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FRANK PRESS

Frank Press has advised four presidents and has made pioneering contributions in several fields. Recognized internationally for his study of the sea floor and the earth's crust and deep interior, he is a respected contributor in geophysics, oceanography, lunar and planetary sciences, and natural resource exploration.

Dr. Press was graduated from the City College of New York with a degree in physics and received advanced degrees from Columbia University. He joined Columbia's faculty in 1952, and three years later was appointed professor of geophysics at the California Institute of Technology. In 1965 he joined the Massachusetts Institute of Technology, and in 1981 was named Institute Professor at MIT, a title reserved for scholars of special distinction.

In 1977, Dr. Press was appointed President Carter's science advisor and director of the Office of Science and Technology Policy. He had previously served on science advisory committees during the Kennedy and Ford administrations and was appointed by President Nixon to the National Science Board, the policy-making body of the National Science Foundation. He has served as president of the National Academy of Sciences since 1981.

"Science today is a kaleidoscope. New fields are appearing. Traditional fields changing. Boundaries between basic and applied research are blurring. For many fields the interval between a discovery and its commercial use is now measured in years rather than decades. It is a golden age for science and technology. It is an age that is redefining the forces of economic change.

This rapid progress in science and its use yields problems and opportunities. The problems are those of seeing to the health of the scientific enterprise, providing the means for young people to enter science and the support demanded by frontier research. And the problems are also those of the pace of discovery, forcing nations to consider what should be supported. Opportunities include global cooperation, cost sharing for expensive projects, new relationships between industry and universities, and breakthroughs that will lead to new technologies, accelerate economic development, and assure better health and quality of life for people everywhere. These opportunities and problems frame the challenge for science. The Academy is committed to addressing them."

Frank Press
President, National Academy of Sciences

NATIONAL ACADEMY OF SCIENCES
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April 17, 1990

MEMORANDUM

TO: MARK LANGE

FROM: CAROLYN CAWLEY

RE: NATIONAL ACADEMY OF SCIENCES

INTRODUCTION AND ACKNOWLEDGEMENTS:

-- Dr. Press will be introducing POTUS

-- People on the stage (IE:acknowledgements)
Dr. Press
Dr. Bromley > definitely

Officers of the Academy > if Advance & Secret Service deem it OK. Will know Thursday 4/19.

By the end of the week, the Academy will fax us a list of which dignitaries have RSVPed their invitation. (Members of Congress, etc.)

NAT'L ACAD. SCIENCES

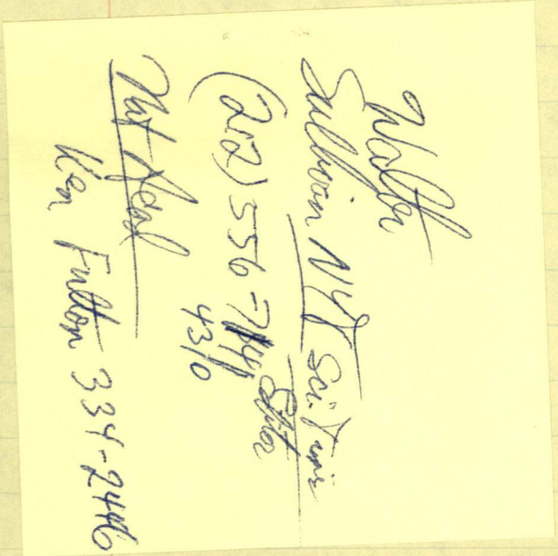
(the news of the day)
Make clear
SSC
SPACE
HUBBLE
R+D INVEST
superconductivity

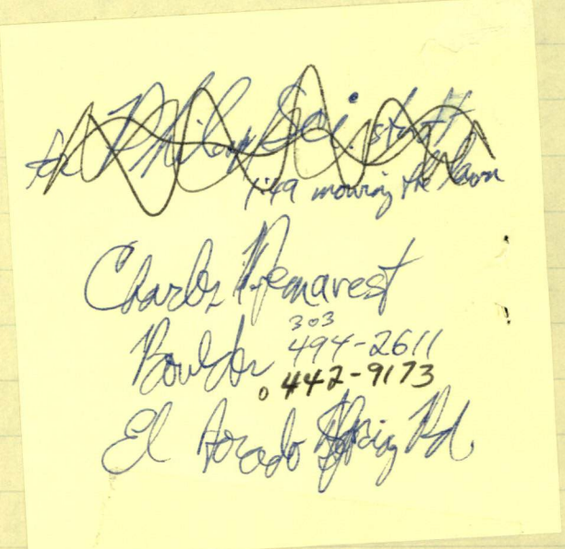
Hubble - 1st pics back - Earmarshave
showed Wall Assy 3 mirrs

(303) 442-9173 Dave Brotter - scientist, lecturer, photographer

DR. HUBBLE was a member
of the National Academy
of Sciences

Also Lyman Spitzer was (is?) a member -





Monday evening, April 9

HUBBLE TELESCOPE

about the size of a school bus...

