight. When each photograph was taken, the camera simultaneously recorded 25 calibration marks across the film to enable corrections for stretching or shrinkage of the film during the development process and subsequent examination.

The photographs were read automatically by a digitizer, which recorded the coordinates of the target images and film-calibration marks in the reference frames of the photographs. These coordinates were processed through a series of computer programs, which performed rigorous, simultaneous least-squares triangulations to determine the relative positions and uncertainties in positions of the targets. The mean standard deviations in the axial coordinates were 0.033 mm for the subreflector and 0.132 mm for the main reflector. These values represent an accuracy of about 1/260,000 of the antenna diameter.

The least-squares best-fit paraboloid was found for each antenna surface, then used to establish a Cartesian reference frame for the photogrammetric target coordinates. The apexes of the best-fit and design paraboloids were brought into coincidence; then the individual axial deviation of each target was taken as its best-fit axial coordinate minus the axial coordinate of the design paraboloid at the same radial coordinate. Plots of individual axial deviations and root-mean-square surface tolerances were computed. Because measurements were taken at two antenna tilt angles, these plots made it possible to quantify the change of antenna shape due to gravitation.

This work was done by W. D. Merrick, F. L. Lansing, F. W. Stoller, and V. B. Lobb of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Precision Photogrammetric Measurements of NASA-JPL 34-m Antenna Reflectors," Circle 73 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 26]. Refer to NPO-17088.

Electronic Systems

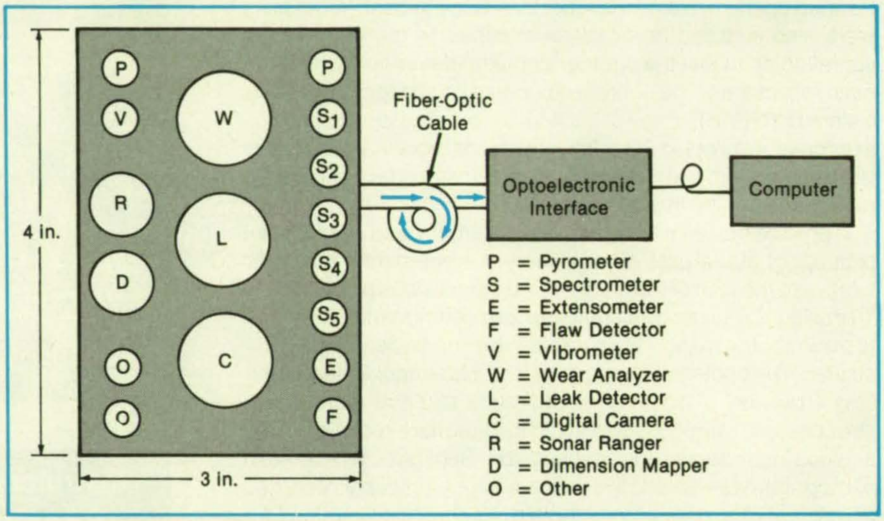
Hardware Techniques, and Processes

Noncontacting Inspection Heads for Robots

A compact end effector would contain sensors.

Marshall Space Flight Center, Alabama

A proposed compact assembly for the hand of a robot would include a group of sensors to monitor internal conditions of such complex equipment as turbines, pumps, motors, and generators. The inspection head (see figure) could include sensors; for example, pyrometers, isotope wear analyzers, spectrometers, and interferometers. Such conditions as overheating of turbines, wear of ball bearings and seals, erosion of blades and impellers, leakage of joints, and deformations of housings, could be monitored without disassembly or shutdown. In contrast, current robots equipped with no more than vision or range-measurement systems cannot perform such inspections.



A **Remote Inspection Head** for robots would include a variety of sensors housed in a compact assembly. Signals from the sensors would be transmitted via fiber-optic cables to an electro-optical interface, converted to electrical signals, and sent to a computer for processing.

The proposed inspection head could be used in typical robot applications, including hazardous environments or assembly lines. Fiber-optic cables would be used to transmit sensor signals to an optoelectronic interface for conversion to electrical signals suitable for computer processing. The computer could be programmed to monitor changes, signal abnormal conditions, or prepare maintenance instructions.

This work was done by Sarkis Barkhoudarian of Rockwell International Corp. for **Marshall Space Flight Center.** *No further documentation is available.*
MFS-29292

Radio-Frequency Strain Monitor

This device measures the overall change in the length of a structural element.

Langley Research Center, Hampton, Virginia

The radio-frequency (RF) strain monitor was developed to measure the lengths of objects. An RF waveguide or cable is bonded to the structure to be monitored. The propagation of an RF signal along the waveguide results in a phase shift proportional to the length of the path traveled.

The RF signal (see Figure 1) originates in a voltage-controlled oscillator and is coupled to the waveguide or RF cable. The phase delay in the path is measured in a signal mixer, and the phase signal is extracted by a low-pass filter. The output of the mixer is integrated, conditioned, and used in the feedback loop. The frequency of the system locks only to fixed points that correspond to 90° phase shift, such that the total phase delay around the feedback loop is $(2m + 1/2)\pi$ (where m is a positive integer).

The path length is found by the difference Δf in frequency between the lock points; for example

$$\Delta f = f_m - f_{m\pm 1}$$

where f_m corresponds to the mth lock point: $\Delta f = c/\ell$, where c is the speed of propagation and ℓ is the path length. Changes in length of the propagation path are determined by noting that $\Delta f_m/f_m = -\Delta\ell/\ell$ (see Figure 2). Unlike other strain

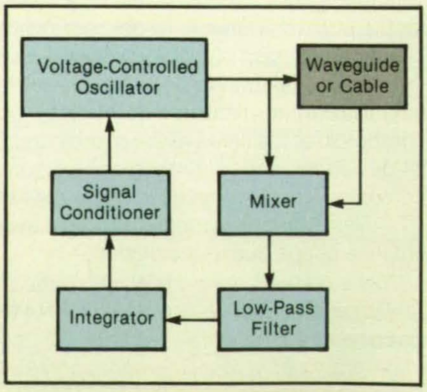


Figure 1. The **Difference Between Lock Frequencies** of a voltage-controlled oscillator is a measure of the length of the waveguide or cable.

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sensors, this device integrates the total strain over the total path length, which can be many meters or kilometers.

Additionally, impedance mismatches could be placed in the RF cable at nodes of the structure. Then the RF signal would record these mismatches and be able to detect not only the overall length of the line but also the lengths of the intervals between nodes. This capability could be used to detect changes in elements of a large structure with a single cable. The RF strain monitor has potential for many applications, including monitoring the stability of such large structures as aircraft, bridges, and buildings in Earthquake zones.

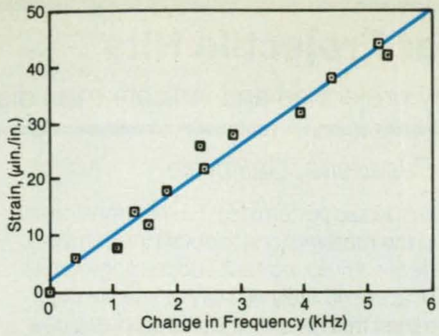


Figure 2. The **Change in Frequency** is well correlated with the strain in these measurements.

This work was done by Joseph S. Heyman and Robert S. Rogowski of **Langley Research Center** *and Milford S. Holben, Jr., of PRC Kentron, Inc. No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 26]. Refer to LAR-13705.

Topographical Mapping With Synthetic-Aperture Radar

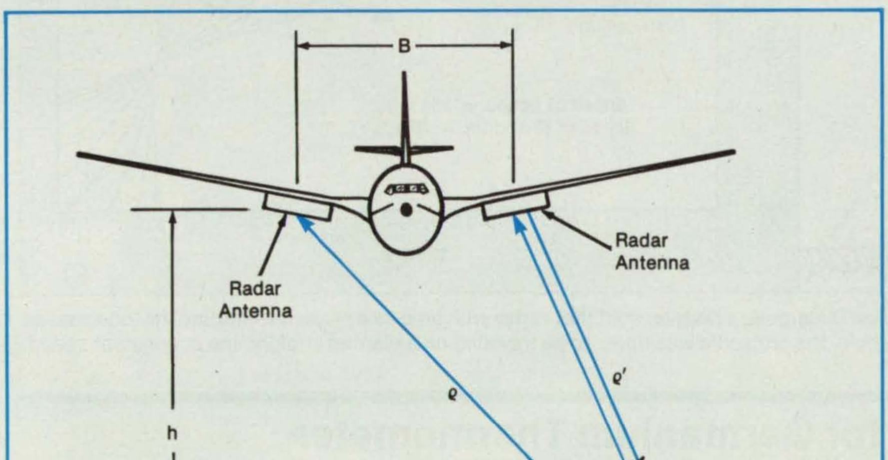
Interferometry assists in locating image points.

NASA's Jet Propulsion Laboratory, Pasadena, California

Interferometric side-looking synthetic-aperture radar shows promise for high-resolution topographical mapping of terrain. While the radar-mapping technique is not yet competitive with conventional stereoscopic aerial photography, theoretically it has the potential to attain a root-mean-square (rms) altitude error as small as 2 m.

The mapping airplane carries two radar antennas (see figure). The radar signal is transmitted by the right antenna, and the signal reflected from the ground is received by both antennas. Both the amplitudes and the phases of the received signals are recorded and processed separately to yield two 10-m-resolution amplitude-and-phase images of the illuminated terrain. The two images are then mathematically combined point by point to obtain a single image containing interference fringes: the phase at each location of the image is the difference between the phases in the two signals, and the amplitude at each location is the product of the amplitudes of the two signals.

The resolution of the slant range, ϱ, provided by the radar pulses is about 7.5 m. Within the slant-range resolution, ϱ is indeterminate, although the distance ϱ-ϱ' can be determined within about 1 cm from the interferometric data. The vertical distance from the antennas to the ground is obtained from simple trigonometric identities. The combination of geometry and interferometry results in an equation for the vertical distance from the antennas to the observed point on the ground as a function of the slant height, the phase difference in the interferogram, the distance between antennas, the wavelength of the radar signal, and the roll angle of the airplane.



Using Both Antennas to receive the echo of the signal transmitted by one of the antennas, the synthetic-aperture radar system generates an interferometric map that increases the precision of the final topographical map of the terrain.

The computed relative altitude is combined with the along-track and slant-range measurements to infer the three-dimensional location of each observed point. The data are then transformed to standard, mutually perpendicular coordinates to obtain the familiar form of an altitude-contour map on square horizontal coordinates. The original radar-brightness map can be rectified and interpolated, using the same height data, with the result that the radar brightness and the topography are coordinated in position. This aids the interpretation of the radar-brightness data, facilitating the decoupling of local topographical features from other factors that contribute to the radar reflectivity.

The technique was tested by the use of a CV-990 airplane to map 11- by 10-km regions on the California coast, sampled on a grid of 11-m picture elements. The total of relative rms errors over land areas due to various limitations on the equipment was about 6 m. Systematic errors in the knowledge of the aircraft attitude may be responsible for a global rms error of 20 m. Measurements over the ocean yielded rms variations of 2 to 10 m, which are consistent with the theoretical value.

This work was done by Howard A. Zebker and Richard M. Goldstein of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 29 on the TSP Request Card. NPO-16665*

Sonic Simulation of Near Projectile Hits

Measured frequencies would identify projectiles and indicate miss distances.

NASA's Jet Propulsion Laboratory, Pasadena, California

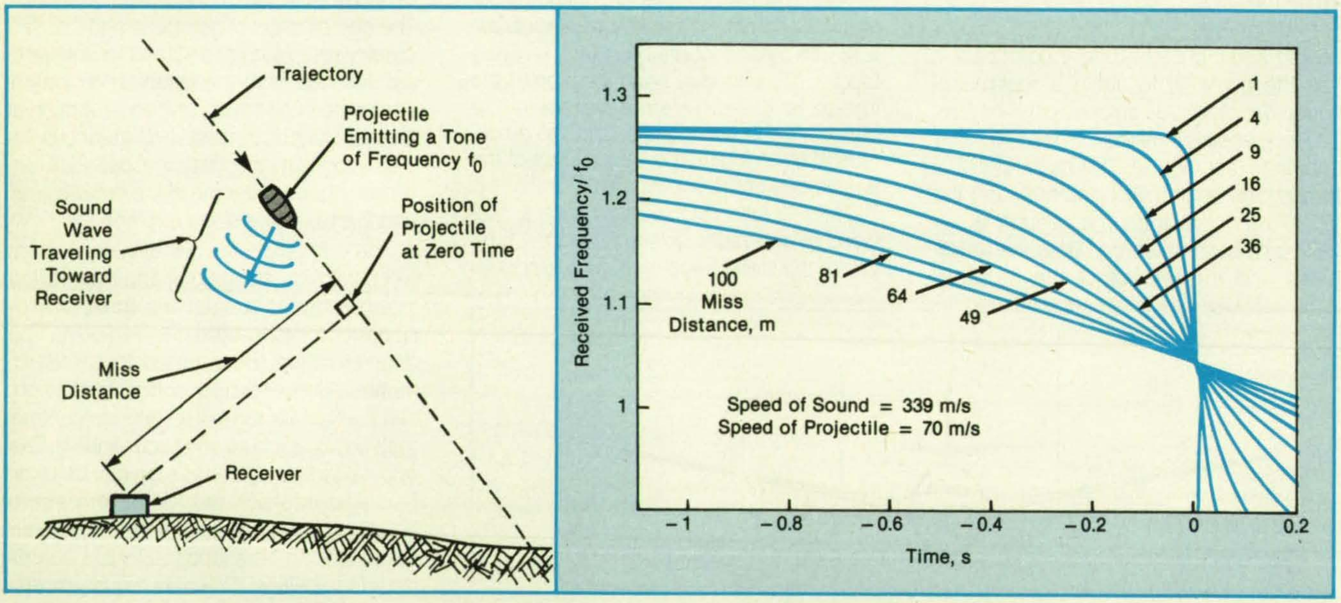
A developmental battlefield-simulation system for the training of soldiers would use the sounds emitted by incoming projectiles to identify the projectiles and indicate the miss distances. Depending on the projectile type and the closeness of each hit, the system would generate a "kill" or "near-kill" indication. With modifications, the system concept may be applicable to collision-warning or collision-avoidance systems.

An artillery shell is simulated by a lightweight plastic projectile launched by compressed air. The flow of air through a groove in the nose of the projectile generates an acoustic tone. Each participant in the training exercise carries an audio receiver that measures and processes the tone signal. When fully developed, the system would perform fast Fourier transforms of the received tone to obtain the dominant frequency during each succeeding interval of approximately 40 ms (an interval determined from practical signal-processing requirements).

From the frequency-versus-time information, the system would extract the rest frequency (the tone frequency in the frame of reference of the projectile); because a different frequency is assigned to each type of weapon, this frequency would be used to identify the projectile. The frequency-versus-time information would also be processed to obtain the miss distance by the use of the known dependence of the Doppler-shifted rest frequency of the received signal on the time, the miss distance, and the speed of the projectile (see figure).

An algorithm has been developed to obtain the desired information by electronic "template matching": the system tries to match the actual frequency-versus-time data to one after another of the sets of relative-frequency-versus-time data stored in memory for each of many combinations of the miss distance and the number of sampling intervals. The rest frequency is computed as a weighted sum of the measured frequencies with a weighting function calculated from the selected relative-frequency-versus-time set.

This work was done by J. I. Statman and E. R. Rodemich of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 107 on the TSP Request Card. NPO-16943*



The **Frequency of the Tone** measured by the receiver undergoes a Doppler shift that varies with time as a projectile emitting the tone passes near the observer. To compute the curves shown here, the projectile was taken to be traveling on a slanted straight line at constant speed.

Analog/Digital System for Germanium Thermometer

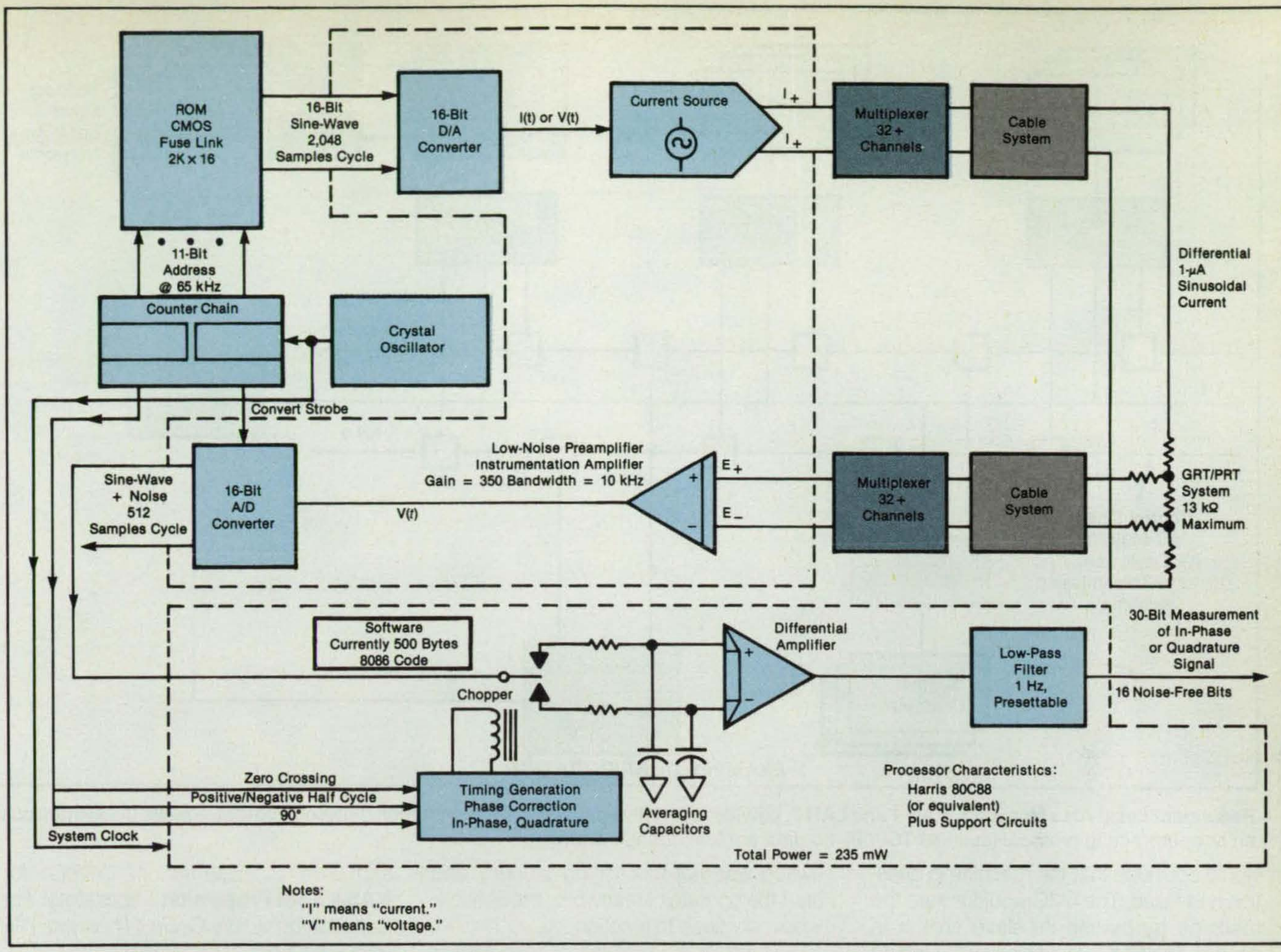
Four-wire measurements of resistance are made with 1-μA excitation in the presence of noise.

Goddard Space Flight Center, Greenbelt, Maryland

An electronic system containing analog and digital circuits (see figure) makes high-precision, four-wire measurements of the resistance of each germanium resistance thermometer (GRT) in an array of such devices, using an alternating current (ac) of 1 μA. The circuit is designed to operate in the presence of the electronic noise encountered in the Space Shuttle cargo bay. It may also be useful in noisy terrestrial environments like those encountered in factories.

A crystal oscillator provides the basic timing for the system. A counter chain counts the oscillator frequency down to about 32 Hz. The outputs of the counter are used to form an address to a pair of programmable read-only memories (PROM's), in which a 16-bit sine wave is encoded. The outputs of the PROM's are converted to an analog signal by a digital-to-analog converter. The analog sine wave controls a 1-μA-peak, high-compliance, balanced current source.

The resulting differential current is multiplexed out through low-leakage analog multiplexers to a selected GRT. The ac voltage on the GRT caused by this current is multiplexed back to a high-common-mode-rejection instrumentation amplifier



This **Analog/Digital System** measures resistance of germanium resistance thermometers with 16-bit precision using only 1-μA excitation in the presence of noise.

with a gain on the order of several hundred. The bandwidth of the preamplifier is limited to the minimum necessary to pass the signal unattenuated. The high-level amplified signal plus noise is digitized to 16 bits at nearly the maximum rate of the analog-to-digital (A/D) converter, about 10 kHz. The analog section operates in ac mode, eliminating offset, bias, differential linearity, and missing-code errors.

These samples are read in by a very compact microprocessor system with a clock rate of about 1 MHz. Because the timing of the outgoing signal is known precisely, a synchronous demodulation is easily implemented by summing readings from the positive half cycle to one register and readings from the negative half cycle to another. A smoothing window may be applied to the data at this point. This process is illustrated symbolically with a relay in the figure but is implemented totally in software, thereby eliminating the errors associated with the chopper and the averaging capacitors.

At the end of the measurement interval, the contents of the negative register are subtracted from those of the positive one, resulting in a very-narrow-band synchronous demodulation of the carrier wave and suppression of the out-of-band noise. The microprocessor is free to perform other duties after the measurement is complete.

This work was done by Christopher Woodhouse of **Goddard Space Flight Center**. *No further documentation is available.*
GSC-13149

Fault-Tolerant Local-Area Network

A concept offers monitoring and control features as well as high reliability.

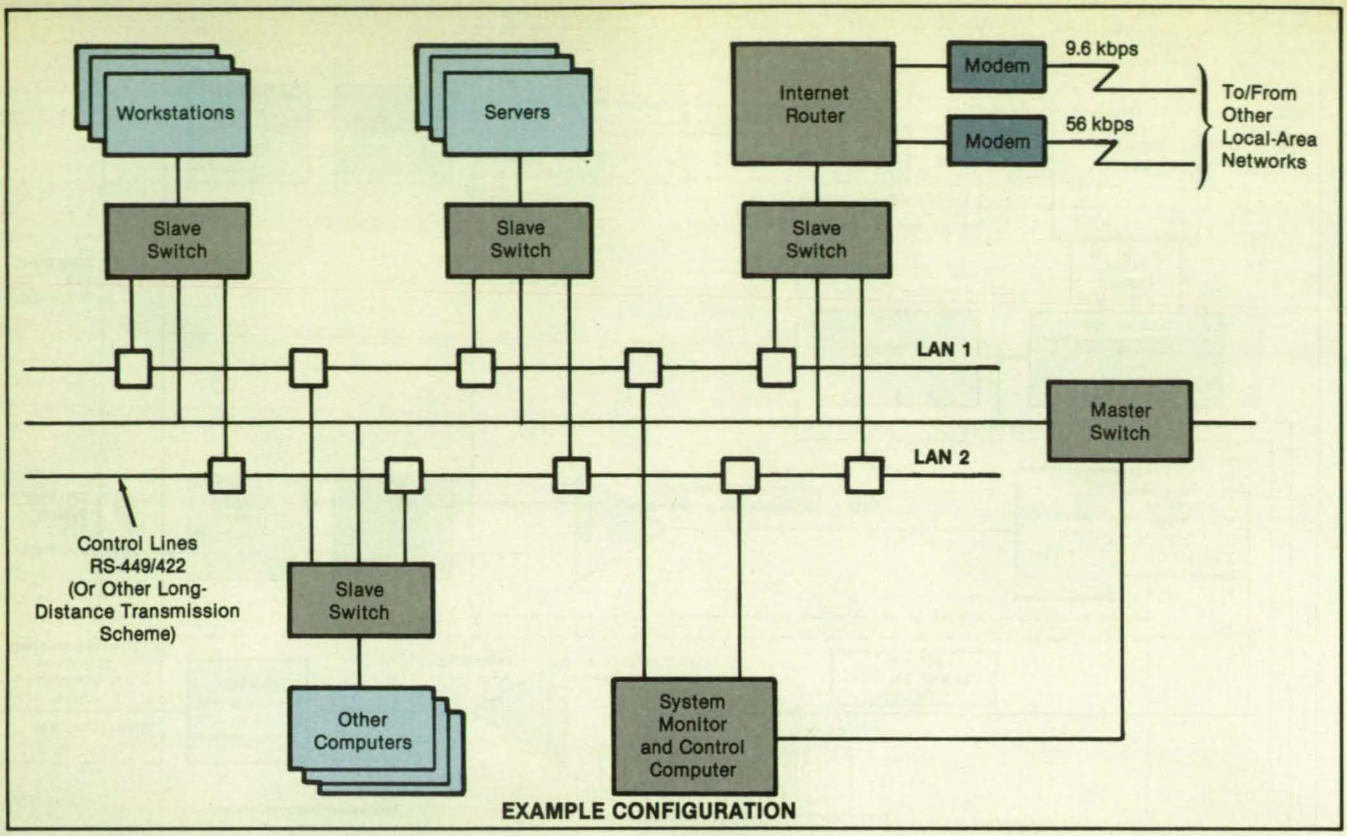
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed redundant local-area network (LAN) for computers would prevent a single-point failure from interrupting communication between nodes of the network. The network would monitor and control itself, automatically route traffic for the efficient use of resources, and isolate and correct its own faults, with a potential dramatic reduction in time out of service.

The network would include two complete cables, LAN 1 and LAN 2 (see figure). Microprocessor-based slave switches would link the cables to such network-node devices as work stations, print servers, and file servers. The slave switches would respond to commands from a master switch, connecting their nodes to either of the two cable networks or disconnecting them so that they are completely isolated. The system monitor and control computer (SMC) would act as a gateway, allowing nodes on either cable to communicate with each other and ensuring that LAN 1 and LAN 2 are fully used when both are functioning properly.

The SMC would poll each node for a status word. If a node device responded, the SMC would go to the next node. If the polled machine did not respond, the SMC would switch it to the other LAN and poll it again. If the machine were still silent, the SMC would verify that the LAN switching mechanism still worked by switching another machine, known to be healthy, to the other LAN and polling it.

If switching were verified, the SMC



Redundant Local-Area Networks, LAN 1 and LAN 2, provide alternative paths for communication between nodes. Because the system uses an error-correcting protocol (such as TCP/IP), no data are lost during switching.

would conclude that the machine in question had failed. The SMC would isolate the machine by putting its slave switch in neutral. The SMC would display a warning message for the system operator.

If the SMC concluded that the slave switch did not work, it would display a warning of this condition. The operator could then use an override switch to connect the node manually to a LAN.

If, after switching several nodes, the SMC found that none of the nodes were working, it would conclude that the master switch was not functioning properly and alert the operator. Meanwhile, the network would continue to function.

Failures of the network or of switching devices would not be catastrophic. Unaffected nodes would still be able to communicate. At all times, the SMC would graphically depict the current LAN configuration by showing what machine is on what LAN on the operator's console. It would also display throughput statistics for both networks.

This work was done by Sergio Morales and Gary L. Friedman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 111 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 26]. Refer to NPO-16949.

Two-Dimensional Systolic Array for Kalman-Filter Computing

A simplified algorithm enables real-time Kalman filtering.

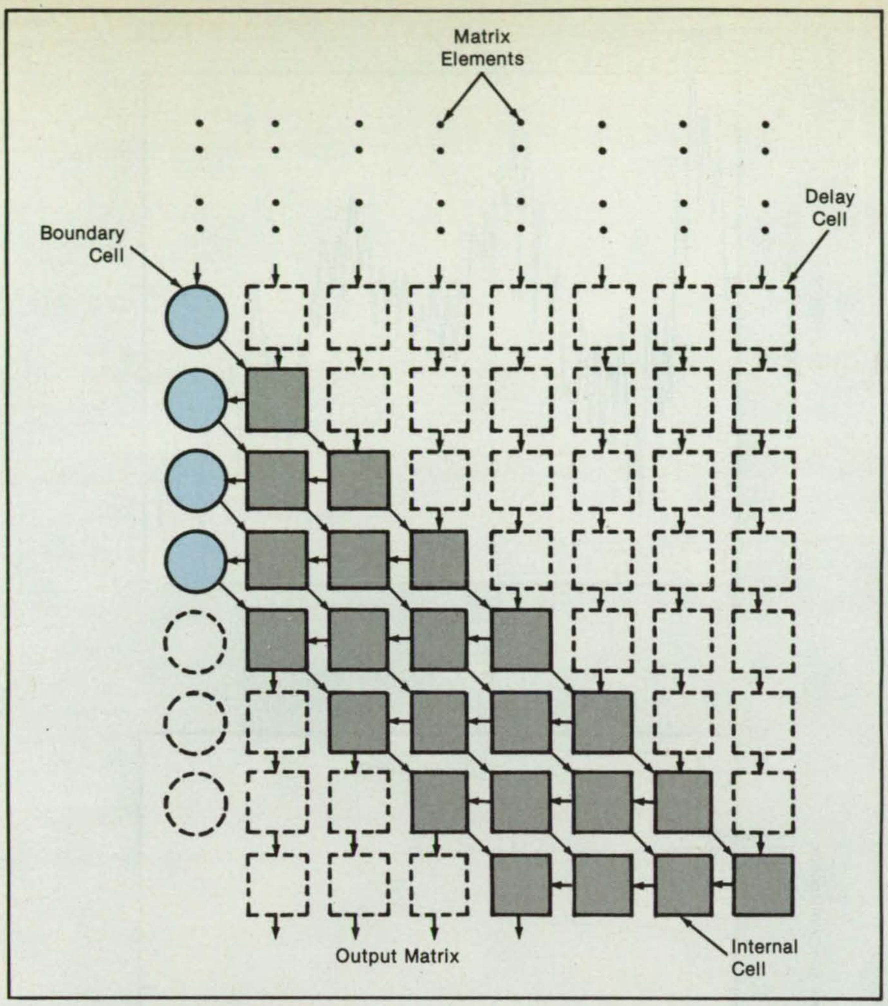
NASA's Jet Propulsion Laboratory, Pasadena, California

A novel two-dimensional, systolic-array, parallel data processor performs Kalman filtering in real time. The Kalman-filter algorithm is rearranged to be a Faddeev algorithm for generalized signal processing, and the Faddeev algorithm is mapped onto a very-large-scale integrated-circuit (VLSI) chip in a two-dimensional, regular, simple, and expandable array of concurrent processing cells. The processor can also do matrix/vector-based algebraic computations. Possible applications include the adaptive control of robots, remote manipulators and flexible structures and the processing of radar signals to track targets.