NBC's Tom Brokaw: Tomorrow morning NASA hopes to launch a satellite that will give us a picture of the heavens that Galileo could not have imagined when he introduced the original telescope almost 400 years ago in 1609. This one is called the Hubble Space Telescope and it is expected to be an epic event in space exploration. The shuttle Discovery is on the launch pad at Kennedy Space Center in Florida tonight, and the telescope, which is the size of a bus, is in the cargo bay ready for liftoff tomorrow morning at 8:47 Eastern time if the weather holds.

NBC's Robert Bazell reports that the space telescope will allow us to see far beyond us, to the limits of the universe. For the first time scientists will be able to observe planets, stars and galaxies from above the atmosphere which limits the view from Earth.

(NBC-Lead, CBS-Lead)

SOVIET ECONOMY/U.S. COMPANIES

ABC's Peter Jennings: We begin tonight with soft drinks and hard liquor, Pepsi and vodka, and ships at sea, $3 billion worth all put together into the largest consumer trade deal ever between the U.S. and the Soviet Union. The Soviets are having to become increasingly creative as they try to keep their economy from wrack and ruin.

ABC's Rick Inderfurth reports from Moscow that under the new agreement Pepsi will more than double its bottling and distribution network in the Soviet Union, meaning more jobs for Soviet workers. It's an example of the opportunities for American business here, but also of the hurdles of dealing with the Soviet economy. Pepsi will continue to take its profits out of the country in vodka. The agreement gives Pepsi the exclusive right to distribute Russian vodka in the U.S. for another 10 years, and to sweeten the deal the Soviets have agreed to build at least 10 commercial ships for Pepsi which the company can sell or lease. This is one bit of good news for a Soviet economy which, according to one of Mikhail Gorbachev's top advisers today, is in desperate need of help. During the first quarter of this year industrial production was down 1.2 percent, partly because of ethnic unrest. Inflation is estimated to be running as high as 17 percent, and the Soviets had their first trade deficit in 14 years, caused largely by a drop in the production of oil for export and increased imports of Western goods. The Soviets want more deals like the one with Pepsi, but President Gorbachev and his advisers say the economy can only be saved by internal reforms -- by a much faster transition to a free-market system.

ABC's Stephen Aug reports that DuPont has been selling agricultural chemicals to the USSR for more than 15 years. But now for the first time it's not getting paid on schedule. And it's not just DuPont that's not getting paid on schedule. Neither are other Western firms that sell grain, textiles, computer equipment. The main reason for the payment problem appears to be the changes in the Soviet economy. Two years ago all foreign trade was controlled by a single ministry. But today that's no longer true. There's no central authority to coordinate the trade and make sure enough hard currencies like the dollar are available to pay for what they buy. All of this is making life difficult, especially for smaller American companies that can't afford to wait very long for payment. And if enough U.S. companies refuse to sell to the Soviet Union, that could put efforts to rebuild the Soviet economy into a stall.

(ABC-Lead, CBS-8)

LITHUANIA

Brokaw: Mikhail Gorbachev continues to tighten the screws on Lithuania tonight. The new Soviet presidential council called for more economic and political sanctions against the rebellious republic, and at the same time Soviet legislators were putting pressure on Gorbachev demanding that Moscow dissolve Lithuania's parliament and impose direct rule. And as the vices tighten in Vilnius and in Moscow, Washington is feeling increasingly uncomfortable as well. The Bush Administration is worried that the Soviet internal pressures could make an arms control agreement more difficult this spring.

NBC's John Cochran: President Bush is finding that Gorbachev's problems in calming down his party's hardliners have also created problems for Bush.

[TV COVERAGE of a Cabinet meeting.]

Today the President told his Cabinet that talks with the Soviet foreign minister last week made some progress on arms control but not as much as hoped. Officials tell NBC News that Secretary Baker suspects the Soviets are in disarray and are having trouble deciding what they want out of arms agreements. On nuclear weapons U.S. officials were disappointed that the Soviets got tougher on cruise missiles. Disagreement too on some conventional, or non-nuclear weapons, especially on which combat aircraft should be included in the cutbacks.

(Baker: "And the proposal that was made to us on aircraft we find unattractive; let me put it that way.")

U.S. intelligence analysts say the Soviet military seems to be reasserting itself and is having second thoughts about the value of arms control. As one Warsaw Pact ally after another rejects communism, the Soviets are re-thinking whether Moscow can afford to give up so much hardware, especially long-range weapons. The Soviet hard-line on arms control also reflects the pressure Gorbachev faces from party conservatives in the Supreme Soviet, which would have to approve an arms treaty. Those are the same conservatives who today demanded that Gorbachev outlaw the Lithuanian independence movement. In Washington the Lithuanian diplomat said his people realize Gorbachev is under great pressure.

(Stasys Lozoraitis: "We are really trying to do everything not to hurt Mr. Gorbachev.")

SSC

Walter Sullivan, cont:

Argument about the big machines

Louis Alvarez (U. Cal Berk, now deceased)

said concentrate on cosmic rays
(less $, higher energy)
- don't always required huge budget

the genome project - - should we try to map out the billions,
or spread $ around, look @ diff L's.
(Barbara McClintock)

James Watson:
Cold Spring Harbor Lab.

Study of the smokers (ocean floor geysers)
ea. dive doesn't cost that much)

chemistry of the oceans

Views against SSC, many in favor.

→ should/could be doing this alone.
Should be more intl collaboration

Victor Weisskopf M.I.T. (retired)
(grand old man of Am. Physics)
was head of CERN

Have lost many to CERN

via
Fanny Griffith
Gov. Cuomo -
I vote on supercollider
that day.
(price going ↑. #8 bil or more)

Charles Demarest

They are mainstream – won't be too receptive to small science

Big Sci – don't want to know in advance what you're going to do how much it'll cost, etc. } "govt. funded research" an oxymoron

Hard in hard

There's room for both Big & small (entrep. won't discover an omega particle in his basement)

Prof. Allyn @ Princeton "Lucky Accidents & the Prepared Mind" (i.e., Penicillin)

The rate of advancement is accel. thru. the medium of the computer / No body looks @ photos now

SSC could neither be operated nor analyzed w/o computers

↳ RECREATING Force @ dawn of univ. in miniature

INFO FLOW & ANALYSIS

genetic – mapping the genome (D.N.A. chain)

– an encyclopedia

If have a disease, can isolate which gene – isolate & locate sections in gene splicing sequence

Info. acquis, assim., analysis

allows accel of scientific advance

computing – a priv. enterp. success story

– small start-ups pooled, pooled memory, storage

pace so fast, & so rapid, Hst since Hubble was left on ground by Challenger

tragedy, the computer on your desk is more powerful than those on HST

Sophisticated

enables us to "see" phenomena we'd otherwise miss, from the diffusion of charge-carriers in a semiconductor to collisions between galaxies

space station freedom - eg. day that station will
gene. enough data to fill the disc. of tape.

P.S RAD may 4/90

INDEPENDENCE

Today many aspects of the economy and the health and well-being of Americans are influenced strongly by the products of science and technology -- a technology that is increasingly far removed from the understanding of most of our citizens.

In these circumstances it is increasingly important that we turn to the National Academy of Sciences UNBIASED for advice on major public-policy issues with a scientific and technical foundation. as a singular source In the past the Academy's advice has been distinguished by its objectivity and its immunity to partisan pressures. Over more than a century and a quarter It is essential that the members of this body -- the most distinguished scientists in America -- preserve that objectivity that has been the Academy's hallmark, and not permit their deliberations to be influenced by pressures and inducements from outside the scientific community. an independent, self-governing institution

also - reaffirm the primacy of basic research, the crucial importance of seeking answers to science's most fundamental questions.

Read either as warning to his admin. or other govt

SUNUNU & DARMAN WILL BE ON BOARD

-1-

4/14/90a

OBJECTIVITY

Educators → Avoiding rhetorical/pseudoscience

→ Show more than ever before objective scientific perspective — issues like global warm, Nuclear power, acid rain, food engineering, food additives

→ using tools at the cost of overreaction is very high. and yet we must not underestimate those risks.