The Kalman filter requires matrix/vector operations. Among these, matrix inversion is the most difficult to implement with speed and accuracy. The Faddeev algorithm has been suggested as a universal algorithm for various matrix manipulations due to the fact that it is easily systematized for matrix calculations and maps easily into a concurrent systolic array. It is natural to arrange Kalman-filter algorithms into forms of the Faddeev algorithm to maximize the capabilities of equipment in systolic arrays.

Kalman filters have been shown to be optimal linear estimators in the least-squares sense for the estimation of the dynamic states of linear systems. A Kalman filter updates the state estimation based on prior estimates and observed measurements. It consists of the model of the dynamic process, which performs the function of prediction, and a feedback correction scheme. The measurements can be processed as they occur, and there is no need to store any measurement data. However, all the associated matrices that describe the dynamics of the system, the measurement system, and the noise are assumed to be known. The conventional discrete time-varying Kalman-filtering process involves the propagation of state estimates and error-convariance matrices from each time sample to the next time sample.

The Faddeev algorithm is simple because it does not require the direct computation of the matrix inverse. It is necessary only to annul the last row. The solution involves triangularization, a numerically stable procedure, combined with an equally-



A **Square Array of Processors** emerges directly from the application of the Faddeev algorithm to the Kalman-filter problem.

stable Gaussian elimination procedure. One of the important features of this algorithm is that it avoids the usual back substitution or solution to the triangular linear system and obtains the values of the unknowns directly at the end of the forward course of the computation, resulting in a considerable saving in added processing and storage.

In the new algorithm, computations are cyclically propagated through an ordered set of eight passes. New data can be shifted into the array from the top, row by row as the calculation proceeds, so that there need be no delay in starting the next matrix computation. The results (in the lower right quadrant) of each pass must be stored and used in later passes as new entries. The square processor arrangement for both triangularization and annulling steps is shown in the figure. However, to compute all eight passes, the size of the processor is $2n$ cells (row) by $2n$ cells (column).

It is desirable to have a processor of fixed size to handle all eight passes. However, the size of the matrix/vector varies from pass to pass. By padding zeros in appropriate places, the $2n$ cells (row) by $2n$ cells (column) become the proper size for implementing Kalman filters. By the use of the fixed-size $2n$-by-$2n$ processor arrays, the state estimate can be updated in each $16n$ time units (assuming that it takes 1 time unit to manipulate data in a cell).

This work was done by Jaw John Chang of Caltech and Hen-Geul Yeh of California State University for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 116 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 26]. Refer to NPO-17108.

Quantile Vocoder

Parameters of the spectral envelope are obtained statistically.

NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm for the digital compression of speech signals encodes the power spectral density of each short interval of speech by the use of quantiles or order statistics. The purpose of this and other speech-compression algorithms is to reduce the bit rate and therefore the bandwidth required for transmission. When fully developed, the quantile vocoder — the speech-encoding system based on the new algorithm — is expected to be only moderately complicated in comparison with other speech-encoding systems and to reproduce high-quality speech from code transmitted at relatively low bit rates.

The speech signal is treated mathematically as though its amplitude spectrum were stationary during the short coding intervals, called "windows." Each window has a duration of 20 to 35 ms, chosen as a compromise between frequency resolution and time resolution. During each window, the short-time amplitude and power spectra are found by sampling at a high rate (typically 10 kHz) and taking fast Fourier transforms (FFT's).

The short-time power spectrum is characterized in part by a spectral envelope that represents the frequency response of the vocal tract and the spectrum of the glottal pulse for voiced speech. The perceptually important features of this envelope are the peaks, which correspond to the formants or resonances of the vocal tract. The short-time power spectrum is also characterized by a fine structure, largely due to excitation.

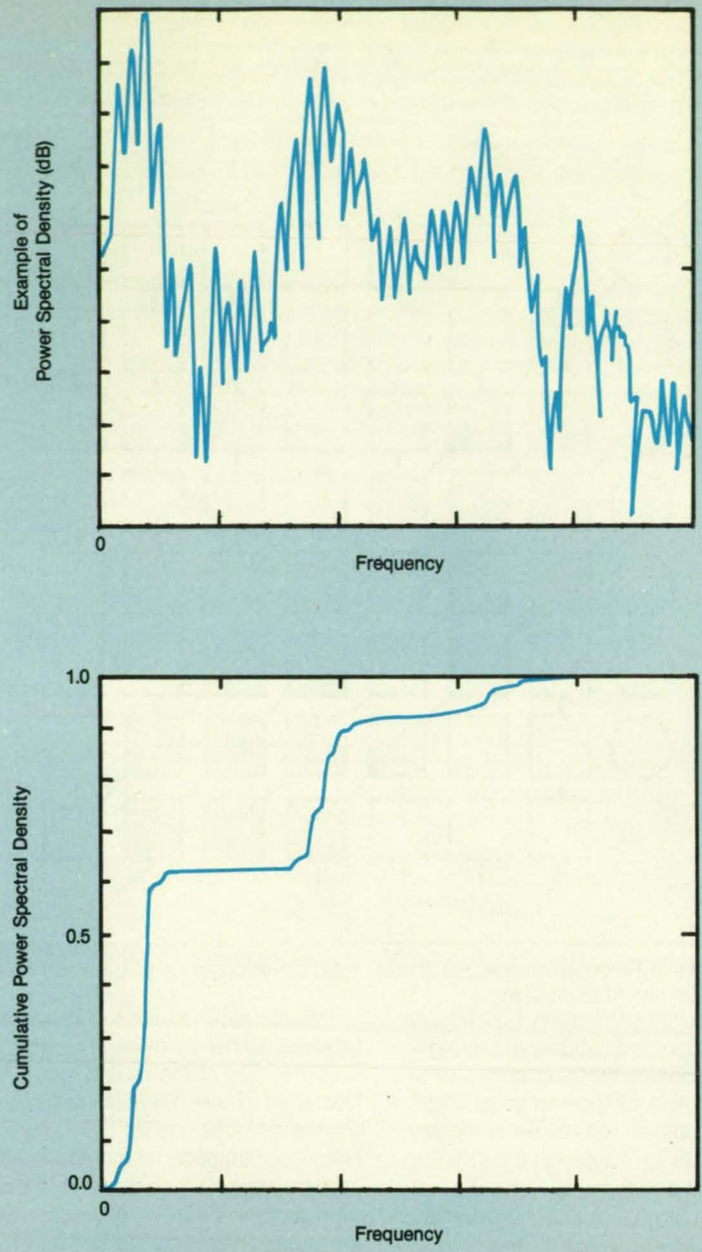
The algorithm uses quantiles of the cumulative power spectral density (see figure) to estimate the parameters of the spectral envelope during each window. The first step is to approximate the portion of the envelope in every interquantile range by a constant equal to the average power in that range. The flat spectral density is then smoothed by fitting an autoregressive or all-pole mathematical model.

The shape of the envelope near the formants can be encoded by careful choice of the quantiles and quantile orders. The process is accomplished with the help of preemphasis (preferential amplification of higher frequencies). The entire frequency range is split into subbands, within which a fixed number of quantiles is chosen. These measures assure that the perceptually relevant features in each subband will be encoded. In addition, the amplitude spectral density is used to decrease the dynamic range near the formants to reveal more detail about those portions of the spectrum.

The spectral fine structure is represented by the parameters of a mathematical model of multipulse excitation in cascade with a mathematical pitch-predicting model. Quantization and encoding for transmission are accomplished via parameters for the quantiles, quantile orders, locations and amplitudes of excitation pulses, parameters of the pitch-predicting model, and a gain term.

The quantile vocoder has been tested by simulation in software at 4.8, 9.6, 16, and 24 Kb/s. As judged subjectively by listeners, the system reproduced speech fairly well at the higher bit rates. Further development will be needed to attain satisfactory performance at the lower bit rates.

This work was done by Kumar Swaminathan of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 72 on the TSP Request Card. NPO-16829*



The **Power Spectral Density** and the cumulative spectral power density (normalized to 1) are approximated and quantized to reduce the bit rate for transmission of the signal.

Optical Recognition and Tracking of Objects

Separate objects moving independently are tracked simultaneously.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental optical image-processing system has been used to demonstrate the simultaneous recognition and tracking of independently moving objects. The system uses coherent optical techniques to obtain the correlation between each object

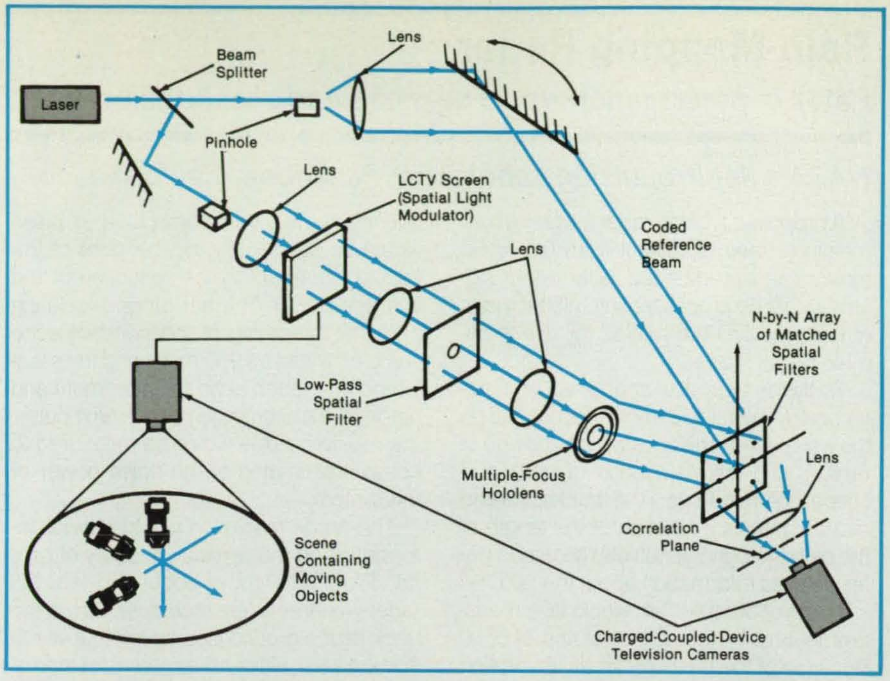


Figure 1. This **Real-Time Image-Processing System** relies on holographic optical techniques to recognize and track several independently moving objects.

and its reference image. Although the demonstration involved only three objects, in theory, the capacity of the system can be expanded to enable the tracking of hundreds of objects.

The principle of operation is illustrated in Figure 1. The scene containing the moving objects is monitored by a charge-coupled-device television camera, the output of which is fed to a liquid-crystal television (LCTV) display. Acting as a spatial light modulator, the LCTV impresses the images of the moving objects on a collimated laser beam. The beam is spatially low-pass filtered to remove the high-spatial-frequency television grid pattern.

An N-by-N multifocus hololens processes the image-modulated, spatially filtered laser beam to generate an N-by-N array of Fourier spectra of the image. These spectra are used to address simultaneously an array of prefabricated holographic matched spatial filters. (During the synthesis of these filters, a linearly shifted, coded reference laser beam can be used to separate spatially the output correlation planes associated with each filter. Therefore, each object can be tracked and recognized in real time.) The output correlation peaks are picked up by an array of charge-coupled-device detectors. An object is considered to be identified and located where its correlation peak exceeds a specified threshold amplitude.

For the demonstration, a commercial LCTV screen was submerged in a liquid gate filled with insulating mineral oil to reduce nonuniformity of phase. A 3-by-3 hololens was formed in dichromated gelatin. For simplicity, a column of 3-by-3

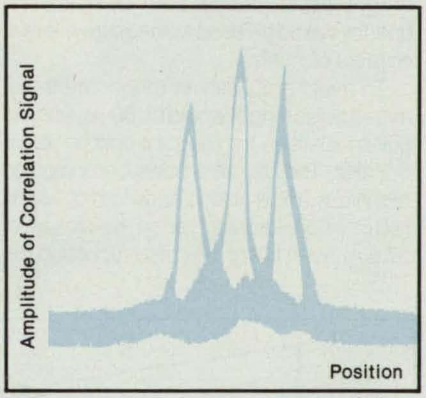


Figure 2. The **Positions of Three Objects** are indicated by the locations of peaks in the signals of correlations of their images with reference images incorporated in matched spatial filters.

matched spatial filters was synthesized to track the motions of three toy cars. The matched spatial filters were recorded by use of a thermoplastic plate for high efficiency of diffraction and ease of processing. Figure 2 shows the correlation peaks of the three cars.

This work was done by Tien-Hsin Chao and Hua-Kuang Liu of Caltech for ***NASA's Jet Propulsion Laboratory****. For further information, Circle 118 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 26]. Refer to NPO-17139.

Rain-Mapping Radar

Rates of precipitation would be measured over large areas.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed orbiting radar system would measure rates of rainfall from 0.5 to 60 mm/h. The accumulated radar return signals would be processed into global maps of monthly average rainfall for use in climatological studies.

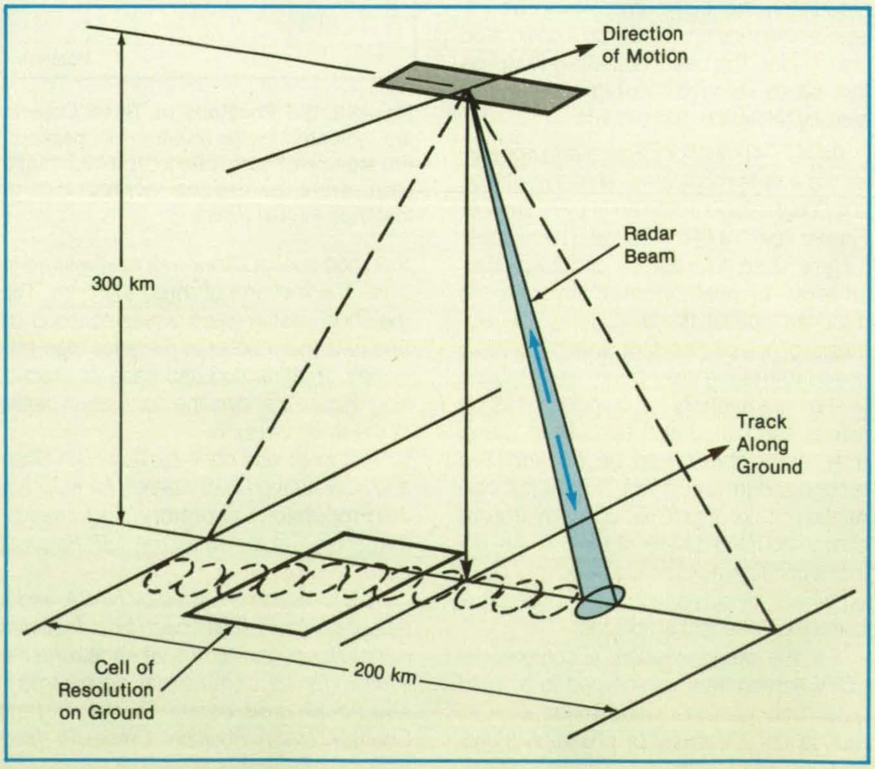
Radar waves are scattered and absorbed by rainfall to extents that depend on the wavelength, the polarization, the rate of rainfall, and the distribution of sizes and shapes of raindrops. The backscattered radar signal as a function of the length of the path through the rain can be used to infer detailed information about the rain.

The proposed system would take measurements at frequencies of 14 and 24 GHz. Because of the relatively small absorption by rain at 14 GHz, this frequency would be used to measure moderately heavy to heavy rain. Because the radar reflectivity of light rain is stronger at 24 GHz, this frequency would be used to measure the lower rates of rainfall.

To avoid ambiguity in range, the transmitted pulse length would be 80 μs, and the pulse-repetition frequency would be about 3.5 kHz. The use of a pulse-compression technique and a pulse bandwidth of 4 MHz result in an intrinsic range resolution of 37.5 m. With the given pulse-repetition frequency, the echoes from pulse to pulse would be statistically independent of the fluctuation, enabling the reduction of the average power. The net range resolution after the averaging of independent echo samples would be 250 m. During the silent period after each echo measurement and before the transmission of the next pulse, the received noise would be measured to compile estimates of the noise power of the system.

The range resolution would provide information on the vertical variability of rainfall. From a height of about 300 km, the radar would scan electronically across the track on the ground (see figure) in a swath 200 km wide with a horizontal resolution of 4 km during 90 percent of the time. During the remaining 10 percent of the time, the swath would be widened to 600 km (with a consequent loss in both vertical and horizontal resolution) to obtain supplemental data that aid in the distinction between water suspended in clouds and the rainfall.

The expected performance of the system was estimated via an equation that expresses the signal-to-noise ratio of the radar echo from the raindrops in terms of the peak transmitted power, various parameters of the equipment, the distance to



Scanning Across a Swath 200 km wide, the radar would move along a track to produce a global map of the rate of rainfall.

the measured position, the radar reflectivity of the raindrops, and the attenuation of the signal along the signal path. The reflectivity and attenuation are approximated by empirical equations that relate them to rates of rainfall. It appears that the measurements at 14 GHz can attain accuracies better than 10 percent for rates of rainfall from 0.5 to 50 mm/h. However, because of strong attenuation at higher rates, the accuracies of measurements at 24 GHz are expected to deteriorate with increases in the depth of penetration.

This work was done by K. E. Im, F. K. Li, W. J. Wilson, and D. Rosing of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 140 on the TSP Request Card.*
NPO-17248

System Turns SAR Images Into Maps

Manual registration with known geographical features is unnecessary.

NASA's Jet Propulsion Laboratory, Pasadena, California

A postprocessing system for synthetic-aperture radar (SAR) transforms raw images from the natural rotated and distorted SAR reference frame into geocoded images; that is, images oriented and registered with geographical coordinates in a universal transverse Mercator, polar stereographic, or other standard map projection. The geocoded images are automatically corrected to remove slant-range nonlinearities and Doppler skew. The system can produce multiple-frame mosaics for large-scale mapping. Unlike previous systems, this one does not require the tedious manual registration of representative "tie" points in the raw SAR imagery with known locations on the Earth.

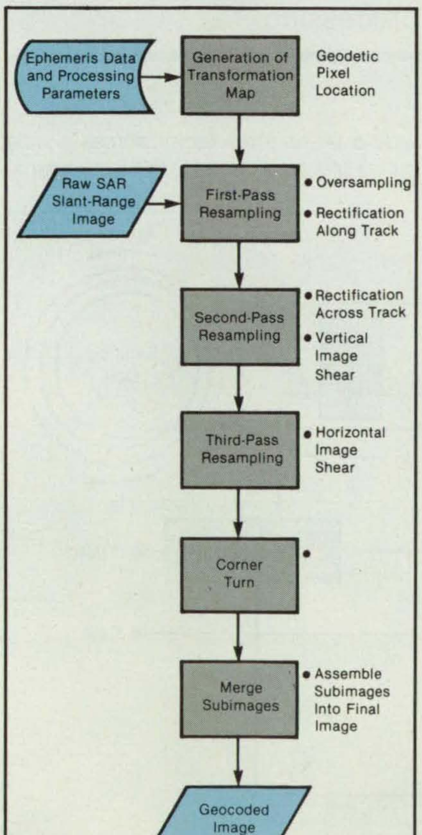


Figure 1. **Ephemeris Data** of the radar platform plus radar-signal and processing parameters are used to transform the raw SAR image into a geocoded map.

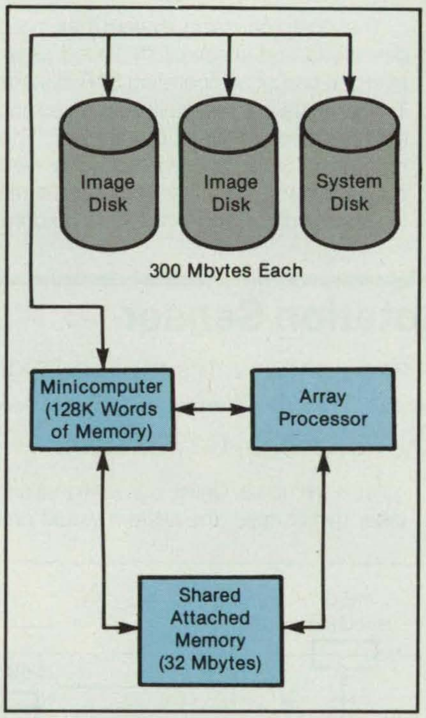


Figure 2. The **Postprocessing Equipment** operates in conjunction with other elements of an SAR digital processor. The postprocessing equipment is shared with the SAR correlator.

In effect, the new system replaces the tie points with a combination of data on the trajectory and velocity of the radar platform (see Figure 1) plus reliance on the amplitude and frequency of the radar echoes (as functions of time) to determine the slant range and the aiming (squint) angle of the target. This information is processed to obtain distortion- and orientation-correcting factors.

An essential step is the solution of three simultaneous equations for the three-dimensional Earth-based coordinates of a target represented by an arbitrary picture element. These are the equations for (1) the surface of an oblate ellipsoid that represents the geoid, (2) the Doppler shift of a point target, and (3) the slant range.

The solution involves an iterative numerical process. First, the intersection of the range vector with the geoid is found to determine the nominal target location and Doppler shift. The range vector is then squinted to find the intersection of the appropriate iso-Doppler line for the given Doppler shift while maintaining the correct slant range. This operation is repeated for a set of picture elements distributed over the image to generate a map of geodetic location versus picture-element number in the raw image.

The picture elements can be mapped onto any desired cartographic projection by a coordinate transformation based on the geodetic coordinates and on the spatial relationship between the SAR slant-range-vs.-azimuth reference frame and the grid of the projection. Because it would involve excessive computation to map exactly by resampling on an element-by-element basis, the process is simplified (at the cost of some geometric distortion) by dividing the image into subblocks and locating the points in each subblock by a bilinear interpolation.

The image intensities of the picture elements are resampled in two one-dimensional passes. The first pass represents a rectification of the image in the along-track direction. The second pass represents a rectification in the across-track direction. To rotate the rectified image to the geocoded format, this image is resampled further in the two one-dimensional passes that represent vertical and horizontal image shears. Oversampling is performed prior to rotation to reduce aliasing of the image data.

The postprocessing system has been developed and successfully tested as an intergral part of an operating SAR system. The software is completely automated and optimized for efficient processing. This equipment is configured around a minicomputer with an array processor, three 300-Mbyte disks, and a 32-Mbyte random-access memory (RAM) with system interfaces to both the minicomputer and the array processor (see Figure 2). The minicomputer, which acts as a host to the array processor, is equipped with 128K words of 600-ns solid-state memory.

The input slant-range image records and the output geocoded image records are stored in disk files common with the SAR processor output. The RAM serves as storage for the intermediate image from each resampling pass. All resampling is performed in the array processor to optimize the throughput. The ephemeris data and the processor-control parameters, like output-image size, picture-element spacing, and the center location, are stored in a parameter file that is automatically established on a magnetic disk by the SAR correlator during the initial generation of the image.

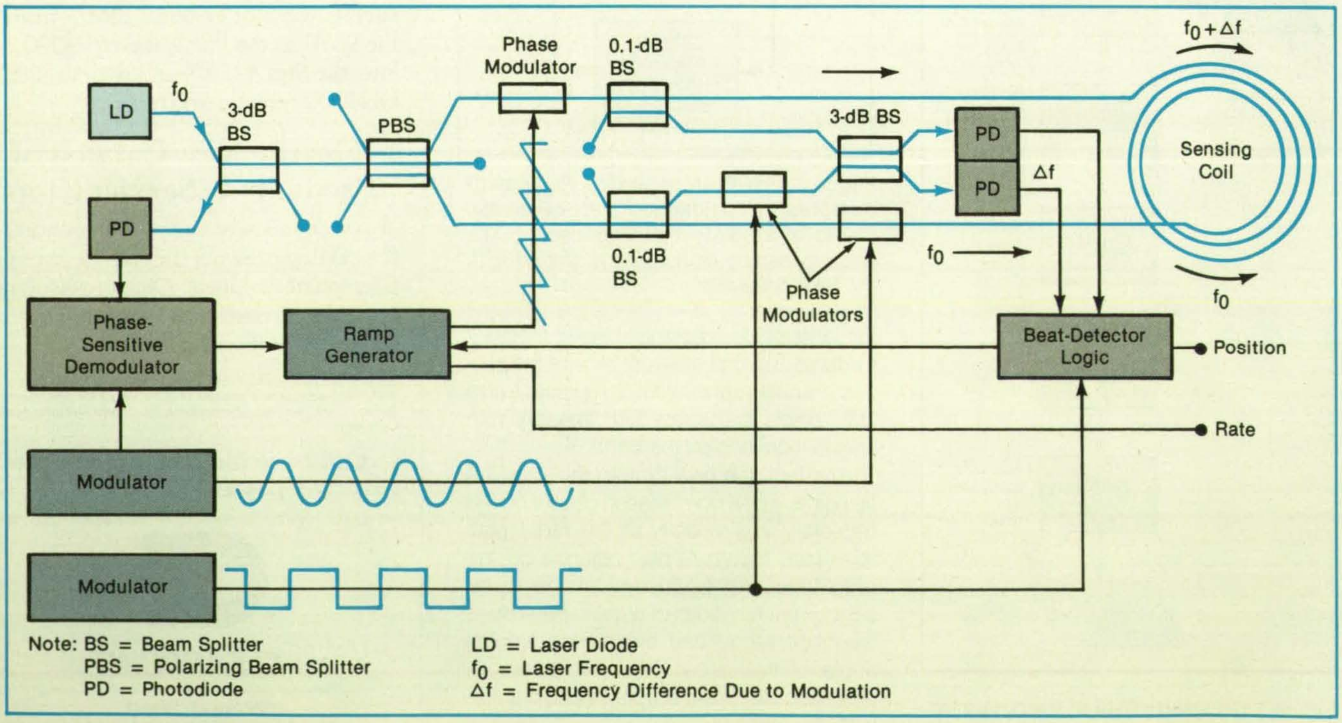
This work was done by J. C. Curlander, Ronald Kwok, and Shirley S. N. Pang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 35 on the TSP Request Card.*
NPO-17106

Closed-Loop Optical Rotation Sensor

Integrated optics can improve performance with simplified signal processing.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed optical/electronic system can sense rotation and emit pulses at angular increments. Unlike conventional ring laser gyroscopes, the system would provide a linear scale factor across a wide range of rotation rates (0.003° per hour to



The **Optical Rotation Sensor** would be built with integrated optics to simplify the generation of pulses that represent the increments of rotation.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300° per second) with no lockup at the null. Because of the integrated optics, the new system design needs no analog-to-digital converters with elaborate signal-processing circuits.

The system is shown schematically in the figure. Light from a laser diode is split evenly into two beams propagating in opposite directions around a rotation-sensing coil of optical-fiber waveguide. In the absence of phase modulation, the beams acquire a phase difference proportional to the rotation rate as they pass through the coil. After emerging from the coil, the beams are recombined in a beam splitter, and the coherent sum is fed to the photodiode shown at the left in the figure.

Before entering the coil, the lower beam is modulated with a sinusoidally-varying phase shift. A phase-sensitive demodulation of the left photodiode output synchronized with the sinusoidal phase modulation produces an output signal proportional to the sine of the rotational phase shift. This signal can be used directly as the rotation-rate signal for slow rotations or as an error signal for closing a phase-nulling control loop.

In response to the error signal, the upper beam entering the coil is modulated with a ramping phase change. The resulting difference in frequency between the two beams is directly proportional to the rotation rate. Two 0.1-dB waveguide beam splitters tap off a small portion of each beam, and the beat note between them is obtained optically by recombination in a four-port, 3-dB beam splitter.

Two photodiodes (one is redundant) convert the optical beats to electrical signals, which are fed to the beat-detector logic. A square-wave modulator imposes an additional $\pm\pi/2$ phase shift: This alters the sequence of beat-note maximums and minimums in a way that is used by the beat-detector logic to determine the algebraic signs of the rotational increments. The output is thus a series of pulses that are used to count the angular increments up and down to the present angular position.

This work was done by Willis C. Goss, Bruce R. Youmans, Noble M. Nerheim, and Randall K. Bartman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 141 on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 4,662,751). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 26]. Refer to NPO-16558.

Physical Sciences

Measuring Flow With Laser-Speckle Velocimetry

Spatial resolution is sufficient for calculation of vorticity.