ADDRESS OF
THE PRESIDENT OF THE UNITED STATES
AT THE
ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES
APRIL 25, 1961
Kennedy

The President of the Academy

Mr. President, during the few first months of your Administration, we have been greatly heartened by your many actions and encouraging words in support of our efforts to use science for the furtherance of human welfare. We deeply appreciate your willingness to meet with us this morning, despite the heavy burdens of your office. I know that I can speak for all the members of this Academy, for all the scientists of the country, in the challenging words of your Inaugural Address: We ask not what our country can do for us - we ask what we can do for our country through you.

Ladies and gentlemen, the President of the United States.

The President of the United States

Dr. Bronk, Dr. Wiesner, ladies and gentlemen, I want to express my appreciation for your generous invitation to be here. It has always been a source of interest to me that in the earliest days of the founding of our country there was among some of our founding fathers a most happy relationship, a most happy understanding of the ties which bind science and government together. I am sure that even some of our English friends who may be here today would probably agree that the two most exceptional men of the eighteenth century, both in this country and I think probably in western Europe, would have been Benjamin Franklin and Thomas Jefferson, both leading political figures of their time, both scientists, social as well as natural.

JFK - 1961

This Academy was founded in the administration of another President, who, though not a scientist himself, did understand the intimate ties which must exist between science and government. This Academy is, I think, now about a hundred years old. I don't suppose there has ever been a time, even during the days of World War II, when the relationship between science and government must be more intimate. Nearly every question which we approach, those of us who hold political office, has scientific overtones.

We are a free society in this country. Therefore all of you are able to pursue your own private interests, but it is a fact that the members of this Academy have also recognized, probably as much as, if not more than, any other group in our society, their obligations to society, to the public interest. And therefore, though all of you either teach or work in private industry, some of you in government, all of you have been willing to give your time and your talent to the service of society as a whole.

We are on the threshold of a good many new frontiers. The work which some of you have done in oceanography, the work which we hope we can carry through to fruition in the next months and years on desalinization, the work under Dr. Bronk which you have recently undertaken on an analysis of our natural resources, the work which we must try to undertake on the problems of our urban society - all these problems are political problems, are social problems, are scientific problems. And therefore, as President of the United States, I would like to emphasize again the message which all of you have heard in other days: We need your help. This country must move forward.

INDEPENDENCE - KENNEDY

Most of the areas where we move forward involve most sophisticated problems, which your experience and training can help us to solve. One of the problems, it seems to me, of a free society is the fact that all of the questions which we must decide now are extremely sophisticated questions. It is difficult enough for those who hold office, either in the Administration or in the Congress, to attempt to make a determination between alternate courses of action, fiscal policy, monetary policy, agricultural policy, international policy, disarmament, arms control, all the rest. All of these involve questions to confound the experts. For those of us who are not expert and yet must be called upon to make decisions which involve the security of our country, which involve the expenditure of hundreds of millions, of billions of dollars, we must turn in the last resort to objective, disinterested scientists, who bring a strong sense of public responsibility and public obligation.

So this Academy is most important. Speaking personally as President, I am called upon to make decisions, for example, in the field of space which involve many billions of dollars, where men are committed to one program or another. This Academy serves as a great natural resource, then, where those of us who are called upon to make these decisions can turn to you, ask your view, ask your advice. You are motivated by a desire to see the public interest expanded. It is the same desire that we have. Therefore, I think that in the long history of this Academy, stretching back over a hundred years, never during that time has there been a greater need for understanding and support by the Government, the scientific community, and by the public at large. So I was anxious to

come here today to express my appreciation to you, to ask your help in the days and months to come, because I think together we can build a stronger society here in this country.

SCIENCE

~~Phys. evol~~ - milieu

mankind's intellectual evolution

- last century

our place in the universe (ft. Copernicus, Galileo

- the more we know, the more humble we are.

so fast in terms of pace of univ.

~~((what is this big explosion - no race~~

~~what is the significance of that))~~

the Univ. began rapidly

(snapshots -- .01 second, plasma

.05 second, particles @ x mil a/hr)

and slowed down.

while the speed of light may be fixed,

the speed of development is accel. in latter part of this C.

cf. Brower (make

positive

Mankind's intellectual evol. began slowly

and has since begun

∴ Mankind's (big bang intellectual has happened in last ten years

- A CHAIN REACTION based in gray matter, that has effect of

both (heat and light.