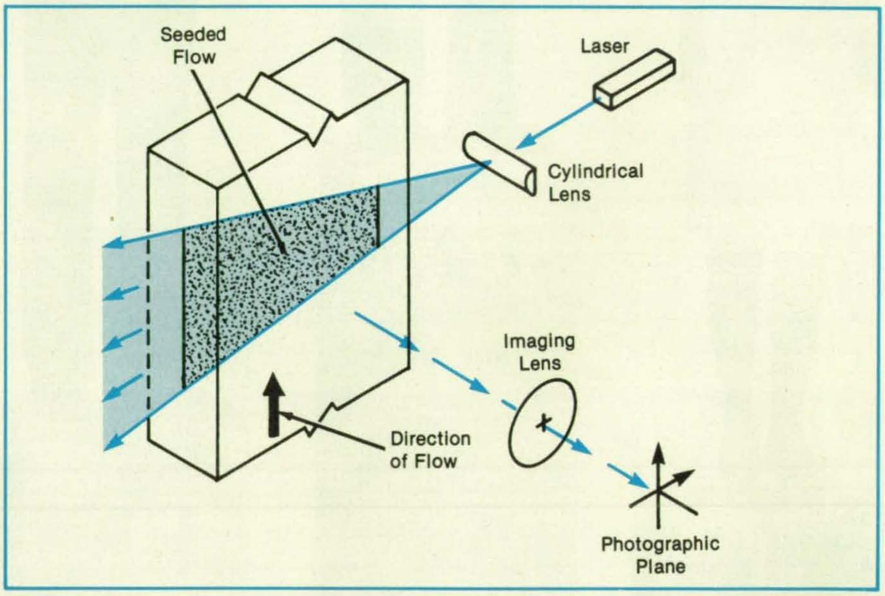
Ames Research Center, Moffett Field, California

Laser-speckle interference can be used in flow experiments to visualize two-dimensional streamline patterns and to quantify the associated velocity fields. The main advantage of laser-speckle velocimetry is that a velocity field can be measured with sufficient accuracy and resolution to enable the computation of the vorticity field. This technique is suited for the study of vortical flows like those about helicopter rotor blades or airplane wings at high angles of attack.

In laser-speckle velocimetry, a pulsed or chopped laser beam is expanded in one dimension by a cylindrical lens to illuminate a thin, fan-shaped region of the flow to be measured. The flow is seeded by small particles. A lens with an optical axis perpendicular to the illuminating beam forms an image of the illuminated particles on a photographic plate (see figure). If the seed particles are distributed densely enough, the image is a random speckle pattern caused by the interference of light reflected from the seed particles.

In effect, the speckles form a random grid embedded in the image of the illuminated region. If the laser is pulsed more than once, and if the motion of the fluid between pulses is large enough to cause a shift of at least one average speckle diameter but not large enough to destroy the coherence between the speckle patterns at the different pulse times, then the resulting multiple-exposure speckle photograph (specklegram) contains laterally shifted versions of nearly-identical speckle patterns. Because the magnitude and direction of the local shift between the two patterns is determined by the velocity in the illuminated plane and the known interval between exposures, the specklegram can be analyzed (at least in principle) to extract the velocity field.

A combination of optical and electronic image-processing techniques can be used to analyze a specklegram. In one method, the specklegram is illuminated by a laser beam at a designated point in the flow field.



The **Speckle Pattern of a Laser-Illuminated, Seeded Flow** is recorded in multiple-exposure photographs and processed to extract data on the velocity field.

Because the specklegram is essentially a complicated diffraction grating, it produces interference fringes, the orientations and distances between which indicate the local velocity. The fringe pattern is digitized and processed digitally by a Fourier and/or autocorrelation algorithm to extract the velocity information.

In another method (which is not specifically a speckle method), a low seeding density is used, and the analysis is directed toward the measurement of displacements between subsequent images of individual particles. This requires digital image processing to obtain the two-dimensional autocorrelation of the image field within each interrogation spot to obtain the velocity in that spot. In yet another method, the specklegram is viewed through a spatial filter to obtain isovelocity contours of the entire flow field.

Laser-speckle velocimetry is limited in part by the unavoidably finite thickness of the illumination fan and the presence of velocity components perpendicular to the plane of the fan. Measurable speeds are limited by the finite durations, intensities, and repetition rates of laser pulses. The ultimate objective of development efforts is a technique to measure three-dimensional, unsteady, vortical flows in wind tunnels at high Reynolds numbers.

This work was done by C. A. Smith of **Ames Research Center** *and L. M. M. Lourenco and A. Krothapalli of Florida State University. Further information may be found in AIAA-86-0768-CP, "The Development of Laser Speckle Velocimetry for the Measurement of Vortical Flow Fields."*

Copies may be purchased [prepayment required] from AIAA Technical Information Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 26]. Refer to ARC-11766.

Simplified Microwave Radiometer

The cost, weight, and size would be less than half of those of conventional radiometers.

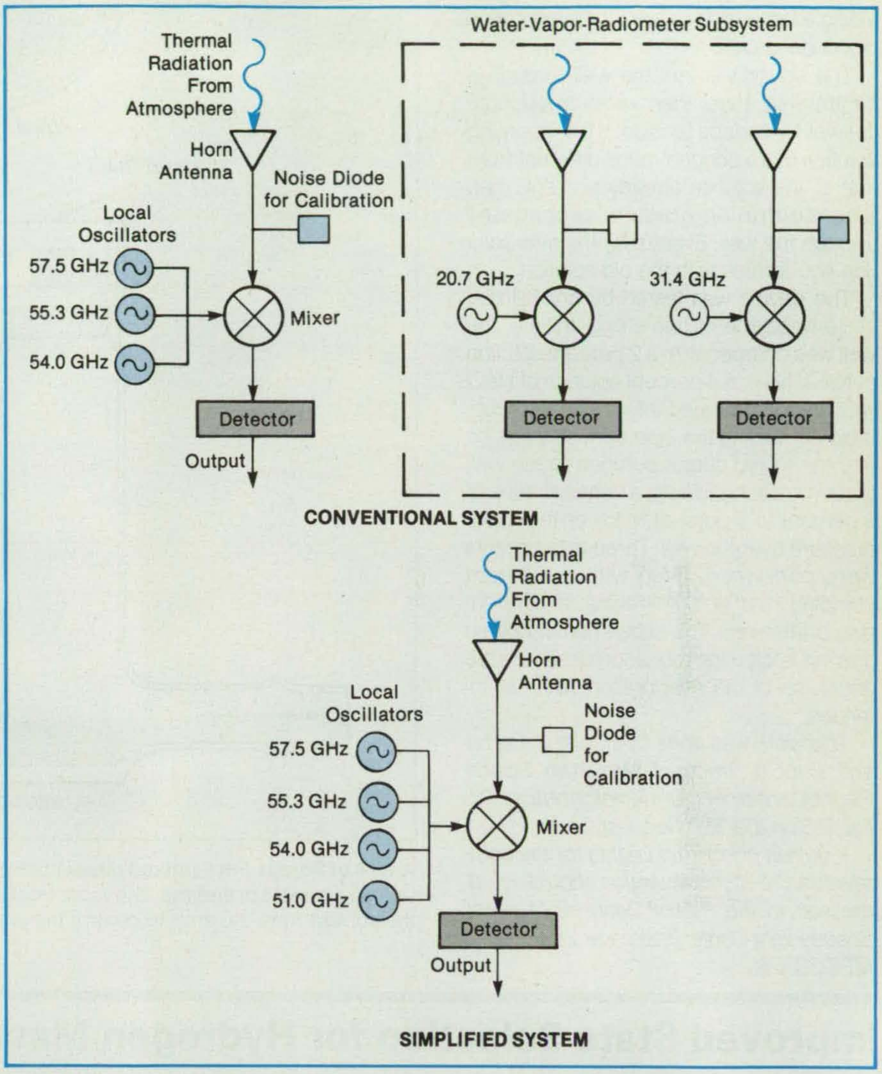
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed ground-based instrument would measure temperatures in the upper atmosphere while correcting for the liquid water in clouds. Its weight, size, and cost would be less than half of those of conventional radiometers used for the purpose. The instrument would be light, compact, and portable and may be inexpensive enough for use in sensor arrays. Its availability would encourage the use of microwave radiometry for routine weather forecasting.

A conventional microwave radiometer contains a water-vapor radiometer subsystem operating at 21 GHz and 31 GHz in addition to the main temperature-sensing system operating at 53 to 58 GHz. The sole purpose of the water-vapor subsystem is to correct for the effect of clouds on observations; yet it accounts for about half the total size, weight, and cost. In the proposed instrument, a different microwave channel — one at 51 GHz — would be used to correct for the effects of clouds. This channel is close enough in frequency to be included in the main system with minimal increase in size, weight, and cost.

Although a conventional, separate water-vapor radiometer measures water content more accurately, the difference in the quality of temperature profiles between the conventional and proposed systems is hardly noticeable. For example, a computer simulation showed that the derived air temperature at an altitude of 10,000 ft (3 km) was 1.97 °C for a conventional system equipped with a separate radiometer and 1.96 °C for a system equipped with a 51-GHz channel. Simulations for a variety of sites showed that the 51-GHz channel is comparable to the separate radiometer in correcting for the effects of clouds.

The 51-GHz channel can be added simply by including a 51-GHz local oscillator to the group of local oscillators required for temperature profiling. The local oscillators can be multiplexed with a single wideband mixer (see figure).



The **Addition of a Channel at 51 GHz** to the channels used for making upper-atmosphere temperature profiles adds little to the cost of a microwave radiometer. However, the added channel eliminates the need for a separate water-vapor radiometer subsystem, with its attendant size, weight, and cost.

This work was done by Bruce L. Gary of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 31 on the TSP Request Card.* NPO-17101

Controlling Vapor Pressure in Hanging-Drop Crystallization

The rate of evaporation is adjusted to produce larger crystals.

Marshall Space Flight Center, Alabama

A device helps to control the vapor pressure of water and other solvent(s) in the vicinity of a hanging drop of solution containing a dissolved enzyme or protein. The device thus facilitates the control of the rate of approach to critical supersaturation during the crystallization of protein or enzyme macromolecules. With the help of the device, the rate of nucleation can be limited to decrease the number and increase the size (and perhaps the quality) of the crystals — large crystals of higher quality are needed for x-ray diffraction studies of these macromolecules.

The protein solution includes a precipitating agent (for example, NaCl) that competes with the protein for the solvent, thereby diminishing the solubility of the protein or enzyme and driving the solution toward supersaturation as the solvent evaporates. The drop of protein solution is hung over a well filled with another solution that has a higher concentration of the precipitating agent and, therefore, a solvent vapor pressure lower than that of the drop.

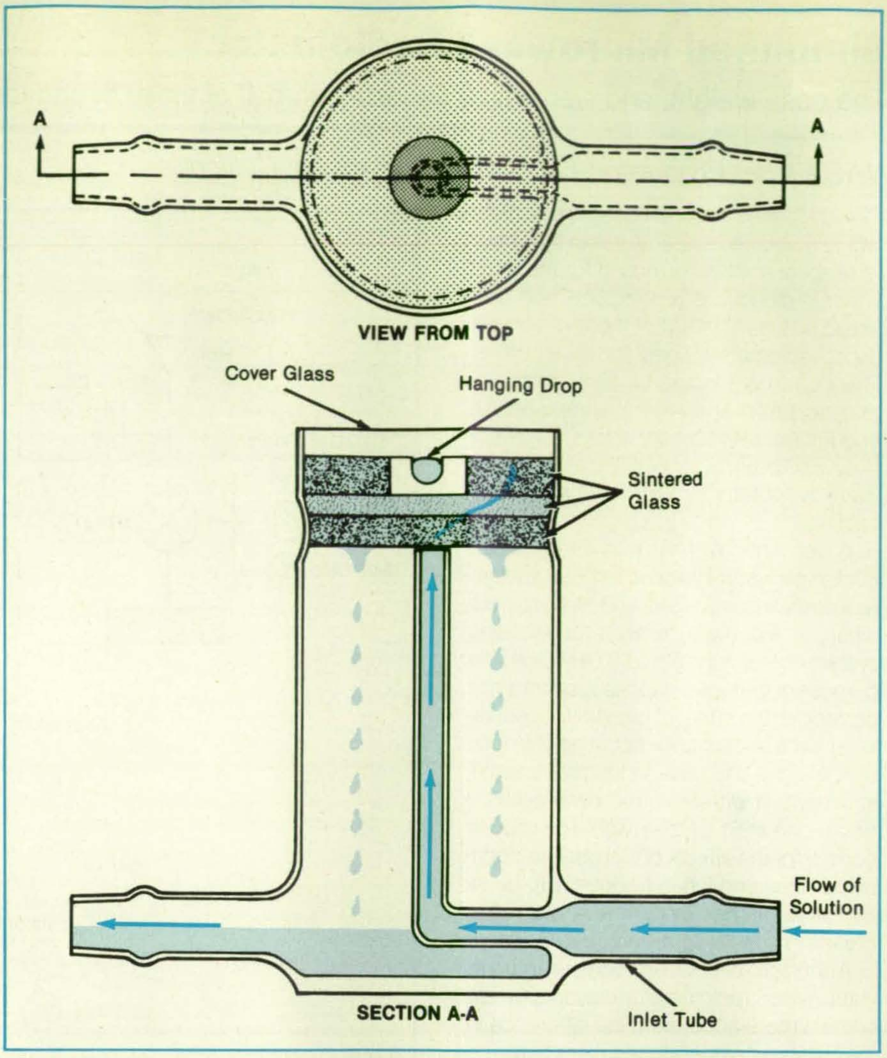
The rate of evaporation can be increased or decreased by increasing or decreasing the difference between the two vapor pressures. In this version of the hanging-drop method, fine control of the vapor pressure and the vapor-pressure distribution is achieved by adjusting the concentration and the gradient of concentration of the precipitating agent in a well of porous sintered glass (see figure). To reduce the lag in the equilibrium of the vapors, the drop is suspended close to the sintered glass. The porosity of the glass also helps to equilibrate the system by providing a large surface area for evaporation or condensation.

The solution enters the well through a central inlet tube, then wicks throughout the well by surface tension. If the incoming solution has a concentration different from that of the solution already present, then a concentration gradient propagates through the well. Eventually, the new solution equilibrates with the old solution.

The device was tested by crystallizing white lysozyme of hen's egg. Initially, the well was charged with a 2-percent solution of NaCl. Next, a 4-percent solution of NaCl was steadily pumped into a mixing receptacle containing the 2-percent solution, so that the mixed output pumped to the well gradually changed from a concentration of 2 percent to 4 percent to lower the vapor pressure over the well. Three experiments were performed, each with a different pumping rate and, therefore, a different evaporation rate. The experiments showed that the nucleation rate decreases with the decrease in the evaporation rate, as intended.

This work was done by Daniel C. Carter and Robbie Smith of **Marshall Space Flight Center**. *For further information, Circle 126 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 26]. Refer to MFS-26056.



A **Well of Porous Frit** (sintered glass) holds a solution in proximity to a drop of solution containing a protein or enzyme. The vapor from the solution in the frit controls the evaporation of the solvent from the drop to control the precipitation of the protein or enzyme.

Improved State Selection for Hydrogen Masers

Atoms that do not contribute to maser oscillation are removed.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved selection system for a hydrogen maser helps to exclude the hydrogen atoms from the storage bulb in undesired quantum states that do not contribute to the amplification/oscillation process. The atoms in the undesired states limit the stability of the maser by reducing the storage lifetime of the atoms in the desired state, reducing the output power, and colliding with atoms in the desired state under circumstances that can cause systematic shifts in frequency.

There are four ground hyperfine states (energy levels) of monatomic hydrogen. At the point of origin, the hydrogen beam has approximately equal numbers of atoms in all four states. The maser transition takes place between states *c* and *a*, as shown in Figure 1. Consequently, the ideal hydrogen beam entering the maser should contain only atoms in state *c*. Prior selection schemes have eliminated atoms in states *a* and *b* but have allowed atoms in state *d* to enter the storage region in numbers equal to those in state *a*, with consequent degradation of the maser output.

The improved selection system is shown in Figure 2. The monatomic hydrogen enters through a hexapole magnet, which focuses the *c* and *d* atoms into a beam. The beam then passes through a dc axial magnetic field, the strength of which varies along the axis. A perpendicular ac magnetic field is applied in this region at a frequency that matches the energy difference between the *c* and *d* levels at some point in the region. With the proper choice of the frequency and amplitude of the ac field in relation to the parameters of the dc field, the atoms that entered in state *d* emerge in state *b*, while the few entering atoms in state *b* emerge in state *d*. The atoms in the desired state *c* remain unchanged.

The beam passes through a second hexapole magnet, which eliminates atoms that have shifted to state *b*. The magnetic field focuses the remaining atoms in state *c* toward the hydrogen-maser storage bulb at various angles according to their velocities. The apertures and stopping disks are strategically placed according to the anticipated distribution of trajectories to pass mostly atoms in state *c* in the desired velocity range and to block atoms in the other states and velocity ranges. Disk stop 3 also prevents ultraviolet light from the hydrogen-molecule dissociator from entering the maser storage bulb and decomposing its polytetrafluoroethylene coating.

Error-Tolerant Quasi-Paraboloidal Solar Concentrator

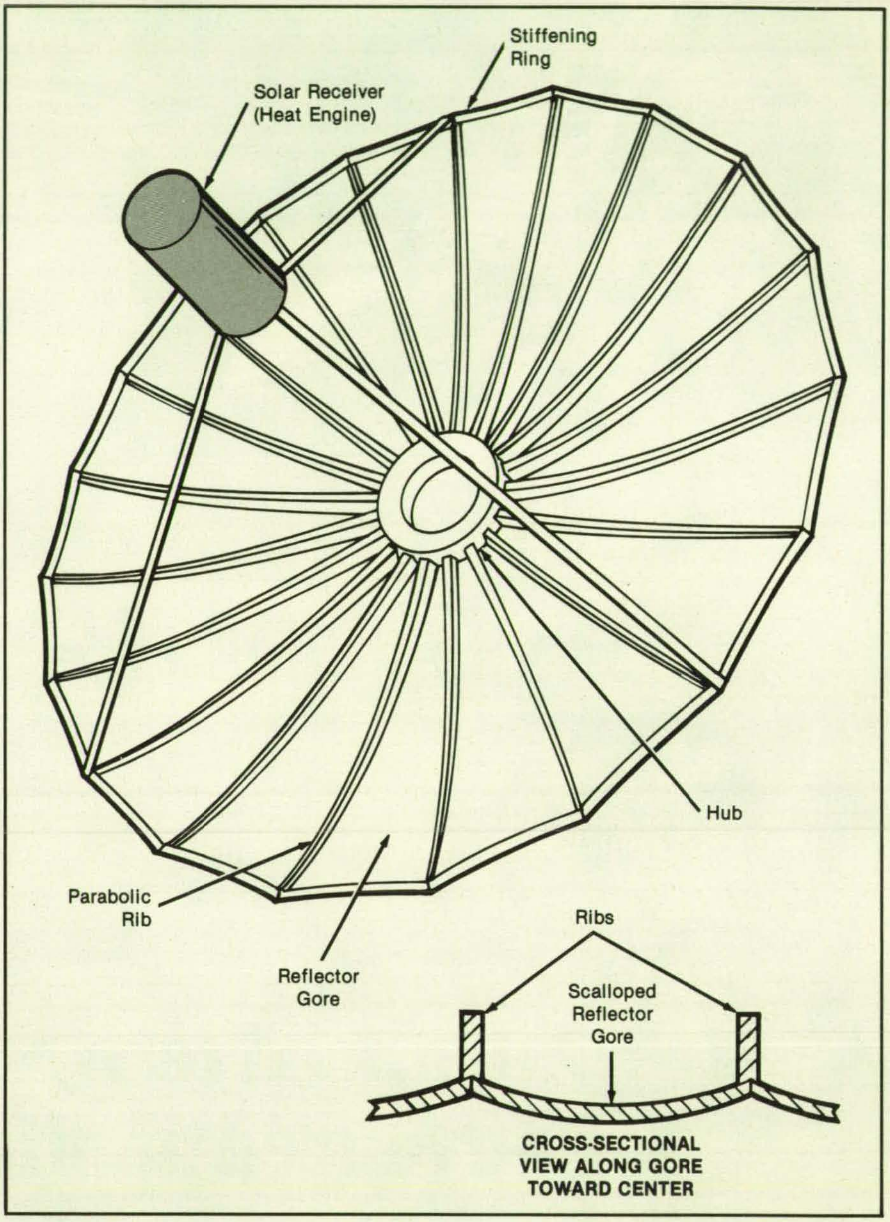
Scalloping the reflector surface reduces sensitivity to manufacturing and aiming errors.

Lyndon B. Johnson Space Center, Houston, Texas

Contrary to intuition, the most effective shape of a concentrating reflector for a solar heat engine is not a perfect paraboloid. According to design studies for a Space Station solar concentrator, a scalloped, nonimaging approximation to a perfect paraboloid offers better overall performance in view of the finite apparent size of the Sun, the imperfections of real equipment, and the cost of accommodating these complexities. The scalloped-reflector concept can also be applied to improve the performance while reducing the cost of manufacture and operation of a terrestrial solar concentrator.

A lightweight reflector might be constructed, for example, by suspending gores of metalized plastic sheet from approximately radially-aligned parabolic supporting ribs (see figure). The gores would be slightly wider than the circumferential distances between the ribs so that when attached to the ribs, the gores would bow outward slightly to attain the required scalloped shape. In principle, a gore could also be made by bending a flat metal strip into contact with two adjacent ribs, then machining the scallop depression into the sheet with a point cutting tool pivoted about the focal point of the corresponding ideal paraboloid.

A perfect paraboloidal reflector would offer the highest concentration of incoming solar energy if the Sun were a point source of radiation and if the reflector could be aimed precisely toward the Sun all the time. In such a case, all the intercepted solar flux would be concentrated to a tiny, diffraction-limited spot. In practice, the finite angular subtense of the Sun (about 0.53°) gives rise to a solar image of finite size at the focal spot. The image is blurred and spread out by slope errors of the reflector surface, and radiant energy is diverted from the desired focal spot by aiming errors. As a result, some of the insolation is lost because it misses the receiver. A larger, more-exposed solar-receiver surface could accommodate the aiming errors and spreading of the image, but would also parasitically reradiate more of the received energy, and the receiver could not attain as high a temperature as desired.



A **Solar Concentrator With Scalloped Gores,** resembling a floppy umbrella, would approximate an ideal paraboloidal reflector but could maintain a smaller, more-precisely-located focal spot in spite of errors in manufacturing and pointing.

A computer ray-tracing study was performed on three conceptual concentrators 60 ft (18.3 m) in diameter, based on the same ideal paraboloid: the paraboloidal reflector itself; a 60-rib, flat-wrapped-gore reflector; and a 60-rib version of the new scalloped-gore reflector. The ideal paraboloidal and flat-wrapped-gore versions were both found to be more vulnerable to surface-slope errors than to aiming errors; the scalloped version proved to be more vulnerable to aiming errors than to slope errors. The highest sensitivity of the scalloped version to either kind of error was lower than the lowest sensitivity of the ideal paraboloid: in other words, at the same level of performance, the scalloped version is easier to manufacture and to aim. Furthermore, the 1.6-ft (0.49-m) diameter of the receiver aperture required by the scalloped version is much smaller than those of the paraboloidal and flat-wrapped-gore versions [6.9 ft (2.1 m) and 9.3 ft (2.8 m), respectively], so that in the presence of imperfections, the concentration ratio of the scalloped version is at least 18 times that of the others.

This work was done by Howard A. Wagner of **Johnson Space Center**. *For further information, Circle 4 on the TSP Request Card.*
MSC-21061

This work was done by Robert F. C. Vessot and Edward M. Mattison of the Smithsonian Institution for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 1 on the TSP Request Card. NPO-17114*

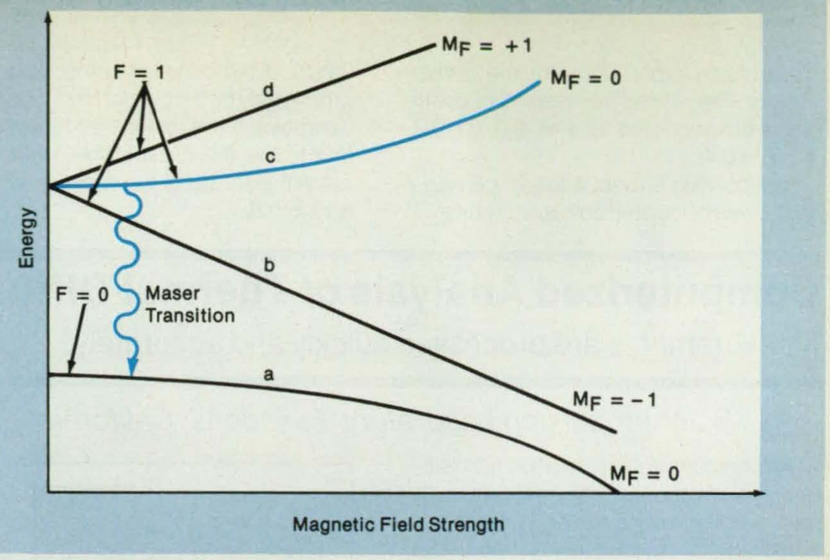


Figure 1. The **Hyperfine Ground Energy States** of monatomic hydrogen are distinguished by the maser transition between states *c* and *a* and by splitting in a magnetic field. *F* is the quantum number of the total (nuclear plus electron spin and orbital) angular momentum, and M_F is the quantum number for the component of total angular momentum aligned with the applied magnetic field.

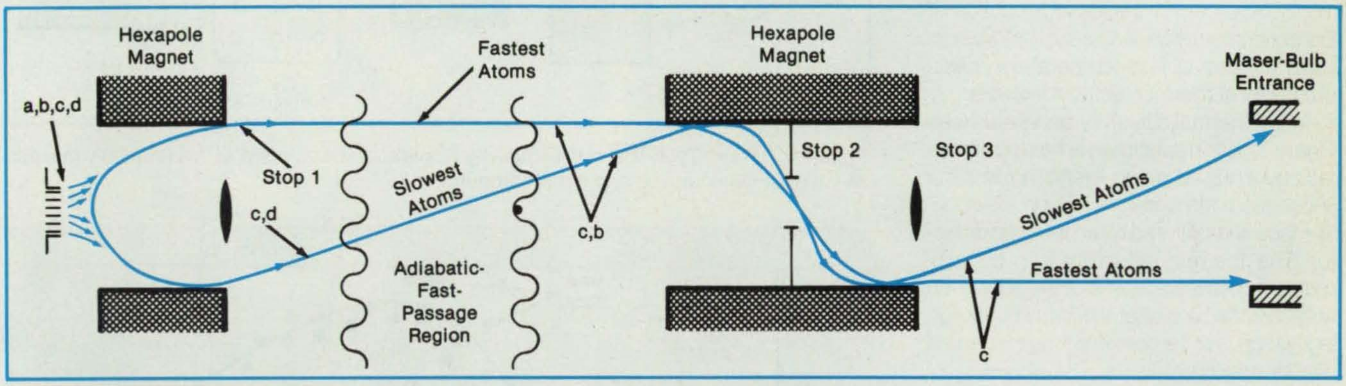


Figure 2. The **Selection System** includes hexapole focusing magnets and an adiabatic-fast-passage region in which a transverse alternating magnetic field superimposed on a steady axial magnetic field inverts the populations of the $F = 1$, $M_F = \pm 1$ states. The beam that enters the maser storage bulb contains a high proportion of atoms in the desired *c* state.

Calculating Optical-Transmitter Radiation Patterns

A new formula gives more-accurate gains and pointing losses.

NASA's Jet Propulsion Laboratory, Pasadena, California

A set of approximate formulas predicts the angular dependence of the far radiation field of a coherent optical transmitter, the telescope of which has a central obscuring disk (for example, a reflecting telescope). The formulas are derived without recourse to the simplifying assumption of uniform plane-wave illumination used to derive the less-accurate traditional formulas.

Assuming illumination by a laser with a Gaussian beam, the telescope gain, g_t, is given by

$$g_t = 2(\pi D/\lambda\alpha)^2[\exp(-\alpha^2) + \exp(-\alpha^2\gamma^2)]^2$$

where D is the telescope aperture diameter, λ is the wavelength, γ is the ratio of the diameter of the obscuring disk to that of the aperture, and α, which is related to the size of the cross section of the Gaussian beam, is given by $1.12 - 1.30\gamma^2 + 2.12\gamma^4$. This formula is not new; it has been used previously in the design of optical communication links.