Hubble - ~~staring~~ gazing back to the birth of time

from a one dimensional

PRESIDENTIAL DOCUMENTS

Week Ending Friday, April 27, 1979

National Academy of Sciences

Remarks at the Academy's Annual Meeting. April 23, 1979

President Handler, distinguished members of the National Academy of Sciences, guests who are equally distinguished in your own field of work:

I'm indeed pleased to be here. I know that election to the National Academy is the highest honor that can be paid to a scientist or an engineer in the United States, and I again congratulate all of you.

I understand that in the Soviet Union, when someone is chosen to their National Academy of Sciences, his or her salary immediately doubles—[*laughter*]—and a chauffered car is made available for use. I understand there's a slight difference in our own country. [*Laughter*] You immediately get a bill for membership dues, and you are pledged voluntarily to give advice to your Government free of charge. [*Laughter*] And I thank you for that.

I am honored to address this distinguished convocation and to join with you in commemorating the 100th anniversary year of the birth of Albert Einstein.

The National Academy of Sciences was already a thriving institution when Albert Einstein was born. In 1942, soon after taking out American citizenship, Dr. Einstein was elected to this Academy, becoming at once its newest and, perhaps, its most eminent member. His coming to our country was a matter of carefully considered choice. In this respect, he was like many thousands of scientists from all over the world—drawn to this country by an atmosphere of intellectual freedom, adventure, and hospitality for the pursuit of scientific truth.

That atmosphere has invigorated American life from our Nation's beginnings. Scientists-statesmen such as Benjamin Franklin and Thomas Jefferson were among the authors of our own national independence. Their influence helped to establish the young American republic as a place where scientific endeavor was not only encouraged but was honored.

We've never deviated from that commitment. And it's significant, I believe, that the Congress and President Lincoln chartered this National Academy of Sciences at the height of our gravest national crisis. In so doing, they demonstrated a deep understanding of the importance of science to the very survival of our Nation.

There is little that we can predict with certainty. But we can be very sure that whatever the future holds, we will be better prepared for it if we pursue a strong national program of support for science and technology. That's why even in this time of budgetary restraint, I have remained firmly committed to such a program.

Scientific enterprise will be a key to our future strength, but we in this room cannot take this for granted. In this cen-

tennial year, it's well to remember that faith in the future was a notable quality of Albert Einstein. Only an optimist could have undertaken the incredibly ambitious task that Dr. Einstein set for himself—the discovery and the explication of the underlying order of our universe.

Throughout his life, Dr. Einstein sought not only to discover order in the natural world, but also to promote order in the human world.

Einstein the humanitarian has much to teach us, as does Einstein the physicist. He saw the pursuit of science as good in itself, but he also saw that the uses of science are only as good—or as bad—as the moral and political choices that determine those uses. In his own words, and I quote, "Concern for man himself and his fate must always form the chief interest of all technical endeavors—in order that the creation of our minds shall be a blessing and not a curse."

The tree of science is always beautiful, but its fruits can be bitter as well as sweet. Our task is to nourish the tree of science and to attempt as best we can to harvest the fruits that are sweet. And that task must be shared by all of us—scientists, engineers, industrial leaders, educators, and public officials alike.

I hope that science and technology in the United States will continue to be shaped by Einstein's vision of knowledge that keeps the good of human beings always at the forefront.

It's in that context that I want to share with you briefly some ideas and observations about basic research, about a strategy for energy technology, about industrial innovation, about scientific cooperation among nations, and about the role of science in helping to control its own most fearsome offspring—nuclear weapons. I'll be very brief.

The last President to address a convocation of the National Academy of Sciences, John F. Kennedy, spoke of basic research in these words: "We realize now," he said, "that progress in technology depends on progress in theory; that the most abstract investigations can lead to the most concrete results; and that the vitality of a scientific community springs from its passion to answer science's most fundamental questions."

One month to the day after President Kennedy spoke those words, he was stricken down by an assassin's bullet. And then began a long period of political trauma in our country. But in many ways, those following years were exciting ones in science and technology—years of breakthrough discoveries in molecular biology, particle physics, and many other fields, and of technological progress epitomized by the triumphant landing of men on the Moon. Yet for scientists, as for so many of the rest of us in politics and other fields, they were also difficult years. American science found itself beleaguered by two very different kinds of anti-intellectualism: on the one hand, by the romantic antirationalism of the counterculture and, on the other, by the veiled hostility of a national administration that distrusted the academic and the scientific community.

The latter presented the most serious threat. Federal policy toward science became infected with a simplistic search for a simple fix. Research that seemed to promise a quick payoff was more amply funded, while support of basic research was allowed to decline. The future of our scientific and technological primacy was put at risk.