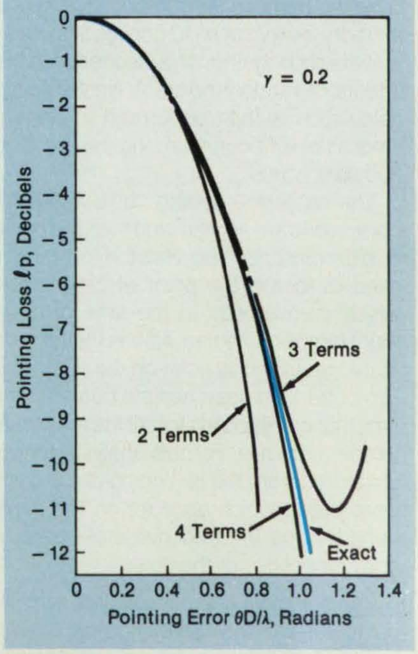
The assumption of a Gaussian beam with obscuration requires a more accurate formula for the pointing loss, $\ell_p(\theta)$, which is the ratio of beam intensity at angle θ off the beam axis to the intensity on the beam axis. The exact equation for $\ell_p(\theta)$ is a ratio of two integrals that cannot be reduced to closed form and, consequently, have to be evaluated numerically. However, because the Taylor series for the ratio of the integrals converges rapidly, the first few terms of the series yield a formula more accurate than the traditional approximation. The new formula is

$$\ell_p(\theta) = [1/f_0^2(\gamma)]\{f_0(\gamma) + [f_2(\gamma)/2!](\pi D\theta/\lambda)^2 + [f_4(\gamma)/4!]\,(\pi D\theta/\lambda)^4 + [f_6(\gamma)/6!](\pi D\theta/\lambda)^6 + \ldots\}^2$$

where the coefficients f_i are the ith derivatives of

$$\int_{\gamma^2}^{1}[\exp(-\alpha^2 u)]J_o(\pi D\theta u^{1/2}/\lambda)du$$

with respect to $(\pi D\theta/\lambda)$ evaluated at $\theta = 0$. These coefficients can be evaluated from



The **Pointing Loss** given by the new formula converges rapidly toward the exact value as more terms of the Taylor series are included.

closed-form expressions for the derivatives or interpolated from tables of coefficients precalculated for γ = 0.0, 0.1, 0.2, 0.3, and 0.4.

The pointing error of a telescope with γ = 0.2 was calculated both exactly by evaluation of the complete integrals and approximately by the new formula (see figure) using two, three, or four terms. With only four terms, the result of the new formula lies within 0.1 dB of the exact result for all $\theta D/\lambda \lesssim 0.9$.

This work was done by William K. Marshall and Brian D. Burk of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 115 on the TSP Request Card.*
NPO-17105

Computerized Analysis of Thermal-Diffusivity Data

Measurements are processed quickly and accurately.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved data-acquisition and data-analysis system for thermal-diffusivity measurements using the flash method incorporates a digital oscilloscope and a microcomputer for the rapid reduction of the experimental data. The system was devised for use in high-temperature measurements of thermoelectric materials.

In the thermal-diffusivity apparatus (see Figure 1), a thin specimen is heated on one face by a pulsed xenon flashlamp, and the subsequent temperature rise on the opposite face is monitored by an infrared detector. The thermal diffusivity can be estimated from the thickness of the specimen and from the time after the initial pulse during which the temperature rise reaches half its maximum value. The accuracy of the estimate can be improved by correcting the temperature measurements for the radiative loss of heat from the specimen and for the finite duration and specific waveform of the flashlamp pulse.

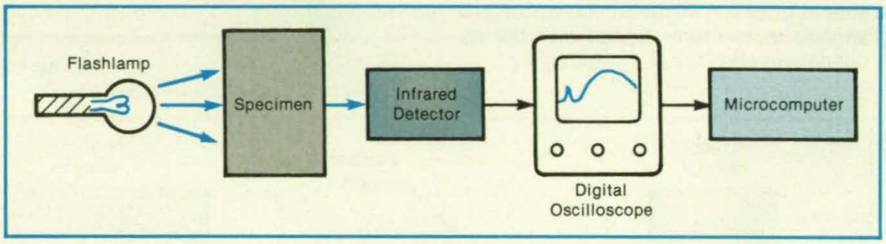


Figure 1. A **Flash-Type Thermal-Diffusivity Apparatus** is equipped with a relatively-inexpensive digital oscilloscope and microcomputer.

The output of the infrared detector is fed to the digital oscilloscope. From the oscilloscope, 2,000 digitized data points (see Figure 2) are fed to the computer. To reduce the demand for computing time and memory, every set of 10 contiguous points is averaged together; this also reduces the effects of random noise. A least-squares calculation is then performed to draw a smooth best-fit curve among the resulting 200 data points.

The radiative-loss and pulse-waveform corrections are applied, and then the curve is differentiated. The Newton method is used to locate the point of zero slope, which corresponds to the time of maximum temperature rise. Noting the temperature rise from this point on the curve, the computer then searches the curve for the time that corresponds to half the maximum temperature rise. For this analysis, time is measured from the beginning of the flashlamp pulse, which appears on the curve because the infrared detector receives stray reflections of the pulse.

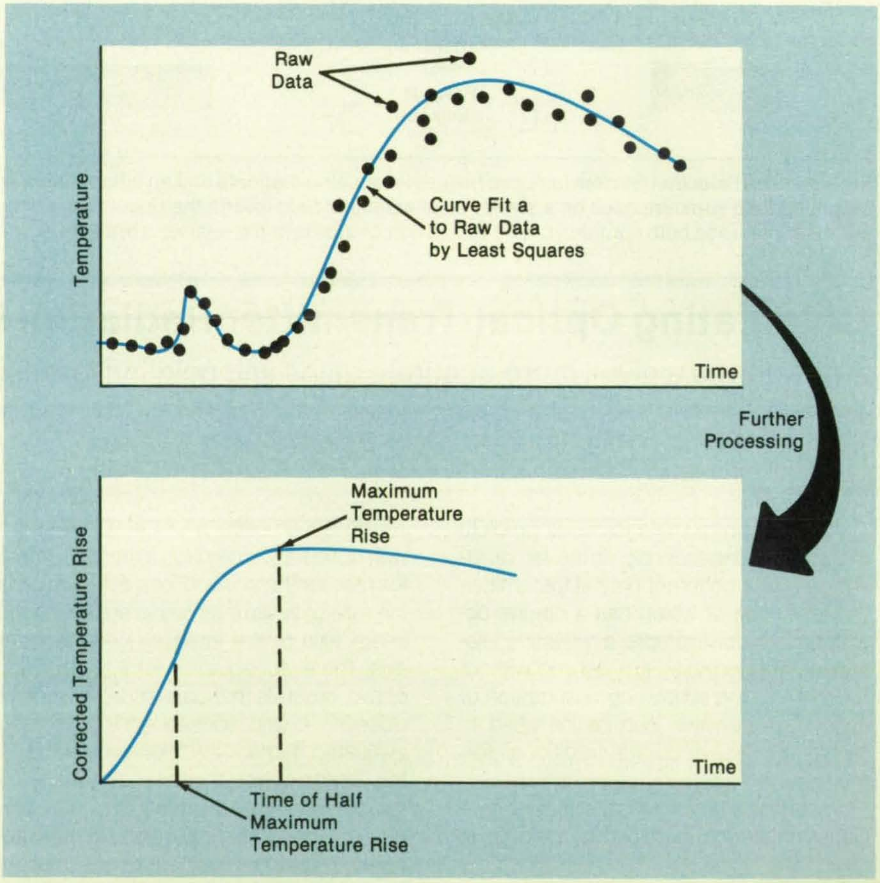
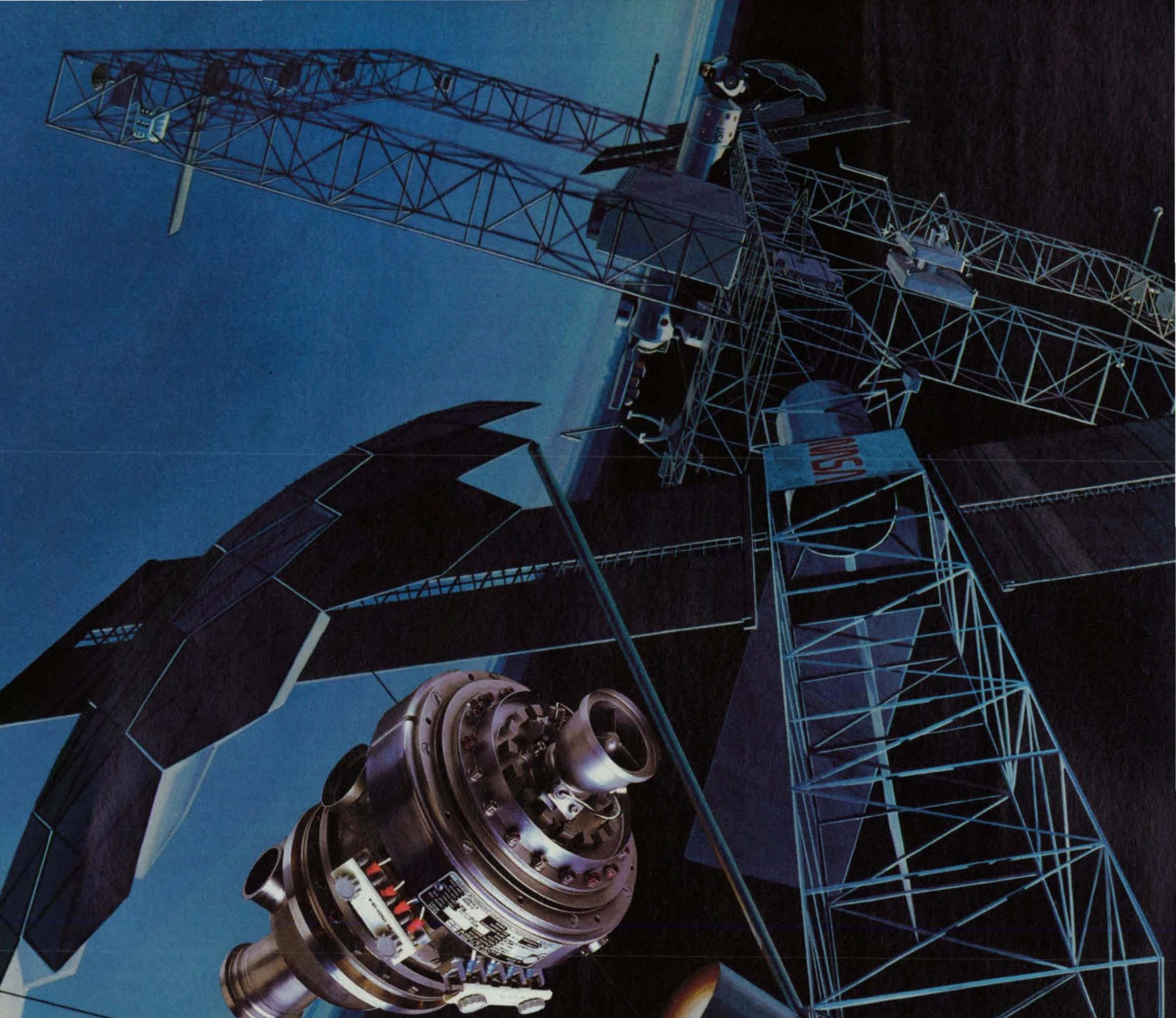


Figure 2. The **Digitized Output of the Oscilloscope** is fed to the computer for curve fitting and other processing.

The complete analysis requires a microcomputer with only 16K of memory. In addition to data-point averaging, the analysis program incorporates the following memory-saving features:

- Variables are reused in different parts of the program.
- Data acquisition, curve fitting, and corrections are done by independent portions of the program that are stored separately and called in sequence.
- All lookup tables are stored as polynomials.
- Customary memory-saving program formats are used wherever possible.

This work was done by Artur B. Chmielewski, Charles Wood, and Jan W. VanderSande of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 88 on the TSP Request Card.*
NPO-16729



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Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Calculating Shocks in Flows at Chemical Equilibrium

Boundary conditions prove to be critical.

A conference paper describes an algorithm for the calculation of shocks in hypersonic flows of gases at chemical equilibrium. Although the algorithm represents an intermediate stage in the development of a reliable, accurate computer code for two-dimensional flow, the research leading up to it has contributed to an understanding of what is needed to complete the task.

The derivation begins with the equations for the conservation of mass, momentum, and total-energy in a two-dimensional, planar or axisymmetric, inviscid flow of gas. Either of two methods is used to include real-gas effects in the equation of state.

In the first method, all of the coupling between the equations for the gas-dynamic and those for chemical effects is accomplished through the ratio, β, between the static enthalpy density and the static energy density. For a perfect gas, β equals γ, the ratio of specific heat at constant pressure to specific heat at constant volume; for a real gas, β is obtained from a separate chemistry algorithm or a table lookup. In the equation of state, the pressure is expressed as the product of β-1 with the difference between the total- and kinetic-energy densities.

In the second method, the pressure is found from the product of the density and temperature according to the ideal-gas law. For this purpose, the temperature is determined from an alternate form of the equation for the energy density that includes terms representing the specific heat at constant volume and the total, kinetic, and chemical-reaction energies. This method is mathematically more rigorous than the first method.

The equations are solved by use of a total-variation-diminishing, implicit, finite-difference algorithm with upwind differencing and with dissipation that suppresses spurious numerical oscillations, thereby enabling the capture of strong shocks. The scheme was applied to flows of an ideal gas and a mixture of N_2, N, O_2, O, and NO at mach 15 over a hemisphere, alternately using the two methods for the equation of state.

The solutions for the ideal gas were stable at all mach numbers investigated, up to mach 20. The real-gas equilibrium-chemistry solutions are more strongly dependent on the computational grid than are those for the ideal gas: slight modifications in the grid could make the algorithm stable or unstable. The first method for the equation of state proved superior in the sense that solutions converged, albeit to slightly inaccurate values. The second method did not yield stable solutions. Both methods suffered from improper real-gas boundary conditions; as a result, detailed analyses of numerical boundary schemes for real gases will be an important topic for future research.

This work was done by Scott Eberhardt and Grant Palmer of **Ames Research Center**. *Further information may be found in AIAA Paper No. 86-1284, "A Two-Dimensional, TVD Numerical Scheme for Inviscid, High Mach Number Flows in Chemical Equilibrium."*

Copies may be purchased [prepayment required] from AIAA Technical Information

Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 26]. Refer to ARC-11741.

Optical Image Subtraction

Progress of a recent decade is reviewed.

A report reviews the optical image subtraction techniques developed during the years 1975 through 1985. Optical image subtraction is useful in such disciplines as studies of earth resources, meteorology, automatic surveillance, pattern recognition, studies of urban growth, and compression of bandwidth in communication systems. Optical image subtraction requires the tedious, precise alignment of expensive equipment by highly trained technicians and has limited dynamic range. Nevertheless, it offers an attractive alternative to digital electronic image subtraction in that it is much faster and treats all parts of the images simultaneously.

There are two categories of optical image-subtraction techniques: real-time and non-real-time. The report describes the following real-time techniques:

- Source encoding — an amplitude-subtraction technique involving an extended quasi-monochromatic (filtered white) light source encoded by a one-dimensional (parallel-slit) mask;
- Polarization modulation — an amplitude-subtraction technique that includes a monochromatic point light source and polarizing filters;
- Pseudocolor image-difference detection — an intensity-subtraction technique that includes an extended white light source and red and green filters;
- Holographic-shear-lens technique — an amplitude-subtraction technique with a monochromatic point light source and a holographic shear lens synthesized by the superposition of two Fresnel zone plates at different spatial frequencies; and
- Nonlinear electro-optics — amplitude subtraction of monochromatic light from a point source, based on two- or four-wave mixing in nonlinear electro-optical crystals.

The reported non-real-time image-subtraction techniques are the following, all of which involve intensity subtraction:

- Speckle-diffuser encoding — a double-exposure method that uses an extended quasi-monochromatic light source and exploits the multiple-imaging effect of a speckle pattern on photographic film to modulate an input image with multiple demagnified images of a coarse, one-dimensional mask;
- Speckle-pattern encoding — another double-exposure method that uses a point source of monochromatic light, a diffuser, and a two-pinhole mask to produce speckle-modulated Young's fringes;
- Halftone-screen encoding — a three-step method involving an extended white light source and a succession of contact prints through one-dimensional halftone screens; and
- Polarization-shifted carrier encoding — a double-exposure method involving a quasi-monochromatic slit light source and the formation of shifted high-contrast sinusoidal modulation patterns on the transparencies of the images to be subtracted.

The real-time techniques are probably the most useful because they enable the immediate processing of enormous amounts of information. However, this is not to discount the non-real-time techniques. Moreover, some of the non-real-time equipment may be converted to real-time operation through the installation of advanced, real-time spatial light modulators or electro-optical devices.

This work was done by Hua-Kuang Liu and Tien-Hsin Chao of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Optical Image Subtraction Techniques, 1975–1985," Circle 117on the TSP Request Card. NPO-17016*

Materials

Numerical Analysis of Interlaminar-Fracture Toughness

Finite-element analysis is applied in conjunction with strain-energy and micromechanical concepts.

Lewis Research Center, Cleveland, Ohio

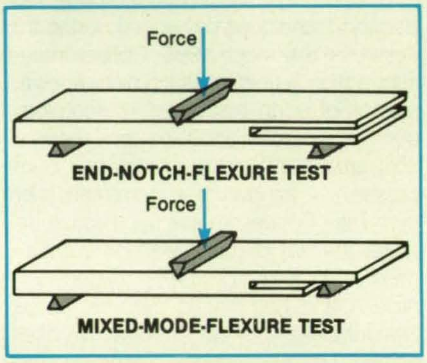

Figure 1. **The End-Notch-Flexure and Mixed-Mode-Flexure Tests** are performed on specimens of standard size and shape to determine fracture-toughness parameters and other mechanical properties.

A computational procedure has been developed for the study of the interlaminar-fracture toughnesses of unidirectional-fiber composite materials in end-notch flexure (ENF) and mixed-mode flexure (MMF). Because interlaminar fracture (that is, delamination) is an important failure mode, an understanding of it is necessary for the design of composite structures. The new computational procedure assists in the interpretation of the ENF and MMF fracture tests (see Figure 1) that are performed to obtain fracture-toughness parameters, by enabling the evaluation of the states of stress that are likely to induce interlaminar fractures.

The computational procedure involves the local method, the local-crack-closure method, and/or the "unique" local-crack-closure method developed at NASA Lewis Research Center, for the mathematical modeling of ENF and MMF. These methods are based on three-dimensional finite-element analysis in conjuction with the concept of the strain-energy-release rate and with the micromechanics of composite materials.

The global method yields the global fracture toughness, without regard to participating or dominating local fracture modes. The local-crack-closure method yields both the global fracture toughness and the contribution of each local fracture mode to interlaminar or mixed-mode fracture toughness. The NASA Lewis "unique" local-crack-closure method is a variation of the local-crack-closure method. The method involves the use of a single-point constraint force in the finite-element analysis, is conceptually simpler than the local-crack-closure method, and preserves the monotonicity of the increasing displacement under the applied load as the crack extends. In contrast, the local-crack-closure method sometimes erroneously yields a reversal of this displacement.

The computational procedure was tested on the mathematical specimen shown in Figure 2. The numerical results led to the following conclusions (among others):

- The significant properties associated with interlaminar-fracture toughness are the interlaminar shear strength, the transverse tensile strength, the thickness of the interply layer, and the ratio of the volume of fibers to the total volume of the composite.
- Any of the three methods can be used to determine the strain-energy-release rate, but only the local methods give the contributions of individual fracture modes.
- In comparison with the local methods, the global method predicts a higher strain-energy-release rate during slow and stable crack growth, but the predictions of all three methods converge during unstable crack growth.
- The strain-energy-release rates predicted for the shear and mixed shear/double-cantilever-crack-opening modes of interlaminar fracture are in good agreement with the limited experimental data available.
- The shear mode dominates in ENF, while the double-cantilever-crack-opening mode dominates the unstable crack growth in MMF.
- Unstable shear-mode crack growth occurs in ENF when the interlaminar shear-stress intensity exceeds the correspond-

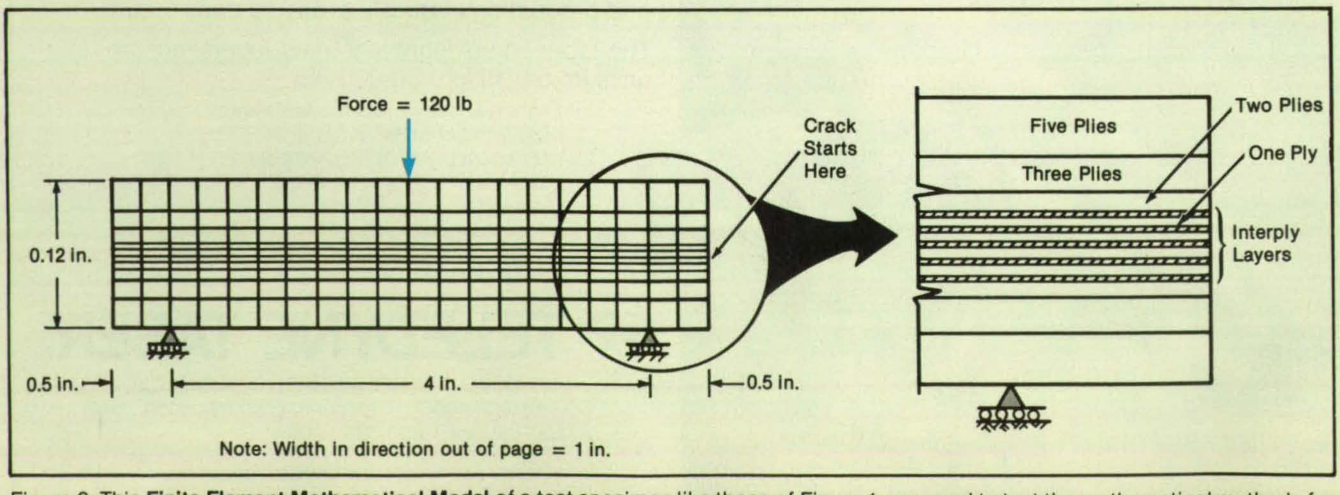

Figure 2. This **Finite-Element Mathematical Model** of a test specimen like those of Figure 1 was used to test the mathematical methods for the prediction of fracture in ENF and MMF.

ing shear strength.

- Mixed-mode unstable growth of the crack occurs in MMF when the through-the-thickness normal stress intensity exceeds its corresponding transverse tensile strength.
- The critical strain-energy-release rates and their attendant crack lengths associated with fractures in ENF and MMF can be calculated.

This work was done by C. C. Chamis of **Lewis Research Center** *and P. L. N. Murthy of Cleveland State University. Further information may be found in NASA TM-87138 [N86-14316/NSP], "Interlaminar Fracture Toughness: Three-Dimensional Finite-Element Modeling for End-Notch and Mixed-Mode Flexure."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14590

Developing Crystallinity in Linear Aromatic Polyimides

A new technique improves the melt flow of polyimide.

Langley Research Center, Hampton, Virginia

Linear aromatic polyimides are well known to have exceptional thermal and oxidative stabilities. However, they are very difficult to process into useful forms because of their poor softening and flow properties. Most of these polymers have to be processed at temperatures approaching 400 °C and at pressures of 500 to 10,000 psi (3.4 to 69 MPa). At these high temperatures and pressures, finely-divided polymer particles sinter.

To be useful for various applications, these polymers must flow at low temperatures and pressures. Accordingly, a process has been developed to make linear aromatic polyimides that exhibit a form of metastable crystallinity resulting in enhanced melt-flow behavior that makes these materials attractive as adhesives, molding powders, and matrix resins for many potential applications.

Previously, polyimides were prepared from polyamide acids by chemically dehydrating the latter. In the methods that were employed, some loss in molecular weight generally occured.

The new process uses chemical imidization or cyclodehydration techniques that do not cause a significant decrease in molecular weight. The process involves the dissolution of the polyamide acid in an amide solvent or a mixture of an ether and an amide solvent at a low percentage of solids followed by the treatment of this solution with an aprotic organic base, such as triethylamine or pyridine, for a period of time prior to treatment with an organic dehydrating agent. The latter treatment facilitates the formation of the polyimide.

This process should prove useful for the production of polyimide molding materials. It is expected to have widespread application in the preparation of easily processed adhesives, molding powders, and matrix resins.

This work was done by Terry L. St. Clair of **Langley Research Center**. *For further information, Circle 155 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 26]. Refer to LAR-13732.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Cold-Worked Inconel* 718 Bars

Cold working and double aging yield high strength without sacrifice of resistance to corrosion.

A report presents data on the mechanical properties and the stress-corrosion resistance of triple-melted, solution-treated, work-strengthened, direct-double-aged Inconel* 718 alloy. (The triple melting consists of vacuum induction melting, electroslag remelting, and vacuum arm remelting.) The data indicate an advance in the processing of large-diameter [4.00-in. (10.16-cm) and 5.75-in. (14.60-cm)] bars. The new process increases the yield strength without reducing the elongation, reduction of area, and grain size.

Inconel* 718 is a nickel-base, austenitic, precipitation-hardenable alloy developed in the late 1950's. It possesses high strength and high resistance to corrosion and is used in the temperature range from −423 to +1,300 °F (−253 to +704 °C). In high-strength fasteners, the alloy has been limited to relatively small diameters because of restrictions imposed by cold working and hot heading. Large-diameter bar material has been limited to solution treating and aging because cold working produces a loss in reduction of area, loss in elongation, and increased grain size.

The new process makes it possible to work-strengthen Inconel* 718 without the usual disadvantages. In specimens tested at room temperature, the average longitudinal ultimate tensile and yield strengths were about 217 and 191 ksi (1.50 and 1.32 GPa), respectively. Charpy V-notch impact and compact tension tests at −100 °F (−73 °C) were equally impressive: they showed little degradation in toughness with decreasing temperature. Moreover, after exposure of 180 days to salt fog, there were no tensile failures or loss of mechanical properties.

*Inconel is a registered trademark of the Inco family of companies.

This work was done by J. W. Montano of **Marshall Space Flight Center**. *Further information may be found in NASA TP-2634 [N86-30753/NSP], "A Mechanical Property and Stress Corrosion Evaluation of VIM-ESR-VAR Work Strengthened and Direct Double Aged Inconel 718 Bar Material."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. The report is also available on microfiche at no charge. To obtain a microfiche copy, Circle 146 on the TSP Request Card. *MFS-27171*

Acrolein Microspheres Are Bonded to Large-Area Substrates

Reactive microspheres are bonded to inert substrates.

A new process grafts reactive microspheres of known size onto large-area polymeric spheres or films. The polymer surface is thus given desired functional properties, and the effective surface area is increased.

Reactive cross-linked microspheres are produced under the influence of ionizing radiation in aqueous solutions of unsaturated aldehydes, such as acrolein, with sodium dodecyl sulfate. The diameters of the spheres depend on the concentrations of the ingredients and generally range from 400 Å to as small as 50 Å. If a polystyrene, polymethylmethacrylate, or polypropylene object is immersed in the solution during irradiation, microspheres become attached to its surface. The resulting modified surface has a grainy coating with a reactivity similar to that of the free microspheres.

The aldehyde-substituted-functional microspheres react under mild conditions with a number of organic reagents and with most proteins. Microsphere-coated macrospheres or films can therefore be used to to immobilize high concentrations of proteins, enzymes, hormones, viruses, cells, and a large number of organic compounds. Potential applications include separation techniques, clinical diagnostic tests, catalytic processes, and battery separators.

This work was done by Alan Rembaum and Richard C. K. Yen of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 96 on the TSP Request Card.*

Title to this invention, covered by U.S. Patent No. 4,534,996, has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)]. Inquiries concerning licenses for its commercial development should be addressed to

Edward Ansell
Director of Patents and Licensing
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Refer to NPO-15635, volume and number of this NASA Tech Briefs *issue, and the page number.*

Computer Programs

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COSMIC, NASA's Computer Software Management and Information Center, distributes software developed with NASA funding to industry, other government agencies and academia.

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Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to make computer programs available to the public. For information on program price, size, and availability, circle the reference number on the TSP and COSMIC Request Card in this issue.

Mathematics and Information Sciences

VICAR/IBIS Software System

A collection of programs provides extensive capabilities for the manipulation of imagery and geographical data.

The VICAR/IBIS software system is a combination of the JPL VICAR (Video Image Communication and Retrieval System) image-processing system and the JPL IBIS (Image Based Information System) geographic-information-management system. The VICAR/IBIS system provides the user with extensive general-purpose image-processing capabilities, as well as an information-management system for accepting, converting, and operating on vector (graphical) and tabular data. The system can be used to perform various image-processing functions on any sort of digitized image data, including such remotely sensed data as those from the Landsat multispectral scanner.

The available image-processing functions include picture comparison, picture expansion with noise elimination, convolution filtering, geometric transformations, Fourier transformations, and many other manipulation and enhancement capabilities. In addition, the user is provided with an information-management system designed specifically for handling data related to images and the merger of image data with other types of data files. The VICAR/IBIS system offers the user a powerful system for analyzing, manipulating, and managing image data.

The IBIS system offers a computer-based approach to the management of geographical-information systems. By grouping selected functions from the IBIS library, a variety of spatial phenomena can be investigated. Tabular and graphical data can be stored in registration with imagery data in the form of overlaid data planes. Information can be derived from

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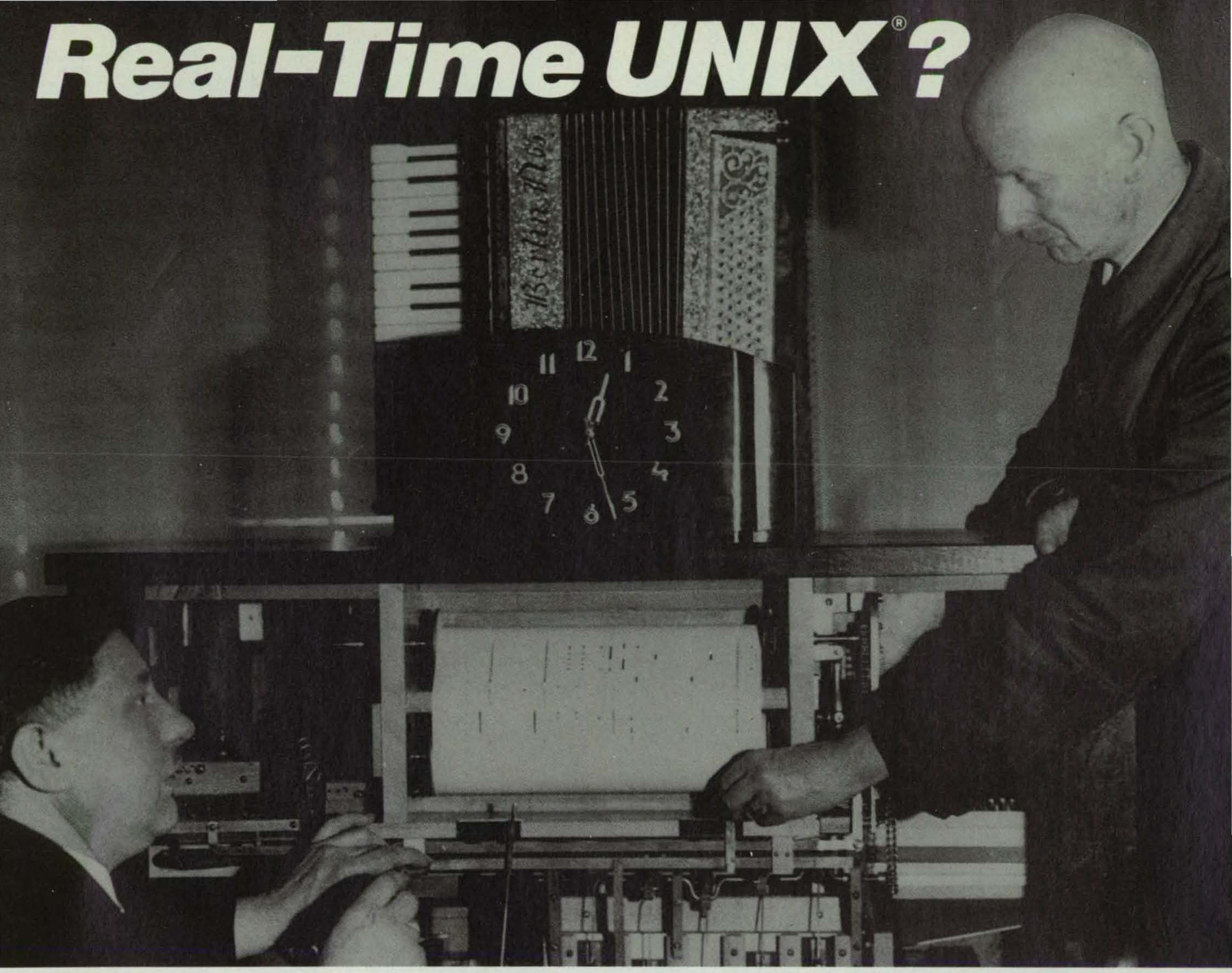

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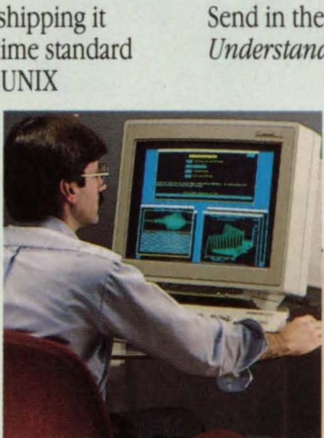

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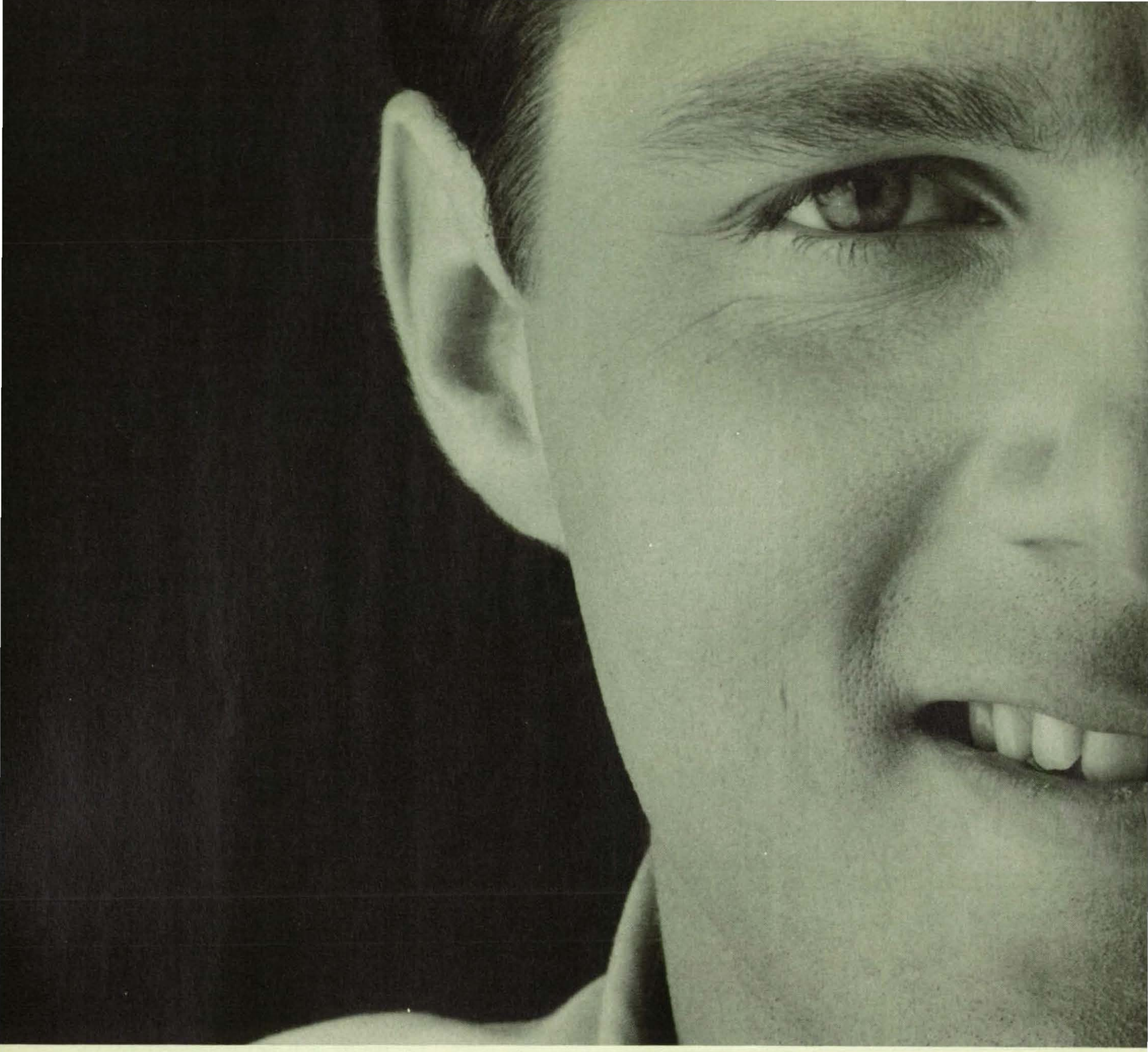

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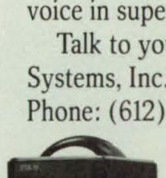

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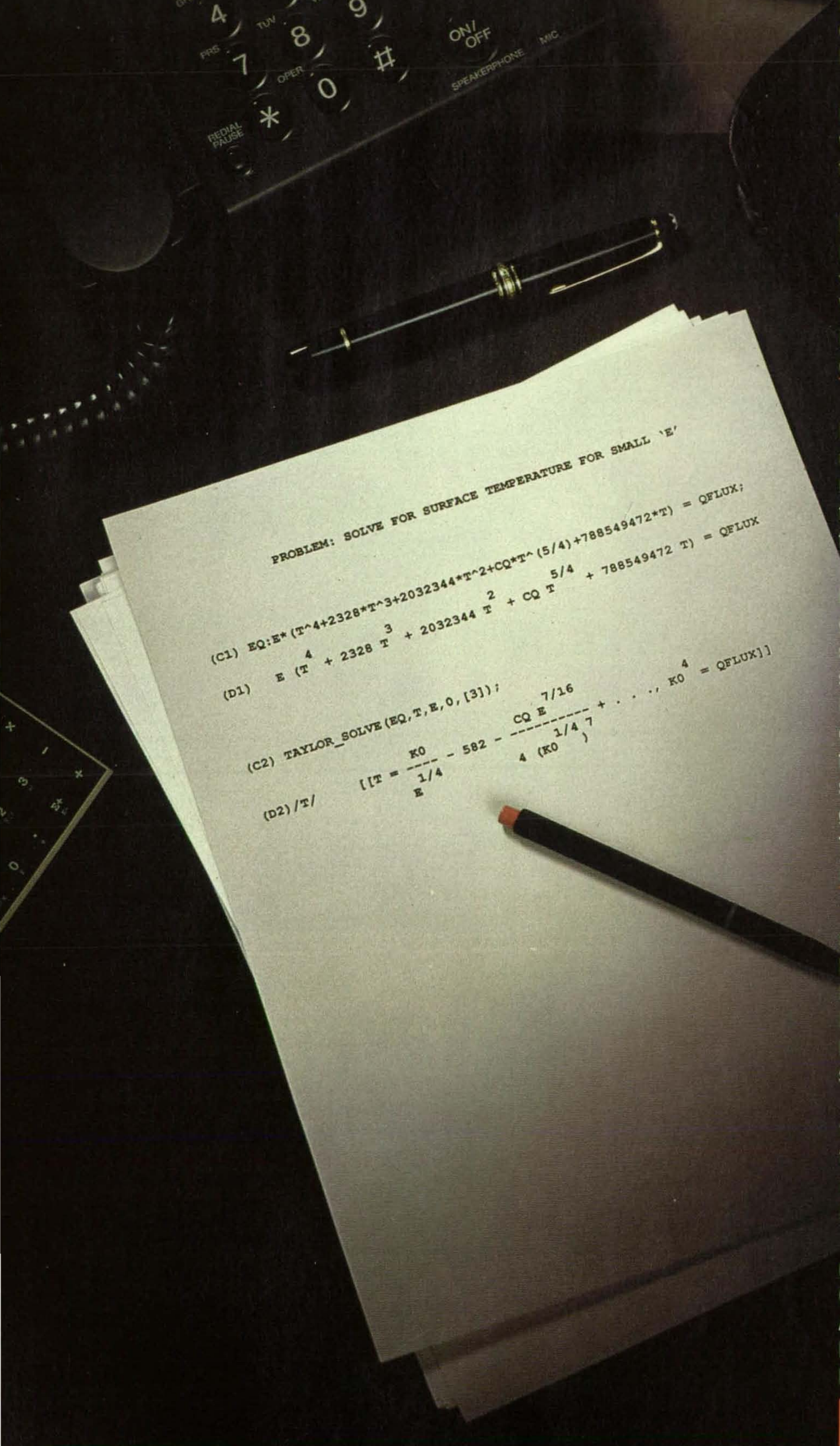

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simple associations and comparisons between two or more data files or from more complex procedures including polygon overlay and cross-tabulation.

The VICAR program library is readily used for the generation, input, output, and processing of image data for the IBIS system. The image analyst can use the VICAR/IBIS system with a minimum of programming knowledge, a simple understanding of the operation of the system, and a minimum of input data. The analyst calls for automatic execution of one or more of the system programs, including the requisite image-data-management services, through a set of command instructions.

The programs of the system are written to be flexible in application, with the user supplying only the parameters specific to a particular application. The system provides special-purpose input/output routines designed for the efficient transfer of image data with reduced memory requirements. New applications programs can be easily incorporated into the VICAR/IBIS system as they are developed.

The VICAR/IBIS system is available for a period of 10 years to approved licensees. The licensed program product delivered includes the source code and supporting documentation. Additional documentation may be purchased separately at any time.

The VICAR/IBIS system is a system of programs and control procedures designed for batch execution and is available in two machine implementations. The IBM version is written in FORTRAN IV, Assembler, and OS JCL and has been implemented on an IBM 360-series computer with a minimum central-memory requirement of approximately 140K of 8-bit bytes. The IBM version of the VICAR/IBIS system was released in 1979. The VAX version is written in C and FORTRAN 77 and has been implemented on a DEC VAX-series computer operating under VMS 4.4 with a minimum disk quota of 150,000 blocks. The VAX version was released in 1987.

This program was written by Daniel F. Stanfill IV and Michael A. Girard of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 10 on the TSP Request Card. NPO-17081*

Selected Tether Applications Cost Model

Diverse cost-estimating techniques and data are combined into a single program.

The Selected Tether Applications Cost Model (STACOM 1.0) is an interactive accounting software tool that provides means for combining several independent cost-estimating programs into a fully-integrated mathematical model capable of assessing costs, analyzing benefits, providing file-handling utilities, and putting out information in text and graphical forms to screen, printer, or plotter. The program is based on Lotus 1-2-3, version 2.0. It was developed to provide clear, concise traceability and visibility into the methodology and rationale for estimating costs and benefits of the operations of the Space Station tether deployer system.

The key to the costing portion of the mathematical model is the Martin Marietta Cost Analysis Data Base, which provides historical cost data from previous programs in the form of cost-estimating relationships. Typical inputs to STACOM include subsystem component weights, operational time constraints, intravehicular and extravehicular requirements, the mean times between the failures of components of equipment, effects upon and caused by the costs and other data of supporting programs, and the specific limitations and capabilities of transportation by shuttle. The program is centered around a primary driver worksheet and macro commands. All revised worksheet information is automatically saved to different files during execution of the model to maintain the integrity of the original program. The use of Lotus 1-2-3 software provides automatic recalculation of the worksheet upon revision of the mathematical model.

STACOM has been implemented on an IBM PC or compatible computer. A minimum of 256K of random-access memory is required. The program also requires at least one floppy-diskette drive and the Lotus 1-2-3, version 2.0 or greater. The use of a color video monitor and an appropriate adapter board is recommended. The program was released in 1988.

This program was written by Michael G. Keeley of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information, Circle 93 on the TSP Request Card. MFS-28260*

Input/Output Subroutine Library Program

This efficient, easy-to-use program can be moved easily to different computers.

The purpose of NAVIO, Input/Output Subroutine Library, is to provide an input/output package of software for FORTRAN programs that is portable, efficient, and easy to use. NAVIO is implemented as a hierarchy of libraries. At the bottom is a very small library containing the only nonportable routines called the "I/O Kernel." This design makes NAVIO easy to move from one computer to another, by simply changing the kernel.

NAVIO is appropriate for a software system of almost any size wherein different programs communicate through files. NAVIO is not appropriate for maintaining a data base where records must be added to and deleted from an existing file. In addition to the standard routines that open, read, write, and close files, NAVIO also performs scatter reads (reads one record into several different arrays), gather writes (writes several different arrays into one record), buffer input/output, the copying of a portion of one file into another, conditional copying of records, and searches of records.

NAVIO can provide direct access to individual records without either the usual restrictions of a direct-access file or the overhead of an indexed file. A NAVIO file has a simple tree structure. Conceptually, a file is a collection of groups, a group is a collection of items, and an item is a sequence of one or more records. The only major restriction of NAVIO files is that all the records in an item must be written before a new item is initiated, and all items in a group must be written before a new group is initiated. However, once a file is written, groups, items, and records can be read in any order. Every record in an item must be of the same type of data (character, double precision, integer, logical, or real). Items in a group do not have this restriction.

NAVIO is written entirely in DEC VAX FORTRAN 77. It has been implemented on a VAX computer operating under VMS 4.1 or higher, with a maximum central-memory requirement of 58 Kbytes. The program was developed in 1985.

This program was written by James B. Collier of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 78 on the TSP Request Card.*
NPO-17053

Production of Viewgraphs With TEX

Typesetting functions are grouped conveniently.

TEXVIEW is a software package of TEX macros that facilitate the production of viewgraphs. TEXVIEW is based on TEX, a public-domain typesetting language developed by Dr. Donald Knuth of Stanford University. The TEXVIEW macros are grouped into the following categories: format control, indentation control, font control, spacing control, graphical control, and page layout.

TEXVIEW is written in TEX. Optional command procedures and command definition files for producing a high-speed version when run under VAX/VMS are included. Although implemented on a VAX under VMS 4.X, TEXVIEW is independent of the computer and output device. The program was developed in 1987.

This program was written by Peter J. Scott of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 60 on the TSP Request Card.*
NPO-17299

Mechanics

Hardware Techniques, and Processes

Books and Reports

Quickly Removable Valve

A conceptual unit could be removed with minimal disturbance.

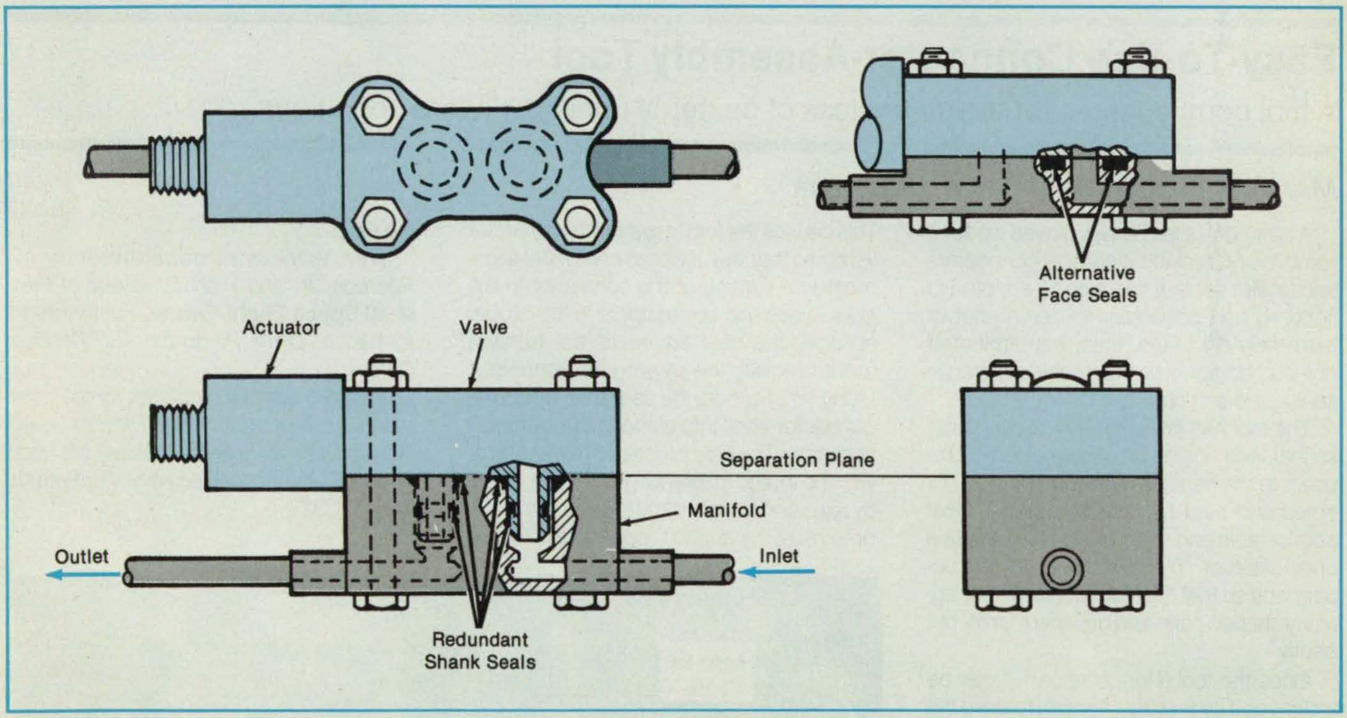
Lyndon B. Johnson Space Center, Houston, Texas

A proposed valve could be quickly and easily removed and replaced in a fluid line without disturbing the mechanical arrangement of the pipe. The valve would be useful where the disturbance of a fluid line is detrimental or where fast maintenance is essential — in the oil and chemical industries, automotive vehicles, aircraft, and powerplants, for example.

According to the concept, the valve inlet and outlet ports would be adjacent to each other on the same side of the valve body (see figure). The ports would be inserted into a special manifold on the fluid line. The valve body would be attached to the manifold by four bolts or, alternatively, by toggle clamps. An electromechanical actuator could move in a direction parallel to the fluid line to open and close the valve.

When it is necessary to clean the valve, it could be removed simply by opening the bolts or the toggle clamps. There would be no need to move or separate the ports of the fluid line.

This work was done by John S. Robbins of Rockwell International Corp. for **Johnson Space Center**. *No further documentation is available.*
MSC-21237



The **Inlet and Outlet Ports** of the quickly removable valve would be inserted into a manifold in a fluid line.

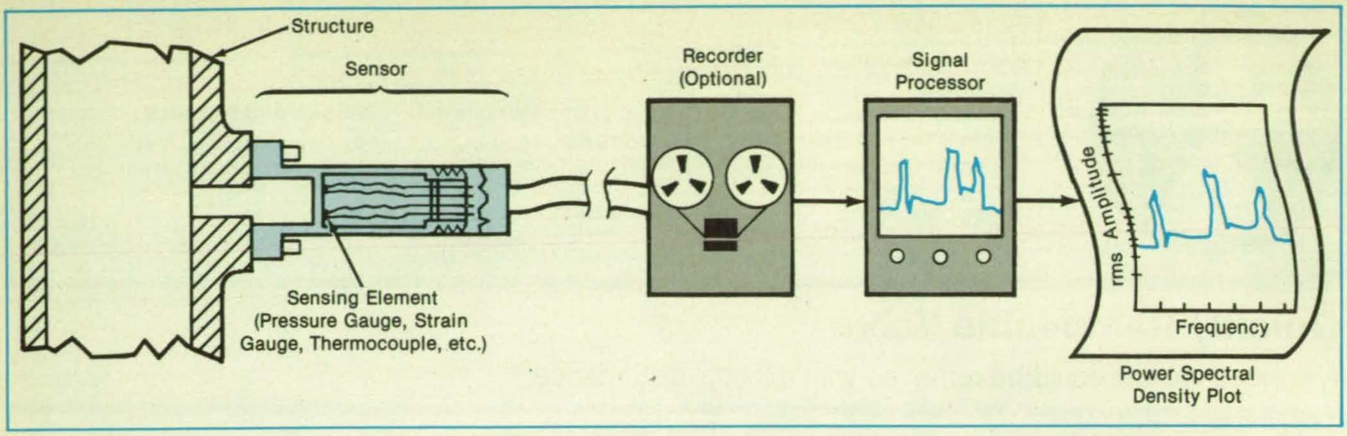
Measuring Vibrations With Nonvibration Sensors

Normally undesired responses are exploited to obtain less intrusive or nonintrusive measurements.

Marshall Space Flight Center, Alabama

Information about the vibrations of a structure and/or of a nonvibration sensor attached to the structure can be extracted from the output of the sensor. For example, the output of a pressure or temperature sensor can be analyzed to obtain vibrational frequencies and approximate relative amplitudes. This type of analysis is useful where limited vibrational data are required but the part to be measured is inaccessible or would be perturbed excessively by accelerometers, strain gauges, or other conventional vibration sensors.

The vibrational data are obtained from those components of the sensor output signal that arise from the usually small and normally undesired response of the sensor to vibrations. The sensor is operated in the usual way except that, in addition, its output is fed to a power-spectral-density analyzer (see figure). The vibrational com-



Vibrational Data Are Extracted from the output of a nonvibration sensor. The normal operation of the sensor is not disturbed by the addition of a signal processor.

ponents are usually easily distinguishable in the analyzer output because they usually have frequencies much higher than those of the more-slowly-varying temperature, pressure, or other normally desired components.

The spectral-analysis technique was applied successfully to high-frequency resistance changes in the output of a platinum-wire resistance thermometer: vibrational peaks in the resistance frequency spectrum were confirmed by the spectrum from an accelerometer. The technique also showed a predicted 17-kHz vibrational resonance in a strain-gauge-supporting beam in a pressure sensor.

This work was done by Arthur J. Hill of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 127 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 26]. Refer to MFS-29200.

Easy-To-Use Connector-Assembly Tool

A tool compensates for the user's loss of dexterity under awkward conditions.

Marshall Space Flight Center, Alabama

A handtool helps heavily gloved workers remove and replace electrical connectors and similar parts. It can also be adapted to handling and positioning extremely-hot or extremely-cold fluid lines, contaminated objects, abrasive or sharp objects, fragile items, and soft objects.

The tool has jaws that swivel over 180° so that their angle can be adjusted with respect to the handles. They can thus be oriented and held in a position that is most comfortable and effective for the user in a given situation. The jaws are lined with rubber pads so that they can conform to irregularly shaped parts and grip them firmly but gently.

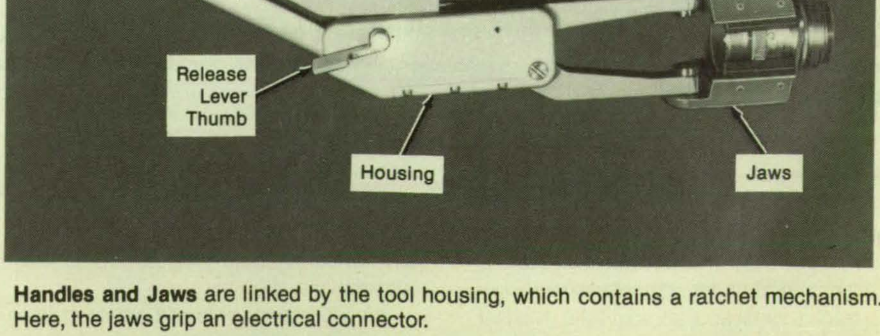
Once the tool engages a part, it can be locked on it so that the user can release the handles without losing the part. A ratchet mechanism in the tool allows the user to work the handles back and forth in a confined space to connect or disconnect the part.

The tool can be quickly positioned, locked, and released. It gives the user a feel of its grip on a part. Unlike conventional pliers, it frees the grasping muscles from work during part of the task, giving the user greater freedom to move the hand. The tool can be operated with only one hand, leaving the user's other hand free to manipulate wiring or other parts.

The user positions the tool over a connector and squeezes the handles together. This causes the tool to grasp the connector lightly so that the user can check the alignment and seating of the connector in the jaws. Once the connector is in the proper position, the user squeezes the handles further, locking the jaws on the connector. Using wrist action, the user then twists the connector shell into place in the electrical assembly. The user presses a release lever with the thumb to disengage the pawl, thereby releasing the jaws for removal of the tool or to relax the grip to reposition the tool on the part.

This work was done by John W. Redmon, Jr., and Fred Jankowski of **Marshall Space Flight Center**. *For further information, Circle 85 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 26]. Refer to MFS-28237.



Handles and Jaws are linked by the tool housing, which contains a ratchet mechanism. Here, the jaws grip an electrical connector.

Measuring Liquid Drops in Gas Flow

A photographic method reveals size distributions and flow rates.

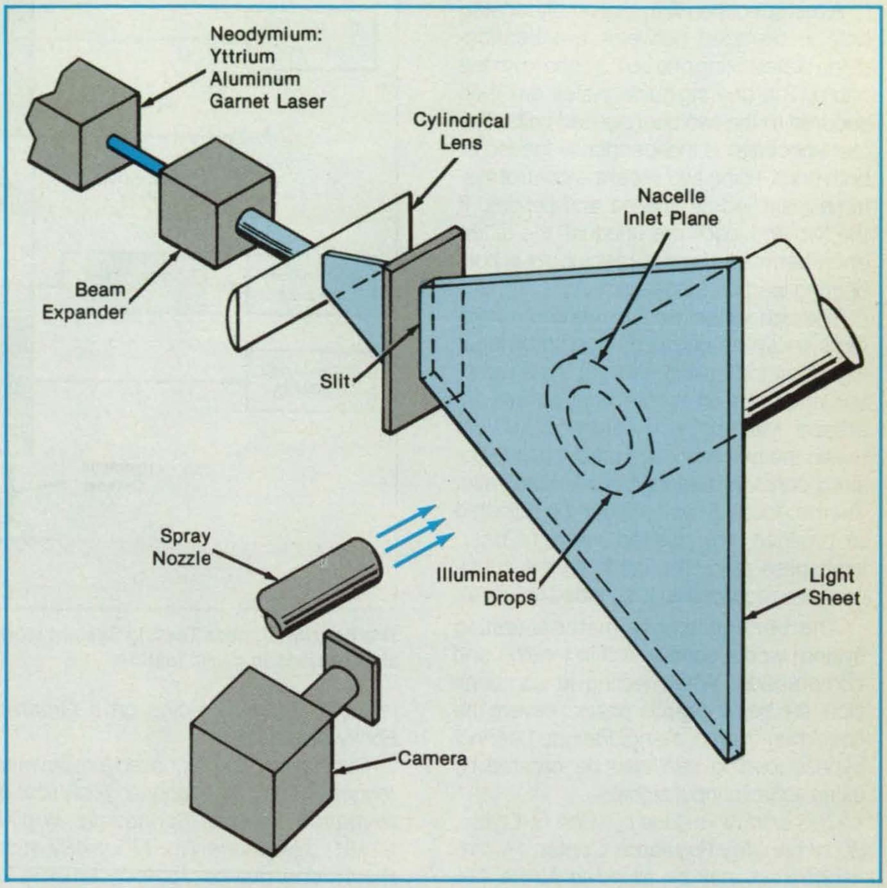
NASA's Jet Propulsion Laboratory, Pasadena, California

A nonintrusive optical technique enables the measurement of drops of water ingested through an aircraft-engine nacelle. The use of the technique yields drop sizes, the spatial distribution of drops at the nacelle inlet, and the instantaneous rate of mass flow of liquid water into the nacelle. The technique is used in research on the ingestion of water from heavy rain or wheel spray, but can be adapted to any droplet-laden gas stream.

The drops are photographed by the light of a laser beam directed across the nacelle inlet (see figure). The beam is shaped by a beam expander and slit into a sheet 9 mm thick. The exposure time is only 10 ns — the length of a laser pulse, and the drop motion is therefore frozen in each of the series of photographs. Fluorescent dye added to the water improves the edge definition of the photographic images of the drops; the scattered laser light and its interference effects can be filtered out and only light at the fluorescence wavelength photographed.

An automated digital image-processing system analyzes the photographs. The image processor is a commercial unit employing a vidicon, random-access memory, digital video processor, and color video display. It is used in combination with specially developed software in a host computer. The image-processing algorithm detects drop edges, defines the drop boundaries, calculates the areas of the drop images, computes the drop diameters from the areas, constructs drop-size distributions, and determines the total water content of the illuminated sheet.

Double-pulse photography is used to determine the velocities of droplets for use in calculating the instantaneous mass flow rate of the airborne liquid water; the drop flow is illuminated by two pulses of a laser, 50 to 200 μs apart. Thus, two images of each drop appear in the photograph, and the drop velocity is calculated from the distance the drops have moved in the known interval between the pulses. The product of the calculated liquid-water content per unit flow-path length over the front of the nacelle area and the drop velocity gives the instantaneous rate of ingestion of liquid water.



A **Thin Cross Section** of the air-and-waterdrop flow close to the nacelle inlet plane is illuminated by a sheet of light from a pulsed laser. A camera photographs the waterdrops in the light sheet.

The optical and image-analysis systems were tried in a water-ingestion simulator in an open-circuit wind tunnel, and its results were compared with the known time-averaged rate of flow of water. The optically-determined flow rate turned out to be about 10 percent higher than the actual rate.

This work was done by Pradip G. Parikh, Miguel A. Hernan, Virendra Sarohia, and Andre H. Yavrouian of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 30 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 26]. Refer to NPO-16950.

Bearing/Bypass Material-Testing System

The system maintains a constant ratio of bearing to bypass loading during testing.

Langley Research Center, Hampton, Virginia

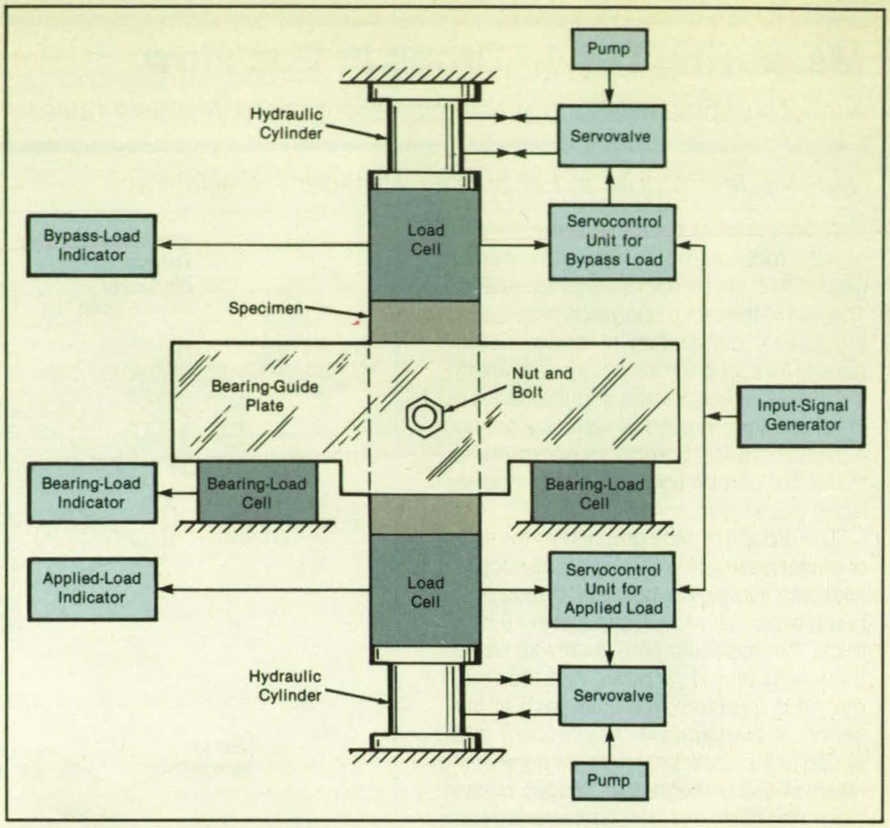
Structural failures often originate at fastener holes in joints. The local loading near a fastener typically consists of two components: (1) a bearing load component that is reacted at the hole and (2) a "bypass" load that is reacted elsewhere. In general, failures at holes are governed by the combined action of these two load components. As a result, material-evaluation tests for joints should include the combined effects of bearing and bypass loading. In such tests, a wide range of tension-and compression-load combinations are needed to represent fastener-hole conditions, but for each combination the ratio of bearing load to bypass load is nearly constant.

The currently used methods for combined bearing/bypass testing are either limited to tensile loading or cannot maintain constant bearing/bypass load ratios throughout the testing. The present system was developed to test specimens in compression as well as tension while maintaining a constant bearing/bypass ratio.

A test specimen with a centrally located hole is clamped between two bearing-guide plates using one bolt, as shown in the figure. The bearing-guide plates are then secured to the two bearing-load cells. The test specimen is independently loaded at both ends, using two separate control systems identified as applied and bypass. If the two end loads are unequal, the difference between them is reacted as a bolt-bearing load on the specimen.

Throughout the test, the two control systems are synchronized by a common input signal (an increasing voltage). As a result, the loads remain proportional as they increase. Maintaining a constant ratio between the two end loads produces the desired constant bearing/bypass load ratio. The two loading systems can be adjusted to produce any desired value of bearing/bypass ratio. The loads on the specimen are recorded as it is loaded to failure.

The bearing/bypass material-testing system works equally well in tension and compression. When testing in compression, the bearing-guide plates prevent the specimen from buckling. Fatigue bearing/bypass loading can also be created by using a cyclic input signal.



The **Bearing/Bypass Testing System** works equally well in tension and compression. It can also be used in cyclic testing.

This work was done by John H. Crews, Jr., of ***Langley Research Center****. Further information may be found in NASA TM-87705 [N86-23660/NSP] "Combined Bearing and Bypass Loading on a Graphite/Epoxy Laminate".*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 26]. Refer to LAR-13458.

Semiautomatic Probe-and-Drogue Attachment Mechanism

Spring-loaded pawls would provide quick coupling.

Lyndon B. Johnson Space Center, Houston, Texas

In a proposed probe-and-drogue attachment mechanism, all of the active components are in the probe. The drogue is a simple fixed cavity, which should require no maintenance. Previous designs had active drogue mechanisms, which would be difficult to replace if damaged.

The proposed probe-and-drogue mechanism is suitable for the attachment of components that must later be disconnected (see Figure 1). Precise alignment is not required prior to coupling, but is achieved after coupling by extending a locking cap. The new mechanism was originally proposed for attaching modules to the Space Station without requiring extravehicular or other astronaut activity. It should be useful for coupling modular components in other applications where ease and security of attachment, precise final alignment, and ease of removal are important and where stresses and bending moments are reasonably low.

As the probe enters the drogue during coupling (see Figure 2), three spring-loaded pawls in the probe latch the probe in the drogue, preventing accidental uncoupling. Then a worm-gear mechanism turned by a standard 0.25-in. (6.35-mm) tool transfers motion to a central threaded shaft, which extends the cap at the tip of the probe until all play is taken up. This centers the probe in the drogue and renders the coupling

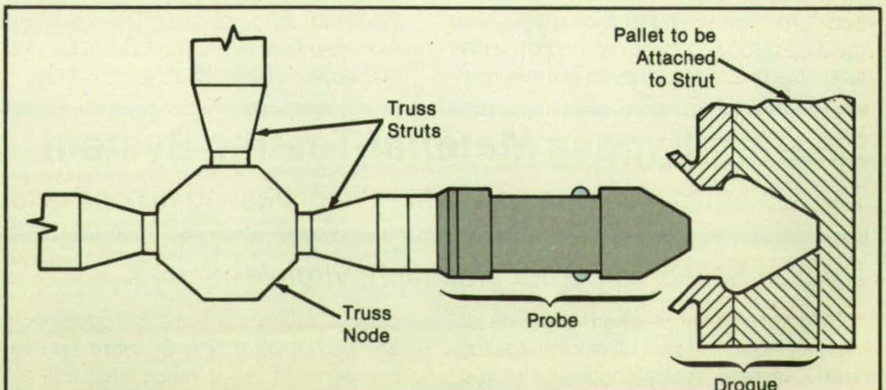


Figure 1. The **Probe-and-Drogue Mechanism** could be used to attach and detach components of modular structures.

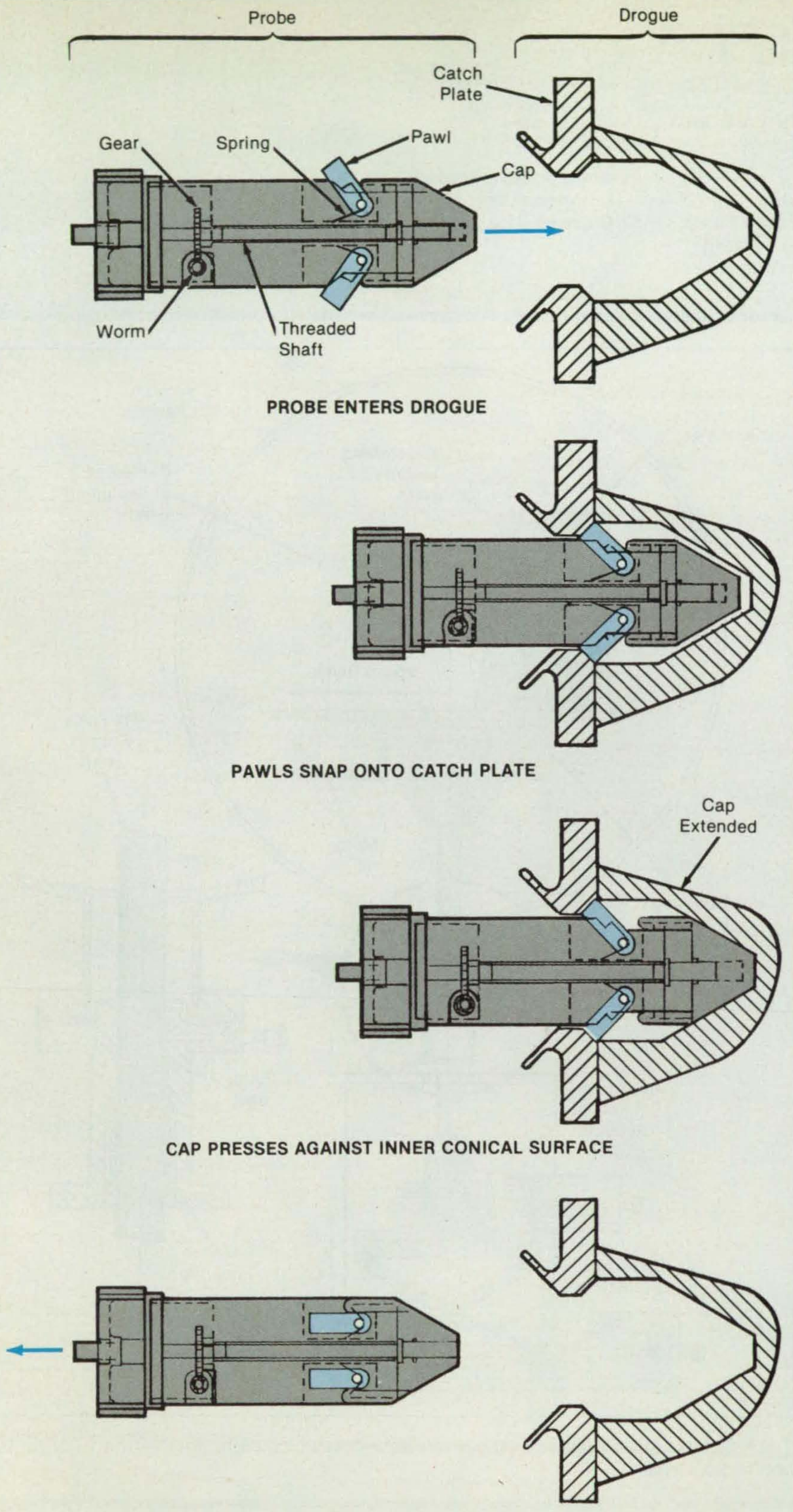


Figure 2. **Spring-Loaded Pawls** latch automatically when the probe enters the drogue. The probe is locked in position when the cap is forced against the inner conical surface of the drogue. To disconnect the probe from the drogue, the cap is retracted enough to cause the pawls to fold into the body of the probe.

rigid.

To uncouple the probe, the worm gear is turned in the opposite direction to retract the probe cap. As it retracts, the rear of the cap depresses the three pawls into the body of the probe. This frees the probe for easy removal. Prior to recoupling, the cap must be partially reextended to allow the pawls to extend again.

This work was done by John D. Wanagas of Rockwell International Corp. for **Johnson Space Center**. *No further documentation is available.*
MSC-21254

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Computational Methods for Composite Structures

Computer codes simulate a variety of effects in fiber/matrix composites.

Selected methods of computation for the simulation of the mechanical behavior of fiber/matrix composite materials are described in a report. The methods encompass mechanics, impact, progressive fracture, and specific structural components. The methods demonstrate the effectiveness of computational simulation as applied to complex composite structures in general and aerospace-propulsion structural components in particular.

For each method, the report describes the significance of the behavior to be simulated, the procedure for simulation, and representative results. The following applications are discussed:

- Effects of progressive degradation of interply layers on the responses of composite structures,
- Dynamic responses of notched and unnotched specimens,
- Interlaminar fracture toughness,
- Progressive fracture,
- Thermal distortions of sandwich composite structures, and
- Metal-matrix composite structures for use at high temperatures.

By virtue of their complexity, the methods are computationally intensive. By necessity, they are in the form of independent computer codes or are embedded as modules in more general codes for the analysis of structures.

This work was done by Christos C. Chamis of **Lewis Research Center**. *Further information may be found in NASA TM-88965 [N87-18614/NSP], "Computational Composite Mechanics for Aerospace Propulsion Structures."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14640

Machinery

Hardware Techniques, and Processes

Manipulator for a Vacuum Chamber

A rotary seal provides for external actuators.

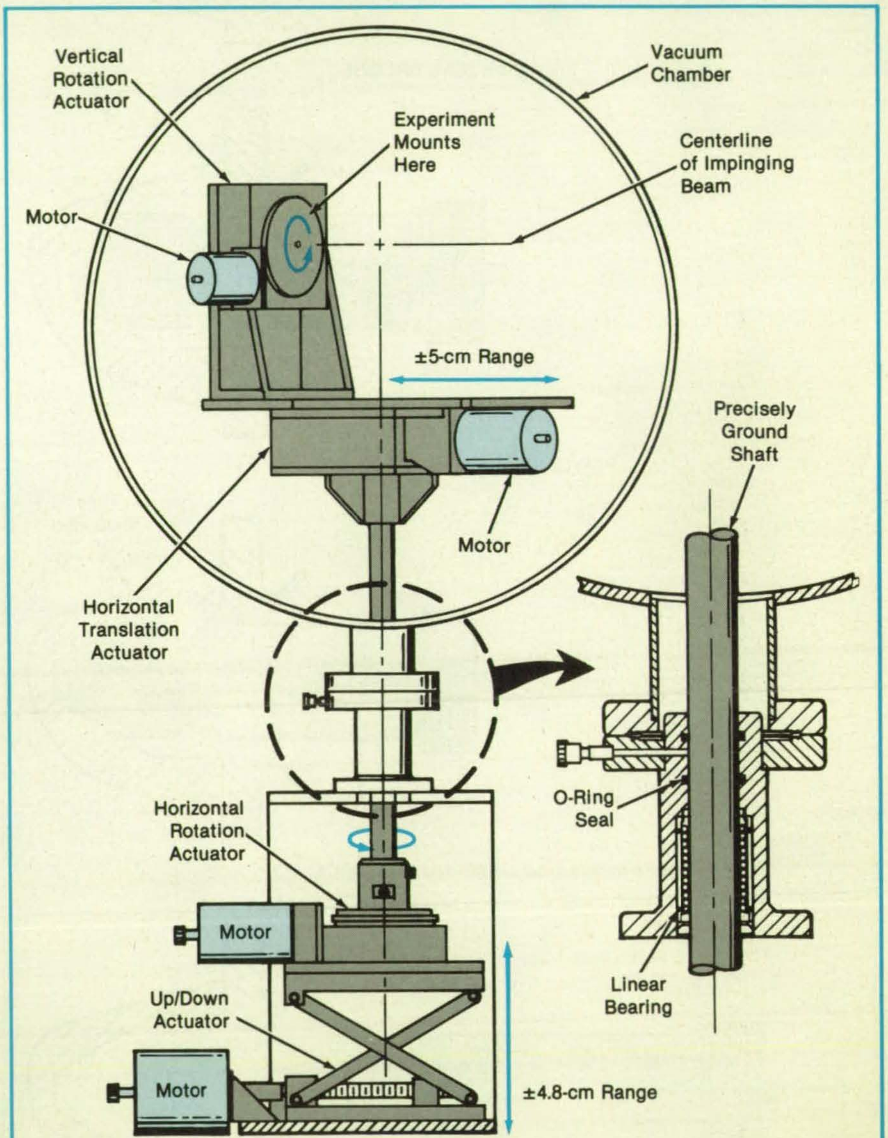
Goddard Space Flight Center, Greenbelt, Maryland

A manipulator precisely positions objects in a vacuum chamber. The motion of the externally driven manipulator does not appreciably increase demands on the vacuum pump at pressures as low as 10^{-7} torr (about 10^{-5} Pa). The manipulator was developed for calibrating plasma detectors by subjecting them to particle beams in a vacuum. Standard, commercially available parts are used.

External up/down and azimuthal actuators drive a shaft that enters the vacuum chamber through a sliding and rotating seal (see figure). The placement of the actuator motors outside the vacuum chamber reduces the heat-removal load on the system. Atop the 2.5-cm-diameter shaft is a stage that can support masses as great as 15 kg. Small motors on the stage provide horizontal translation and rotation in a vertical plane.

A computer controls the motors and measures angles and positions, providing an accurate and convenient readout. Vertical and horizontal positioning is precise to ±25 μm. The angular precision is ±0.01°.

This work was done by F. Hunsaker and K. Ogilvie of **Goddard Space Flight Center**. *No further documentation is available.*
GSC-13130



The **Positioner in the Vacuum** employs four actuators: up/down, horizontal rotary, horizontal, and vertical rotary.

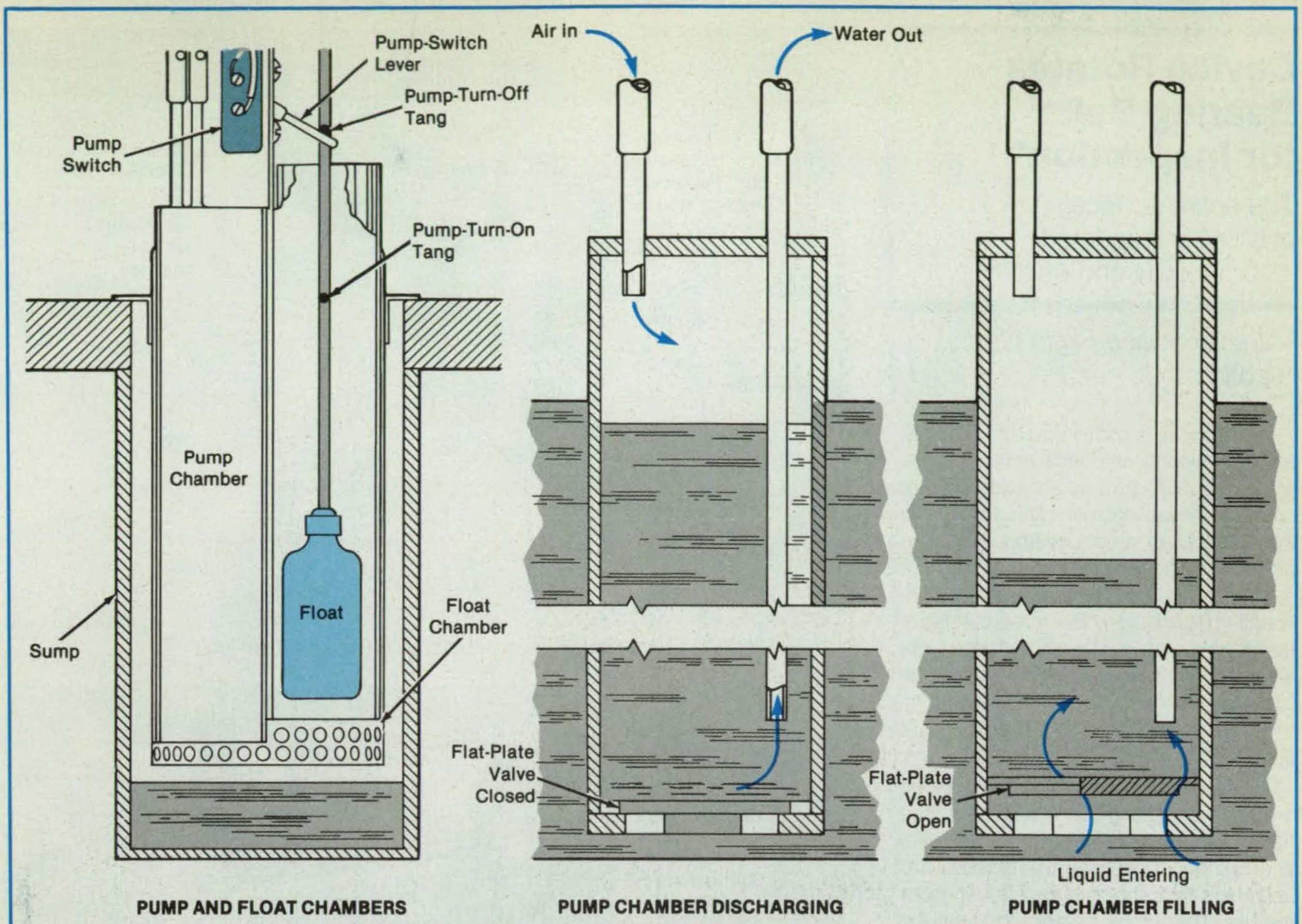
Air-Operated Sump Pump

A compact unit raises water 85 ft.

Ames Research Center, Moffett Field, California

A pump removes liquid seepage from a small, restricted area and against a large pressure head. The pump was developed for moving small amounts of water and oil from a sump pit 85 ft (25.91 m) deep. It fits in a space only 6½ in. (16.5 cm) in diameter and 18 in. (45.7 cm) long.

The pump employs high-pressure air to push the liquid upward through a long pipe. When the liquid rises into the pump chamber, it raises a float that actuates a timer. The timer opens a normally closed solenoid valve, which admits air at 120 lb/in.^{2} (827 kPa) to the pump from a remote supply. The air pressure forces the liquid up the outlet pipe (see figure). As the liquid level falls in the pump, the float drops and deactivates the timer. The solenoid valve



In the **Discharge Part of the Pumping Cycle,** air forces liquid out of the pump chamber through a pipe. During the filling part of the pumping cycle, water enters the pump chamber from the sump pit. A float in a chamber next to the pump chamber controls the pressurization through a timer and solenoid valve.

returns to its normally-closed position and shuts off the pressurized air.

As the liquid rises again into the pump chamber from the sump pit, it pushes open the flat-plate valve at the base of the pump and refills the pump chamber. When the liquid reaches a sufficient height, the float mechanism actuates the timer, and the pumping cycle repeats. If the flat-plate valve is still open when the pumping starts, the pumping pressure closes it.

The pump requires no high voltages in the sump pit: a 12-V supply is all that is needed for the timer and solenoid. The pump is simple mechanically and electrically and inexpensive to operate. It is installed simply by lowering it into the sump pit by its electrical and pressure lines.

This work was done by Gary D. Nolt of **Ames Research Center**. *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center [see page 26]. Refer to ARC-11414.

Device Rotates Bearing Balls for Inspection

The entire surface of a ball is inspected automatically and quickly.

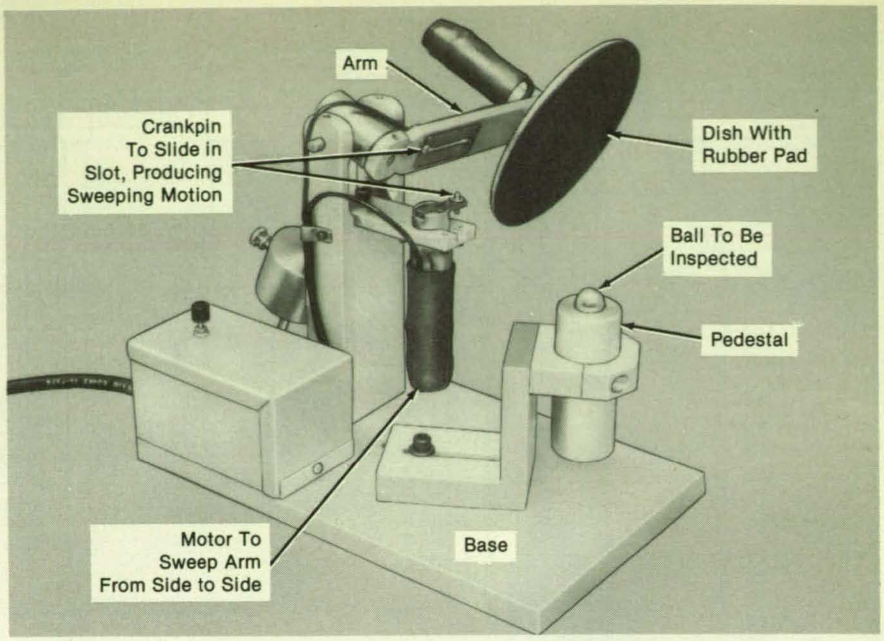
Marshall Space Flight Center, Alabama

A device holds and rotates a bearing ball for inspection by an optical or mechanical surface-quality probe, an eddy-current probe for the detection of surface or subsurface defects, or a circumference-measuring tool. The device ensures that the entire surface of the ball is moved past the inspection head quickly. Because manual rotation of a ball is slower and does not always result in inspection of the entire surface, the new device saves time and increases the reliability of inspections of spherical surfaces.

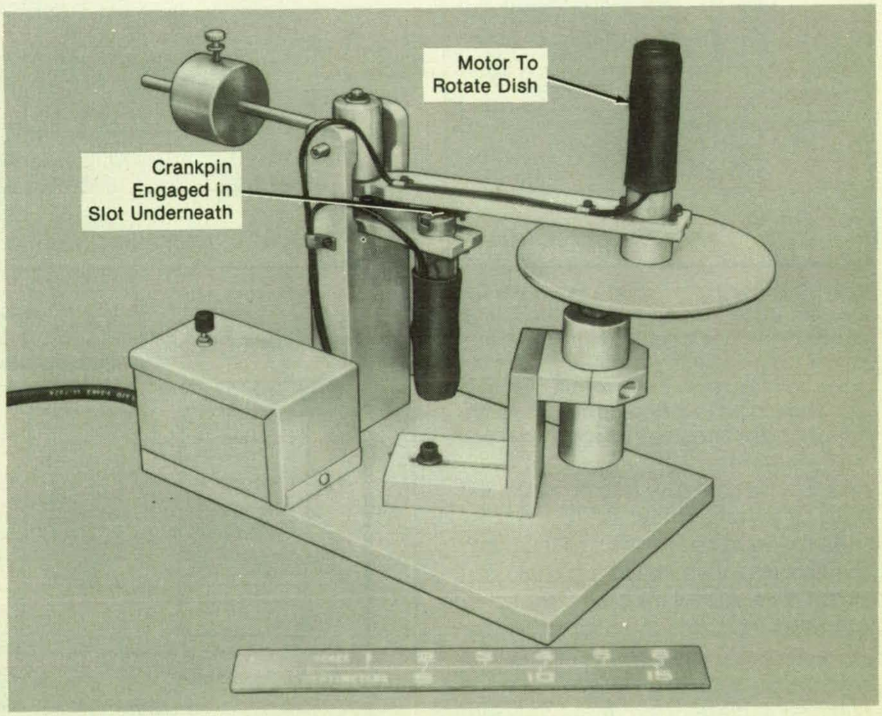
The device includes a counterbalanced arm with a rotating-disk attachment (see figure). Mounted on the base of the device is a cylindrical pedestal that seats a ball and holds the inspecting transducer under the ball. The arm is lowered to place the rubber-padded disk on top of the ball. The disk rotates and the arm is swept horizontally from side to side, causing the ball to rotate about rotating axis. Although such rotational motion is not strictly random, in practice it brings the entire surface of the ball within range of the inspecting transducer at some time during the inspection.

Interchangeable pedestals are easily made to accommodate balls of different sizes. The device is simple to operate and provides quick and easy access for the loading and unloading of the balls during the inspection.

This work was done by R. K. Burley of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 64 on the TSP Request Card. MFS-19717*



ARM RAISED FOR INSERTION OR REMOVAL OF BALL



ARM LOWERED TO PLACE DISK ON BALL

The **Disk Is Placed on the Ball**, rotated, and swept from side to side to rotate the ball to all orientations of interest for inspection.

Angular-Momentum-Compensating Actuator

A rotary actuator imparts no torque to its supporting base.

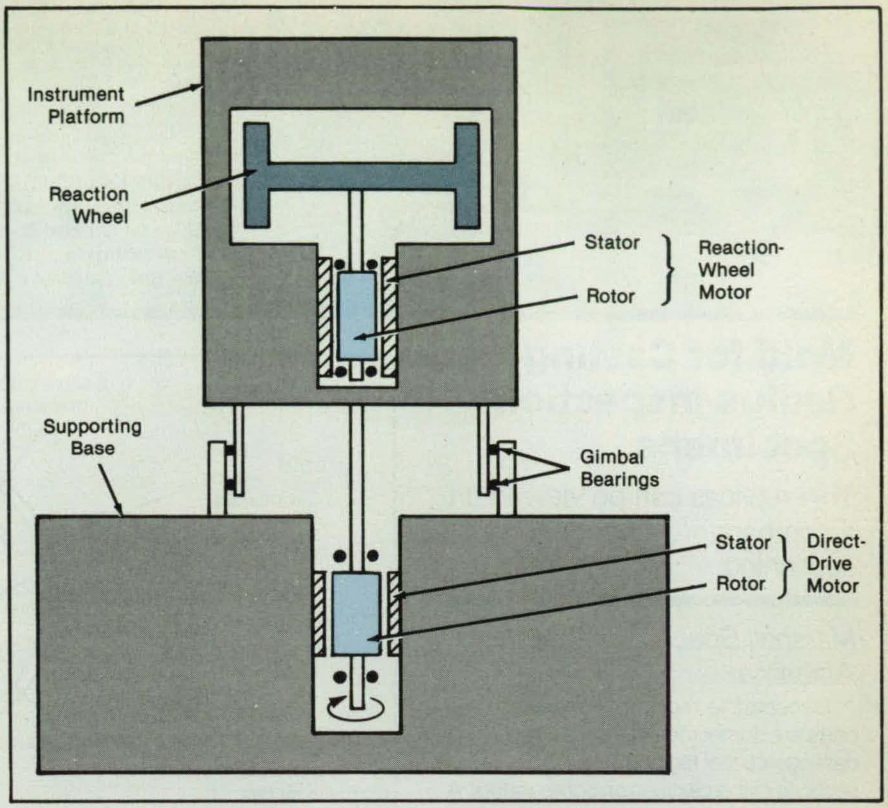
NASA's Jet Propulsion Laboratory, Pasadena, California

A precise aiming actuator for an instrument platform suppresses reactions in its supporting body to the torques that occur when the aiming angle is changed. The reactionless actuator was developed for instrument-pointing platforms on flexible spacecraft; by eliminating reactions, the actuator can change the aiming angle of the platform without inducing vibrations in the spacecraft, which in turn eliminates vibrations in the pointing angle of the instrument platform. The absence of reactions also makes it unnecessary to use thrustor fuel to correct for angular momentum imparted to the spacecraft when an instrument is pointed in a new direction. The actuator can be used on Earth in such systems as helicopter platforms for television cameras in law enforcement and news telecasts.

The actuator employs a pair of counterrotating brushless dc motors on a common axis (see figure). The direct-drive motor applies torque between the supporting base and the instrument platform to compensate for the torques exerted by friction and by the bending of cables in the rotary joint between the platform and the base. The reaction-wheel motor applies torque between the platform and a reaction wheel to turn the platform.

The motors are commutated electronically by a hybrid analog/digital control system that responds to a platform-turning-rate command and to turning-rate feedback signals from angle resolvers in the motors and from a turning-rate gyroscope on the platform. The control system issues torque commands to the motor-drive electronics according to a control algorithm that strives continually for zero net torque on the supporting base. The control algorithm also strives to prevent the excessive buildup of angular momentum in the reaction wheel.

This work was done by Peter J. Wiktor of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 43 on the TSP Request Card.*
NPO-16928



The **Reaction Wheel** negates the effects of torque and angular momentum of the rotating platform. The direct-drive motor replaces the energy lost to bearing friction and to torque exerted by electrical cables.

Stacked-Disk Combustor

Materials could be chosen for strength rather than for thermal conductivity.

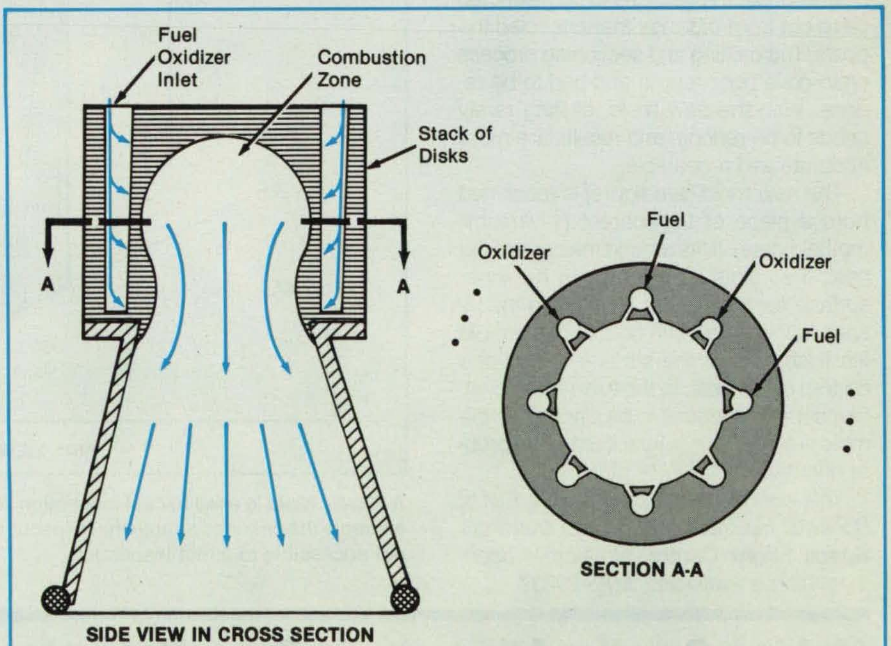
Marshall Space Flight Center, Alabama

A proposed combustion chamber for turbine or rocket engines would be constructed of stacked disks. The disks would be successively shaped to provide the required aerothermodynamic contour in the chamber and would incorporate internal cooling passages. Clamped and diffusion-bonded or otherwise bonded together, the stacked disks would form a combustion chamber that could be operated for greater efficiency at pressures and temperatures higher than those of a conventional tube-wall combustion chamber.

With leakproof internal transpiration cooling of the chamber, the disk material could be chosen primarily for strength rather than as a compromise between strength and heat conductivity. The weight of the combustion system or engine may be reduced as a result.

The disks would be made of thin sheets, perhaps 3 to 5 mils (76 to 127 μm) in thickness. They would be cut to the requisite shapes inexpensively by photolithographic masking and etching. The patterns might be established by computer-aided design and executed automatically at high production rates.

This work was done by Walter B. Ingle of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.* *MFS-29333*



Stacked Washerlike Disks would accommodate built-in coolant passages while providing a combustion zone of ideal shape. Fuel would flow through the coolant passages where it would be preheated before entering the combustion zone through passages in the disks. Here, eight coolant passages are shown in the cross section, although the number in a particular application would be determined by the required rate of flow of fuel and pressure drop.

Fabrication Technology

Hardware Techniques, and Processes

Mold for Casting Radius-Inspection Specimens

Thin replicas can be viewed on a comparator without sectioning.

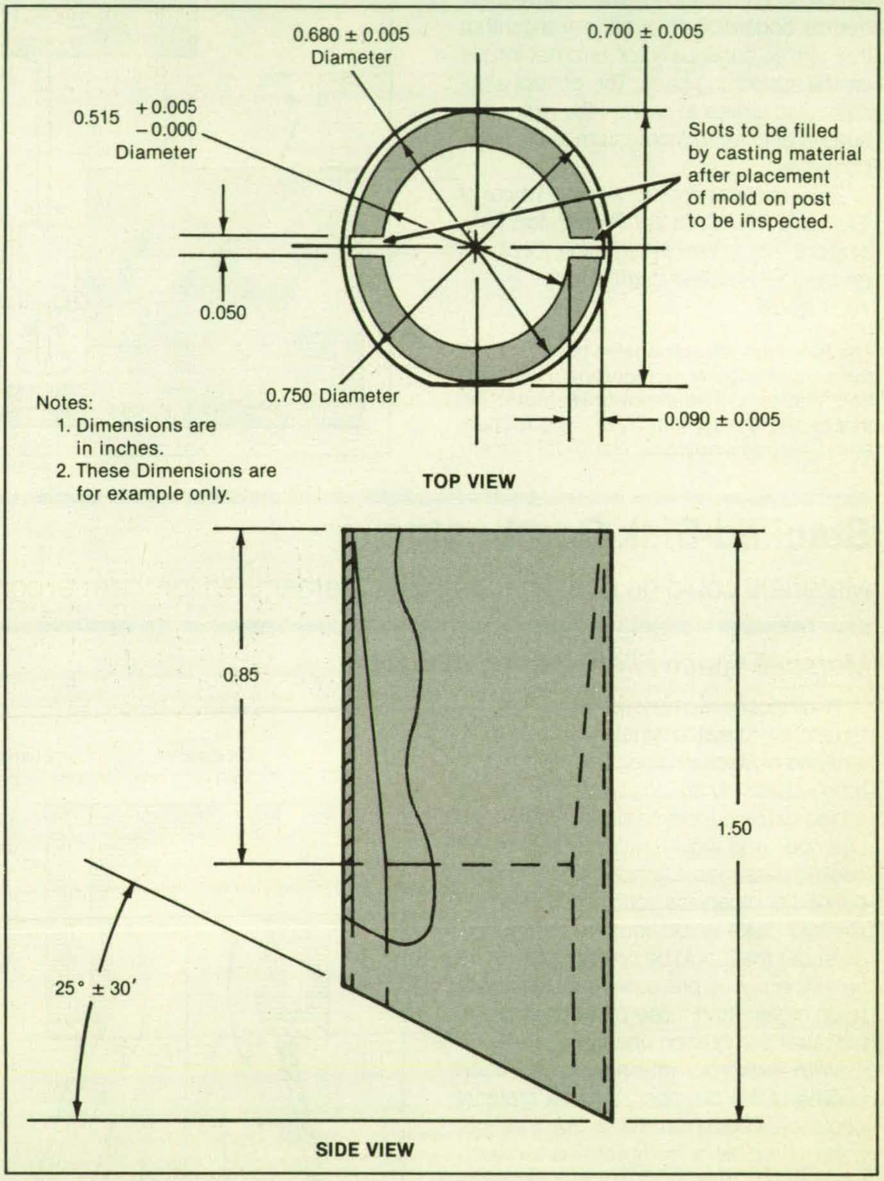
Marshall Space Flight Center, Alabama

Inaccessible regions on manufactured parts are sometimes inspected by making castings of the regions and then viewing sections of the castings on comparators. A special mold is designed to make thin castings that can be viewed on a comparator and that do not have to be sectioned from a larger casting. In the situation in which the mold was conceived, the time required to inspect elliptical radii located at the bottoms of a series of small posts was reduced from 18 hours to 3 hours.

Previously, the sections to be inspected were cut from castings that encircled the posts. The casting and sectioning process often gave poor results and had to be redone. With the new mold, casting rarely needs to be redone, and results are more accurate and repeatable.

The new mold (see figure) is machined from a piece of transparent poly(methyl methacrylate). It fits around the base of the post. Two slots machined into the inner surface form channels for casting the inspection sections. The bottom of the mold fits flush against the surface around the bottom of the post. In the example shown, that surface happens to be slanted, so the mold automatically aligns itself in the proper orientation.

This work was done by Robert N. Ball of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available. MFS-29237*



A **Plastic Mold** is used to cast inspection sections for direct viewing on a comparator. In this example the castings enable the inspection of elliptical radii at the bottoms of posts that are not accessible to direct inspection.

Making Smaller Microshells From Refractory Metals

The tendency toward gas porosity would be exploited.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed process for making ultramicroshells would exploit the great decrease in solubility of a gas in a metal as the molten metal freezes. The process would produce smaller shells in a greater variety of materials than is possible with such current processes as those based on hollow-jet instability, dry-chemical blowing, or fluid-droplet drying. Moreover, the shell aspect ratio (the ratio of the radius to the wall thickness) would be controllable. The new process would make shells having diameters smaller than 100 μm. There are several candidate shell materials including refractory metals.

Molten metal would be saturated with a gas (hydrogen, oxygen, or nitrogen, for example) and atomized into droplets about 10 to 20 μm in diameter. As they fall in a drop tube (see figure), the droplets would then cool primarily by radiating heat so that they would solidify from the outside inward. As the metal cools, much of the dissolved gas would come out of solution and move toward the hotter region at the center of a droplet, where it would form a bubble. The result would be a thick-walled, hollow sphere, 10 to 20 μm in diameter, pressurized with gas.

Substantial amounts of gas would be released to the droplet center by the cooling metal. Molten iron, for example, holds 27 cm^3 of hydrogen per 100 grams at 1 atm (10^5 Pa) pressure, but 100 grams of solid iron holds only 7 cm^3. As much as 20 cm^3 of hydrogen would therefore be released by every 100 grams of solidifying iron.

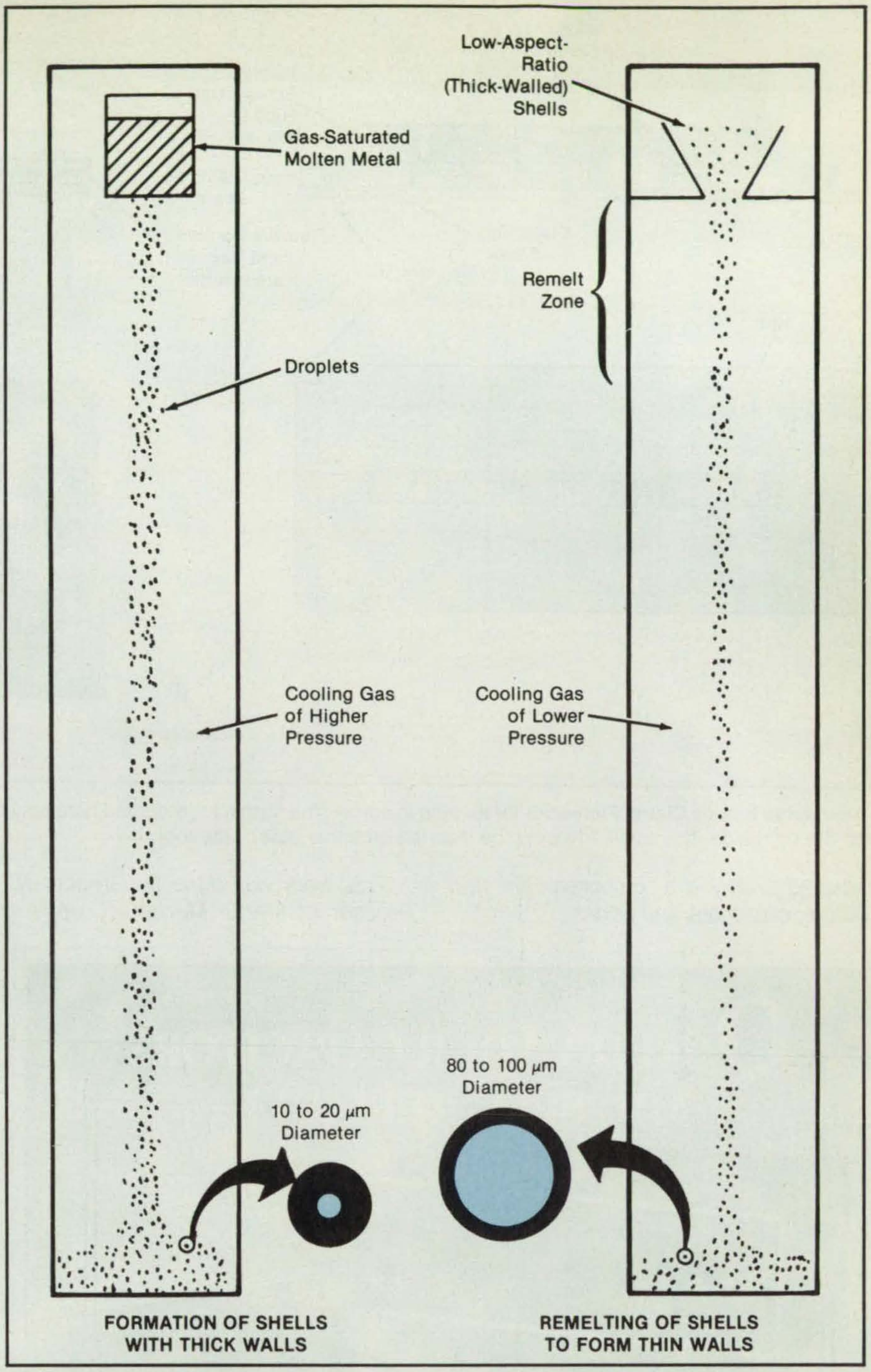
The shells thus formed would ordinarily have an aspect ratio less than 2. If a higher ratio is wanted, the thick-walled shells would be remelted in a drop tube containing a gas at a reduced pressure. The pressurized core gas would expand the shells and thereby reduce the wall thicknesses. The pressure and the cooling rate would be controlled to give the required final size and aspect ratio.

This work was done by Mark C. Lee and Christopher Schilling of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 6 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Edward Ansell,
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1207 East California Boulevard
Pasadena, CA 91125

Refer to NPO-16635, volume and number of this NASA Tech Briefs *issue, and the page number.*



Falling Through a Drop Tube, fine drops of molten metal lose heat to the surroundings, forming hard shells around the precipitated gas. A second heating/cooling cycle in a drop tube of lower pressure lets the gas expand.

Tool for Tinning Integrated-Circuit Leads

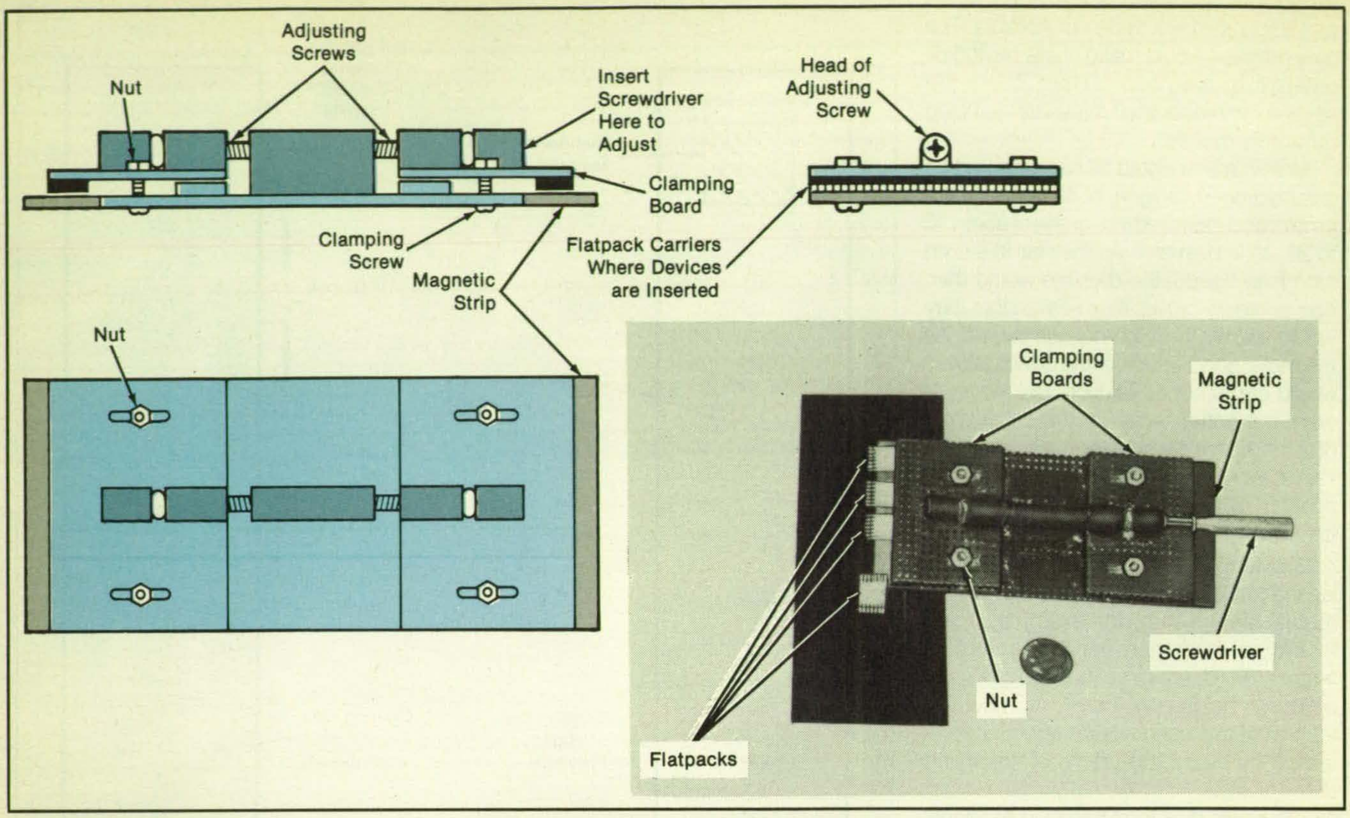
As many as eight flatpacks can be held.

Lyndon B. Johnson Space Center, Houston, Texas

A tool holds flatpack integrated circuits so that their leads can be tinned. The tool accommodates several flatpacks for simultaneous dipping of leads in molten solder. It can be adjusted to accept flatpacks in a range of sizes.

The tool is made of fiberglass boards. It clamps a row of flatpacks by their leads so that leads on the opposite side of the packages can be dipped (see figure). After dipping, the nuts on the boards are loosened, the flatpacks are turned around, the nuts are retightened, and the untinned leads are dipped. Strips of magnetic material grip the leads of the flatpacks (which are made of Kovar, a magnetic iron/nickel/cobalt alloy) while the boards are being repositioned. A micrometerlike screw is used to adjust the exposed width of magnetic strip to suit the dimensions of the flatpacks.

The tool can be redesigned to handle larger hybrid packages. It can also be



Adjustable Boards Clamp Flatpacks for dipping in solder. The flatpacks, mounted here only on the left side of the tool, can also be clamped on the right side. The screwdriver can be inserted on either side of the tool.

adapted to axial-lead components like resistors, capacitors, and diodes.

This work was done by Gregory N. Prosser of Martin Marietta Corp. for **Johnson Space Center**. *No further documentation is available.* MSC-21261

Antireflection/-Passivation Step for Silicon Cells

A new process excludes the usual silicon oxide passivation.

NASA's Jet Propulsion Laboratory, Pasadena, California

An antireflection coating for silicon solar cells also passivates the silicon surface, making an extra passivation step unnecessary during fabrication of cells. The coating consists of a double layer, one of titanium oxides (TiO_x) and the other of Al_2O_3.

The TiO_x and Al_2O_3 are deposited on the cell after the junction has been formed and the contacts have been metalized. The layers are formed by evaporating titanium and aluminum in an oxygen-rich atmosphere. During evaporation, the cell is heated to 75 °C. Afterward, it is annealed in pure hydrogen at 350 to 400 °C for 5 to 10 minutes.

While increasing cell output by reducing light lost by reflection from the surface, the coating is as effective in passivating the cell as is the usual, thermally grown layer of silicon oxides (SiO_x). It reduces the reverse saturation current and thereby increases the open-circuit voltage and efficiency of the cell to almost the same extent as SiO_x. It does so without the disadvantages of the SiO_x passivation: processing temperatures above 450 °C that can degrade performance; questionable stability, quality, and reproducibility; incompatibility with some antireflection coating materials; and the cost of an extra step.

In an experiment, a cell fabricated with SiO_x passivation was compared with a cell fabricated without SiO_x passivation. The increase in open-circuit voltage, short-circuit current, and energy-conversion efficiency due to the antireflection treatment alone was only slightly less than that due to the combination of antireflection and SiO_x-passivation treatments (see table).

Treatment	Cell Number	Open-Circuit Potential, mV	Short-Circuit Current, mA	Efficiency, Percent
None	1	608	90.4	10.94
Oxide Passivation	2	633	90.9	11.49
Antireflection	1	641	132.9	17.19
Antireflection After Passivation	2	643	130.4	17.13

The **Changes in Principal Electrical Parameters** during two kinds of processing suggest that the antireflection treatment is almost as effective as the oxide treatment is in passivating the cells.

This work was done by Gerald T. Crotty, Akaram H. Kachare, and Taher Daud of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 27 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel NASA Resident Office-JPL [see page 26]. Refer to NPO-16810.

Separating Images for Welding Control

Optics in the torch direct views of the weld to two different sensors.

Marshall Space Flight Center, Alabama

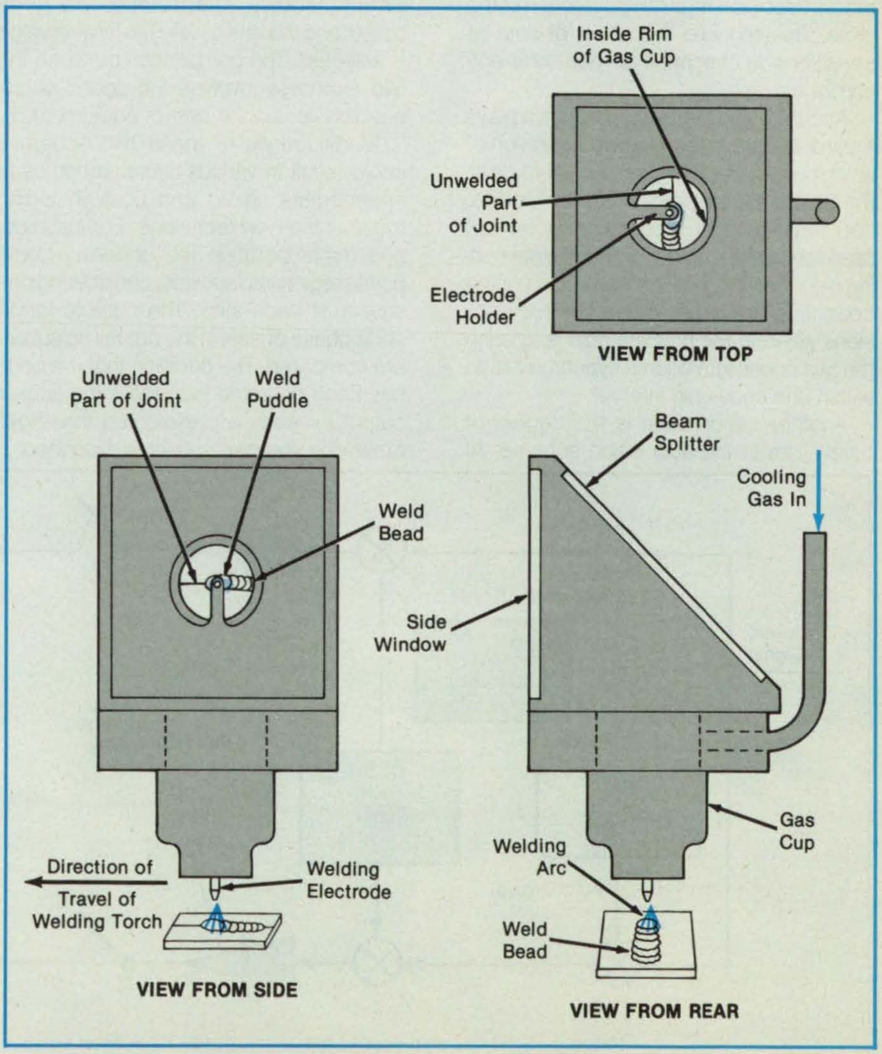
A torch for automatic gas/tungsten-arc welding provides separate coaxial views of a weld to two sensors. Each sensor can function in real time without interfering with the other. One sensor provides information for a vision-guided seam tracker; the other feeds data to an optical weld-contour monitor for control of penetration.

The torch contains a beam splitter at an angle of 45° with the electrode axis (see figure). The beam splitter reflects wavelengths below 550 nm to the sensor for seam tracking. It transmits wavelengths above 550 nm to the sensor for weld-contour monitoring. Filters can be added to the split beam paths to limit further the spectra transmitted to the sensors. Moreover, the beam splitter and the filters can be easily changed to suit the material and the welding parameters.

The torch is based on a water-cooled copper block. Cooling water flows through it in channels only 0.050 in. (1.3 mm) from the electrode, allowing the electrode to be used continuously at a current of 200 A without rising above a temperature of 100 °F (38 °C). A single arm extends from the block to hold the electrode. The arm blocks only a small part of the coaxial view of the weld, not in an area of interest for welding control. If the blockage by the arm should be objectionable in a particular application, it can be overcome by adding a lens between the torch and the beam-splitter holder to "see" around the electrode holder.

This work was done by Stephen S. Gordon of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 14 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 26]. Refer to MFS-29291.



Light Rays From the Weld are transmitted axially through a beam splitter for imaging on one sensor and are reflected to the side by the beam splitter for imaging on another sensor.

Mathematics and Information Sciences

Acquisition Technique for Spread-Spectrum Codes

The ability to lock onto a signal is increased with minimal equipment.

NASA's Jet Propulsion Laboratory, Pasadena, California

A technique has been proposed to improve the acquisition of a spread-spectrum (pseudonoise) coded signal modulated by a digital data signal. In essence, the technique is to divide the correlation time into subintervals, integrate over the subintervals, pass the integrator outputs through square-law detectors, and add the detector outputs over all the subintervals to reach a decision regarding detection of the code. This reduces the effect of data-bit transitions at the price of non-coherent-combining loss.

Accurate and fast synchronization plays a cardinal role in the efficient utilization of any spread-spectrum system. Typically, the first step in the process of synchronization between the spreading (incoming) pseudonoise code and the local despreading (receiver) code is the acquisition of the code. It is a process of successive decisions wherein the ultimate goal is to bring the two codes into coarse synchronization within one code-chip interval.

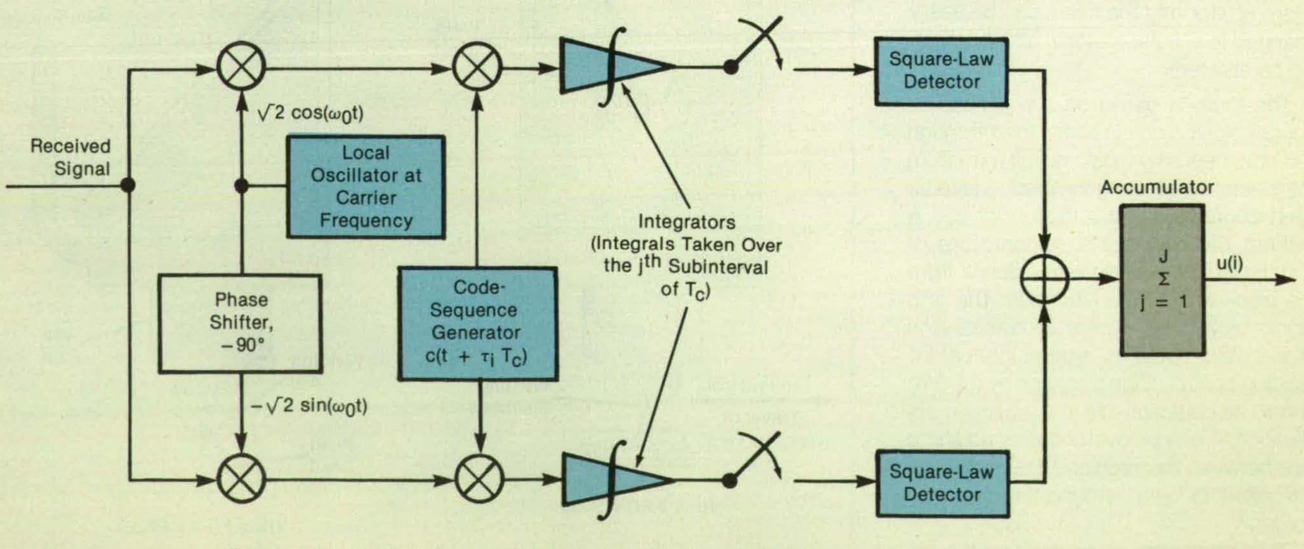
Another major issue is the degree of parallelism in the acquisition scheme. At one extreme, one steps through the uncertain-code-phase region in a serial manner. A detection threshold is selected to perform compromises among the probabilities of detection, missing and false alarms, and the mean acquisition time. At the other extreme is the totally parallel acquisition scheme, in which the correlation for every uncertain code-phase offset is performed simultaneously. The outputs are compared, and the one having the largest value is selected. The comparison between the two extremes involves the speed of acquisition versus the cost of equipment.

Modifications of these two schemes could result in various hybrid schemes of intermediate speed and cost, including those of the new technique. For instance, one might partition the uncertain-code-phase region into subsets, considering one subset at each step. The outputs for all code-phase offsets in the prevailing subset are compared. The decision that the code has been detected is made if the largest output exceeds a preselected threshold; otherwise, the next subset is examined.

The figure illustrates the overall structure of the new detector system. The code despreading occurs at baseband. The local code generator has code-phase offset (lag) τ_j. In the case of parallel acquisition, there are many such correlators, each with different τ_j. The total correlation time is partitioned into J subintervals. The outputs of the square-law detector in the J subintervals are noncoherently combined for detection.

The performance of this system has been analyzed theoretically for several totally parallel and hybrid schemes. The optimum number of coherent integration subintervals was shown to be a function of the total integration time. The dependence of mean acquisition time on the number of subintervals decreases as the signal-to-noise ratio increases.

This work was done by Unjeng Cheng of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 154 on the TSP Request Card.*
NPO-17289

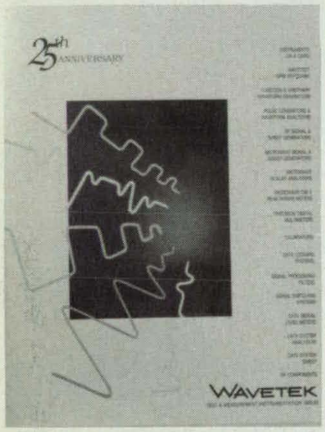


Notes: 1. T_c = the chip time of the pseudonoise code c(t).
2. t = time.
3. J = total number of subintervals.
4. ω_0 = angular frequency of carrier signal.
5. τ_j = code-phase offset (as a fraction of T_c).

The **Partially Noncoherent Correlator/Detector** implements a hybrid scheme for the acquisition of a pseudonoise code in the presence of data modulation.

New Literature

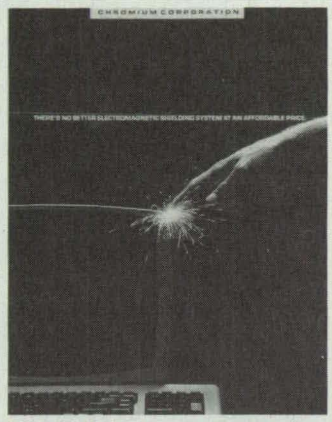
Advanced **vacuum products** are illustrated in a free catalog from Sargent-Welch Scientific Co., Skokie, IL. The 145 page catalog describes Sargent-Welch's line of turbomolecular, high vacuum, and low vacuum pumps, and includes a reference section which explains the operation of these pumps and their use in vacuum systems.
Circle Reader Action Number 716.



A new catalog published by Wavetek Corp., San Diego, CA, contains descriptions and specifications for the company's line of **signal sources and measurement equipment**. Equipment categories illustrated include GPIB software, waveform generators, RF signal and sweep generators, microwave CW and peak power meters, and digital multimeters.
Circle Reader Action Number 714.

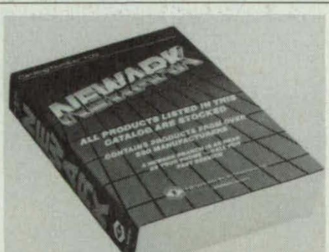
A new catalog offered by National Superconductor Inc., Gardena, CA, features **superconductivity demonstration kits**, superconducting powders and compounds, and a variety of composite magnets. The kits include a primer on high-temperature superconductivity containing historical background and an explanation of the three primary phenomena associated with superconductivity: the Meissner Effect, zero electrical resistance, and the Josephson Effects.
Circle Reader Action Number 720.

A 448 page **power semiconductor and power hybrid** databook is available free of charge from Lambda Semiconductors, Corpus Christi, TX. Among the products featured in Lambda's databook are switching regulators, interface drivers, controllers, overvoltage regulators, and semiconductor die.
Circle Reader Action Number 718.



COMPUSHIELD, a new **electromagnetic shielding process,** is described in a brochure from the Chromium Corp., Richardson, TX. Designed for the computer, medical, and aerospace markets, COMPUSHIELD offers an inexpensive way to shield plastic enclosures requiring up to 80 db attenuation.
Circle Reader Action Number 712.

Technical Insights Inc., Fort Lee, NJ, has published a new research report on **smart sensors** entitled "Intelligent Sensors: The Merging Of Electronics And Sensing." A smart sensor combines electronic data processing—normally done by an external processing unit—and sensing in a single IC chip. The report explains how smart sensors work, assesses their potential commercial impact, and describes the companies and research groups responsible for their development.
Circle Reader Action Number 722



A new catalog from Newark Electronics, Chicago, IL, features more than 100,000 electronic components from leading manufacturers. The 1,040 page catalog provides descriptions and specifications for each item.
Circle Reader Action Number 702.

"Laser Cutting," a new report from MTIAC Operations, Chicago, IL, reviews the use of **laser systems** for cutting of metallic and nonmetallic materials in manufacturing applications. The report describes laser cutting processes, laser source configurations, and multiaxis manipulators for directing the laser beam.
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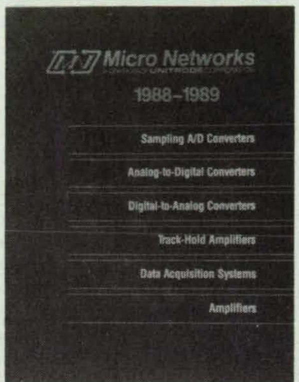
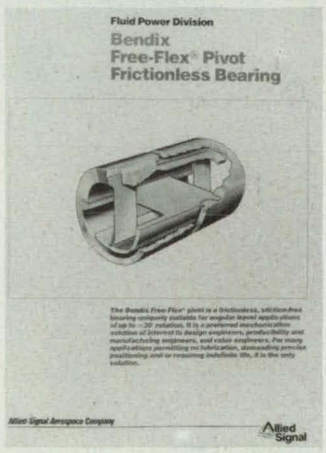


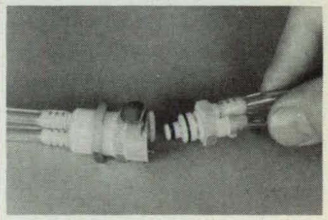
Micro Networks, Worcester, MA, is offering a **free data conversion products** catalog describing new A/D and D/A converters, track-hold amplifiers, data acquisition systems, and linear amplifiers. Tutorial sections cover A/D, D/A, and T/H basics, as well as frequency-domain FFT testing for sampling A/D converters.
Circle Reader Action Number 708.



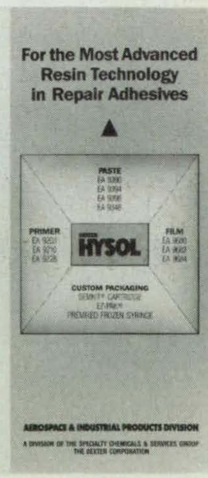
The Free-Flex® Pivot, a **frictionless bearing** designed for angular travel applications up to 30° rotation, is highlighted in a new brochure from the Allied Signal Company's Fluid Power Division, Utica, NY. The free brochure illustrates typical applications of the Free-Flex Pivot, including gimbal ring mounts, pressure transducers, scanner mirrors, and scales.
Circle Reader Action Number 724.

KRS Remote Sensing, Landover, MD, has published a new brochure describing their global **remote sensing** information services. The free brochure illustrates KRS' image processing, analysis, and systems integration capabilities, and highlights products including mosaics, photographic prints, transparencies, and image maps.
Circle Reader Action Number 710.

A free **electrical engineering** handbook from the Belyea Company, Jersey City, NJ, contains useful technical data for engineers who specify, install, or renovate industrial electrical power. The shirtpocket size handbook features electrical tables, nomographs, formulas, and conversion factors, and includes brief descriptions of over 3000 electrical power systems and components available from Belyea.
Circle Reader Action Number 706.



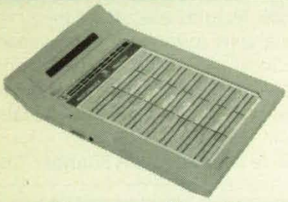
A free 28 page catalog highlights the Colder Products Company's line of **couplings and fittings** for plastic tubings, including Colder's new High Flow Twin Tube Coupling, which combines the function of two couplings in one package. Designed for 1/16 and 1/8 inch I.D. tubing, the Twin Tube Coupling provides two separate flow paths through one quick disconnect.
Circle Reader Action Number 728.



A free brochure spotlights the latest **film and paste adhesive products** from Hysol Aerospace Division, Pittsburg, CA. Peel strength, pot life, viscosity and other characteristics are described in detail. For ease of specifying, a chart is included which evaluates Hysol's entire line of repair adhesives.
Circle Reader Action Number 704.

New on the Market

TEST DRIVE™, a floppy disk drive **diagnostic tool for PCs**, is now available from Microsystems Development, San Jose, CA. Using Dysan precision magnetic media, TEST DRIVE measures and displays critical disk drive operating parameters without system disassembly. Test results are shown on the graphics display screen in simple pass/fail terms, with detailed technical reports available upon request.
Circle Reader Action Number 782.

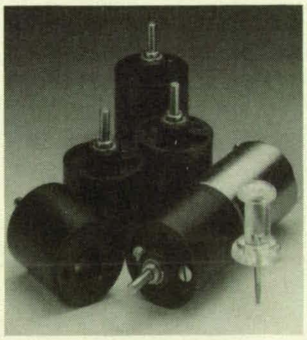


ScriptWriter, **a portable writing surface** from Data Entry Systems Inc., Huntsville, AL, allows forms to be entered directly into a computer, thereby saving time and eliminating errors in the data entry process. The device captures data as it is written on a standard paper form and stores it in a built-in memory. At the end of the work day ScriptWriter is plugged into a host computer, the data is transferred, and the unit is ready for the next day's entries.
Circle Reader Action Number 784

HiTc Superconco Inc., Lambertville, NJ, has announced the availability of new **Bismuth superconductors** in both bulk and powder form. Particle size ranges from .5 to 177 microns. Standard materials are 2-2-2-3 and 2-1-1-1 phases, with other materials made to order.
Circle Reader Action Number 792.

The HT Series **Portable Peck Drills** from Cooper Air Tools, Lexington, SC, produce precision holes without the need for special cutters, coolants, or secondary reaming operations. Designed for the aerospace industry, the HT Series can drill difficult materials such as potted honeycomb and acrylic plexyglass with minimal heat generation. The peck drills require less torque and thrust than conventional drills and work faster than positive feed drills.
Circle Reader Action Number 788.

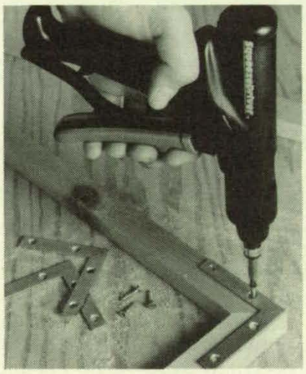
TECH-SA-PORT, Pittsburgh, PA, has introduced a new line of **static control products** for computer systems and electronic equipment. The new products include SAFECLENS, an anti-static cleaner for CRT screens and terminals; ASTAPOL, a protective polish for wooden workstation surfaces; and ASCAT, an anti-static spray for carpets, fabrics, and other nonconductive surfaces.
Circle Reader Action Number 790.



Micro Mo Electronics Inc., St. Petersburg, FL, has introduced a new series of **miniature gearheads** made from plastic composite materials. Available in both sintered and ball bearing versions, the gearheads are targeted for cost-sensitive applications requiring continous output torques of up to 7.1 oz-in., and are especially useful with 15mm and 16mm diameter micromotors as an integral motor-gearhead package.
Circle Reader Action Number 776.

Researchers at AT&T Bell Laboratories have created a new class of **heat-detection devices** so sensitive that they may make thermal imaging more practical for a variety of applications, including medical imaging, factory monitoring, earth resource mapping, and night vision systems. Activated by invisible light given off as heat, the tiny devices work in the 10-micron infrared region where room-temperature objects emit the most radiation. Made from gallium arsenide, the new detectors are potentially cheaper and easier to manufacture than those now employed.
Circle Reader Action Number 780.

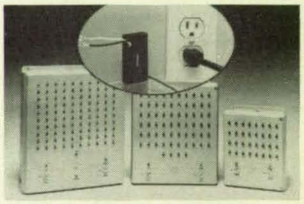
Remcor Products Company, Franklin Park, IL, has developed a line of **refrigerated cooling systems** for laboratory applications. The new systems provide cool water at a constant temperature, pressure, and flow rate for lasers, NMR and ESR spectrometers, condensers, and other laboratory equipment.
Circle Reader Action Number 778.



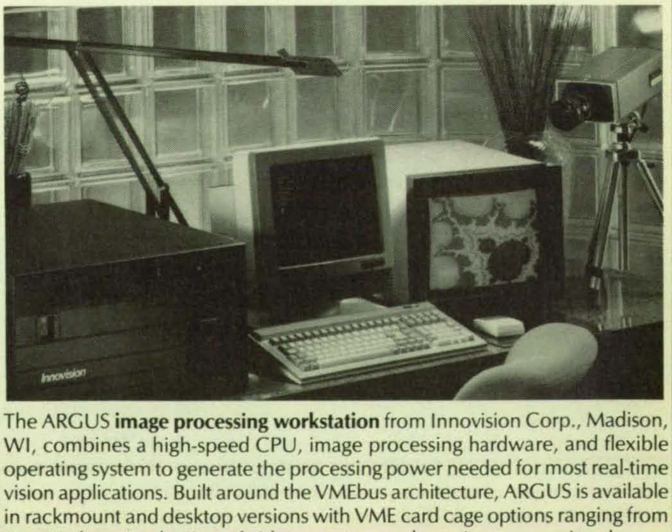
The new SqueezeDriver® driving tool from Worktools Inc., Los Angeles, CA, never needs charging, does not require a cord or batteries, and can be stored anywhere. The lightweight device is driven mechanically by squeezing or ratcheting with your hand. Designed for light duty assembly, SqueezeDriver features progressive torque and can perform both installation and removal of fasteners.
Circle Reader Action Number 800

Microcompatibles Inc., Silver Spring, MD, has introduced PRINTMATIC, a new **printer driver** that allows production of high-resolution 3D plots on a wide array of laser and dot-matrix printers. PRINTMATIC supports Microsoft, Ryan-McFarland, and Lahey FORTRAN, and can run independently or in conjunction with the GRAFMATIC graphics package to produce a screen preview.
Circle Reader Action Number 794.

Laser Technology Inc., Norristown, PA, has introduced the ES-9100 **Electronic Shearography System** for material and structures research as well as nondestructive testing. The ES-9100 employs a solid-state video camera, built-in laser, and image processing system to produce real-time shearographic images.
Circle Reader Action Number 796.



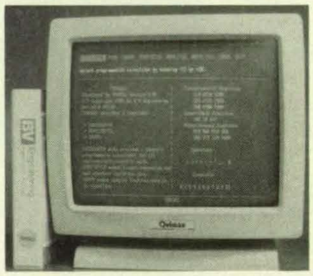
The THIEFBUG from CEPCO, Canoga Park, CA, **protects against the theft of computers**, office machines, laboratory equipment, or any other items that plug into an AC power outlet. Concealed in the electrical outlet box, THIEFBUG detects when an item is disconnected and uses the existing AC wiring to transmit a coded alarm signal to a monitoring unit, which identifies its location. Wireless monitoring units are available that plug directly into the power outlet.
Circle Reader Action Number 798.



The ARGUS **image processing workstation** from Innovision Corp., Madison, WI, combines a high-speed CPU, image processing hardware, and flexible operating system to generate the processing power needed for most real-time vision applications. Built around the VMEbus architecture, ARGUS is available in rackmount and desktop versions with VME card cage options ranging from 5 to 21 slots. A selection of video cameras and monitors are optional.
Circle Reader Action Number 786.

New on the Market

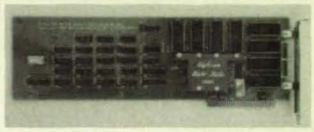
Buehler's new ISOMET™ PLUS **Precision Saw** quickly cuts metals, ceramics, composites, and many other materials. The saw's diamond-impregnated blade can section extremely hard materials such as rocks, minerals, and bone. The variable-speed cutter is housed in a reaction-injection molded cabinet with a transparent protective hood.
Circle Reader Action Number 758.



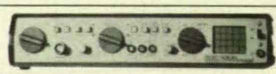
BV Engineering, Riverside, CA, has released a new version of TEKCALC, a programmable **scientific calculator program** for solving complex mathematical problems. TEKCALC now includes parametric graphics, statistics, curve fitting, and sorting. The program reads and writes standard ASCII text files and runs under PC/MSDOS.
Circle Reader Action Number 760.

The MEGAPLUS **CCD Camera** from VIDEK, Canandaigua, NY, exhibits 4 to 16 times the resolution of other solid state cameras. Designed for high-end imaging applications, the MEGAPLUS features a solid state sensor containing 1.4 million picture element dots, or pixels. The pixels are 6.8 microns square and have a center-to-center spacing of 6.8 microns—a feature that results in highly accurate and simplified dimensional measurements. VIDEK also markets a development system that turns an IBM PC/AT into an image processor for the MEGAPLUS Camera.
Circle Reader Action Number 746.

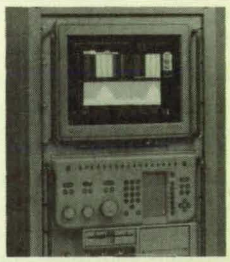
The Voice Connection, Irvine, CA, has developed a **handheld/belt-mounted computer** with built-in voice recognition and speech synthesis capabilities. The standard PTVC 756 computer is readily programmed using an IBM PC and features 128Kb RAM. The battery-operated unit includes a communications port which can be connected directly to a host computer, printer, or external modem.
Circle Reader Action Number 750.



Complex computational problems requiring hours of work on a PC alone can be solved in seconds with the PL800 **Floating Point Array Processor** from Eighteen Eight Laboratories, San Diego, CA. The PL800 provides a peak performance of eight million 32-bit floating point operations per second. The processor's software operates in parallel and yields a total processing power of 64 MFLOPS. Users program the PL800 by calling subroutines in a PC-resident FORTRAN, C, or PASCAL program.
Circle Reader Action Number 748.



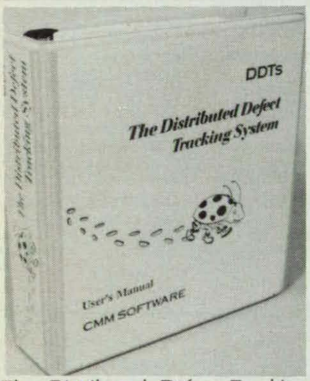
HUB Material Company, Canton, MA, has developed a portable, **handheld oscilloscope** for field service applications. The Model 1010 weighs two pounds and fits easily into a tool kit. Enclosed in a rugged ABS housing, the "mini scope" offers DC to 10 MHz bandwidth, 12 sensitivity ranges, and 21 timebase ranges.
Circle Reader Action Number 770.



The new Tektronix 3052 **Digital Spectrum Analyzer** operates nearly 100 times faster than present spectral analysis methods. The programmable unit features 1024 parallel complex digital filters which provide 800-element spectral signal displays to 10 MHz, with real-time display and analysis to 2 MHz. Applications include communications, signal analysis, radar signal processing, and telephony.
Circle Reader Action Number 766.

New on the Market

The GX-2000 **Graphics Terminal** from Modgraph Inc., Burlington, MA, features a 15 inch flat screen display that combines vector list and pixel replication technologies for high-resolution pan/zoom performance. The DEC-compatible terminal includes a host RS-232/20ma port, RS-232 mouse/tablet/printer port, and VT220-style keyboard. Laser, dot matrix, and inkjet hardcopy interfaces are standard.
Circle Reader Action Number 756.

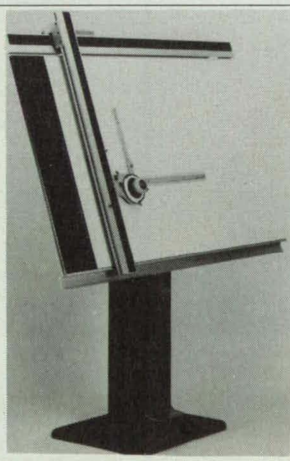


The Distributed Defect Tracking System (DDTs) from CMM Software, Milpitas, CA, records and **reports changes in the status of bugs** in software development programs. Intended for use by project managers and quality assurance managers, the DDTs automates the decision-making process in software development and provides forecasting data for establishing project completion dates. The bug tracking system operates with most UNIX equipment.
Circle Reader Action Number 768.

The Concept 51 **Disk Processing System** from Storage Concepts, Irvine, CA, allows one disk controlling unit to support up to 63 disk drives, thereby significantly reducing the cost per megabyte. The system employs 5¼ inch disk drives and is especially suited for use with mini-supercomputers, imaging computers, and high-speed data acquisition systems. Concept 51 is packaged in a rack-mountable chassis which includes the controller unit, data buffer, system power, and over six gigabytes of disk storage.
Circle Reader Action Number 754.

Alliant Computer Systems Corp., Littleton, MA, has introduced a family of **Visual Supercomputers™** that supports automatic parallel processing of both applications and graphics. Multiple users can work simultaneously on difficult problems, share common databases and color images at high speeds, transfer data files from their VAX™ or Cray™ and produce videotapes for review. The new supercomputers feature a peak applications performance of 377 MFLOPS and a graphics performance of 640 MFLOPS.
Circle Reader Action Number 762.

The VoiceScribe™ 1000 **Speech Recognition System** from Cherry Electrical Products, Waukegan, IL, can recognize 1000 words or phrases with 99.3% accuracy. Vocabulary can be added or edited during an application without exiting the operation. Overlays for spreadsheet, word processing, database, and other application programs can be created using the system's compiler function. The VoiceScribe 1000 package includes software diskettes, an expansion card, a headset microphone, and an instruction manual.
Circle Reader Action Number 752.



The STATOS 5 **drafting table** manufactured by Alphia Inc., Northbrook, IL, is easily adjusted to conform to the individual engineer's needs. The table moves vertically up to $19\frac{5}{8}$ inches and tilts from 0 to 70 degrees. Single pedestal construction and all adjustments can be done while seated.
Circle Reader Action Number 764.

Subject Index

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You have to work with steppers and DC servos. So should your programmable motor controller.

In developing Klinger's MC4 motor control system, our engineers' had the dilemma of choosing between steppers or DC servos, or should they design two systems, one for each type.

Considering the specific application advantages of each motor, we decided the ideal controller should work equally well with both motor types and switching from one motor to the other should be easy and inexpensive.

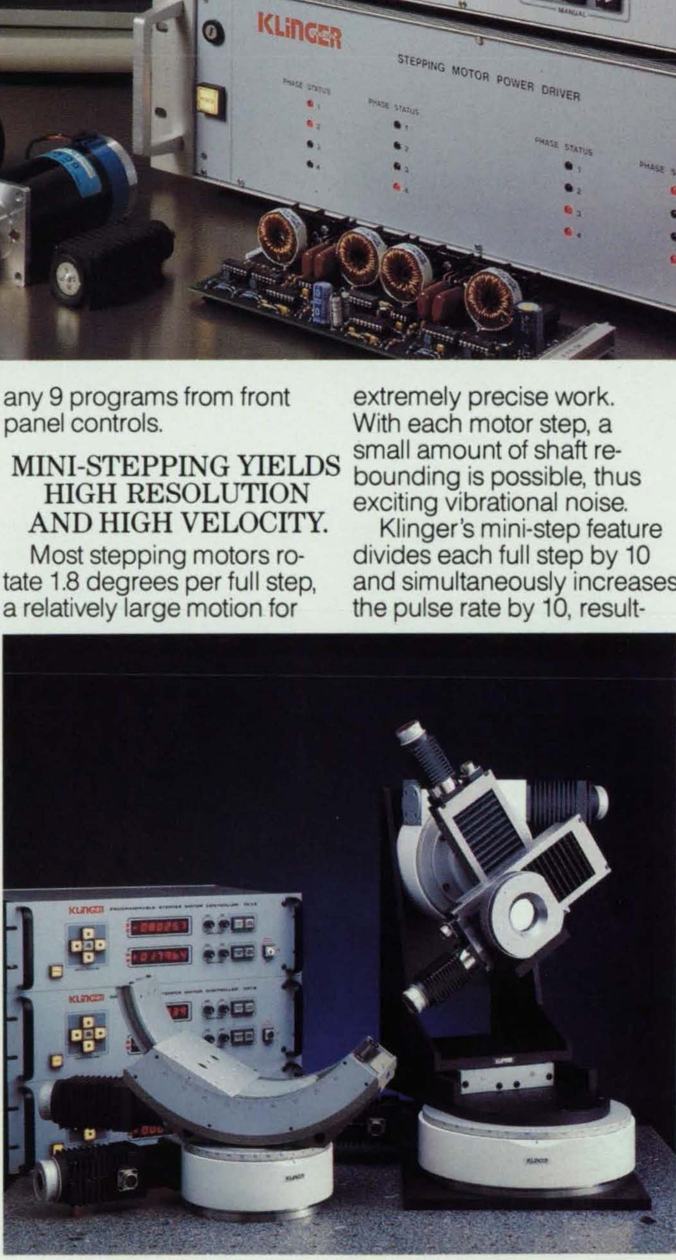
That's precisely what we've accomplished with the MC4 system. Where a simple plug-in power card switches the system between motor types.

The MC4 is a powerful programmable motor control system capable of controlling up to four motors, interfacing with any host computer or, with its 8K of non-volatile memory, it can stand alone to operate on the production floor. You can even store up to 99 programs and locally access any 9 programs from front panel controls.

MINI-STEPPING YIELDS HIGH RESOLUTION AND HIGH VELOCITY.

Most stepping motors rotate 1.8 degrees per full step, a relatively large motion for extremely precise work. With each motor step, a small amount of shaft rebounding is possible, thus exciting vibrational noise.

Klinger's mini-step feature divides each full step by 10 and simultaneously increases the pulse rate by 10, resulting in less shaft rebounding and settling effect, higher resolution without sacrificing speed and virtually eliminating troublesome resonance.



BUY ONE SUPERIOR CONTROLLER. NOT TWO.

You can't buy a better programmable motor controller than the Klinger MC4. And since you only have to buy one for both types of motors, you'll actually save time and money and not have to rewrite extensive software. Just slip in the modular drive card and you're ready to go.

To learn more about Klinger's programmable motor controllers, micropositioners and systems, send for our free micropositioning handbook. Write or call Klinger Scientific Corporation, 999 Stewart Avenue, Garden City, NY 11530. (516) 745-6800.

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