I came to office determined to reverse that dangerous, shortsighted trend. And today I reaffirm to you my commitment to basic research, the bedrock of our scientific and technological future.

During the 2 years of my own administration, I've proposed increases already of more than 25 percent in Federal funding of basic research. I've asked the Congress to support this increased funding in order to meet the long-term needs of our Nation.

I've also sought to strengthen basic research in the individual Federal agencies. Each agency has been asked to reexamine its own budget request to see how basic research commitments could be strengthened. And we've tried to resolve nonbudgetary problems that have inhibited research in our universities—problems of unnecessary Government regulation and excessive bureaucratic papershuffling.

Economists estimate that advances in knowledge have accounted for three quarters of our own country's economic growth in this century. By itself, that is a decisive reason for us to support the basic research that undergirds our technological might. But the value of basic research is even higher and deeper than meeting payrolls and spawning new industries; the fundamental concern of basic research is the discovery of truth about the natural universe. The search for truth is a central part of what it means to be human.

No issue illuminates our Nation's practical need for science and technology more than the energy problem.

Oil remains by far the most important energy source, and we are in the painful situation of relying on a greedy and unreliable foreign cartel for nearly half the oil we use in this country. As that onrushing river of foreign oil flows into our country, a river of American money flows out, threatening the health of our economy, the stability of our currency, and even the security of our Nation.

Science and technology can change that, but only if we commit ourselves to a national strategy of developing energy alternatives. We have such a strategy—one that will enable us to move away from imported oil and increasingly move toward nonfossil fuels—and I'm determined that we will pursue it.

Over the next decade or so, we must rely mostly on existing technologies, but we will pave the way for future progress by fostering conservation, domestic production of oil and gas, greater use of coal, the safety of nuclear plants, and the use of solar power.

From about 1990 through the second decade of the next century, we will pass through a dramatic and sometimes bumpy period of transition. Conservation will be forced upon us, and the mix of our energy resources will change as we turn increasingly toward unconventional sources of fuel.

By the second quarter of the 21st century, we will have learned to rely on cleaner, essentially inexhaustible sources of energy. The principal candidates include, of course, fusion and such solar technologies as photovoltaics.

We are preparing right now for these stages of our energy future. Our energy research and development is already larger in its program size than those of all our allies combined. But we must do more. That's why I have proposed the creation of an energy security fund to supplement our normal budget mechanisms. The revenues for this fund will come from a windfall tax on the unearned, excess profits that would otherwise go to the oil companies because of the decontrol of oil prices—over and above needed incentives for exploration and production within our country.

The energy security fund will provide relief to those least able to pay for more costly energy, and large sums will go to finance projects that are important to our energy future, including a regional petro-

leum reserve, better mass transit, coal and oil shale development, new incentives for solar techniques, and other basic and applied research projects with which many of you are already intimately acquainted.

The energy security fund faces a difficult passage through Congress, but we are making progress because the public supports our proposals. Many of those who only a few weeks ago were dedicated to killing outright the windfall profits tax have now given up on that fight. But the battle is far from over. New strategy seems to be to try to hoodwink the American people by passing a windfall profits tax that is in fact a charade—a tax designed primarily to provide loopholes to the oil companies so that they will get another $4 or $5 billion, in addition to the $6 billion in increased revenue that they would get under decontrol with an honest windfall profits tax proposal passed.

They will try to pass this charade off on the American people as a so-called plowback provision. But it isn't a plowback; it is a plowunder and a kickback, and what is going to be plowed under is the energy security fund with its aid to research and its aid to the poor. And what's going to be kicked back to the oil companies is the money that would go to finance these absolutely necessary programs for the well-being of the future of our country.

I ask for your support in the battle to pass an honest windfall profits tax to finance a real energy security fund for our Nation, in consonance with the program that will give greatly increased incentive and greatly increased profits for the oil companies to explore and to discover and to produce additional sources of domestic oil and natural gas.

And I also call on all of you in the scientific and engineering communities to fulfill the trust of the American people by creating the new energy technologies that are so vital to the future well-being of our country.

We need innovation on a broader scale as well, for new ideas in America are central not only to reducing our dependence on foreign oil but also on our efforts to control inflation, to improve productivity of our workers, to protect the environment, and to ensure the prosperity of the American people.

We tend to think of the inventiveness of American industry as a kind of inevitable birthright, but complacency is the last thing we can afford. Too many of our industries in this country have gone stale. Innovative industries in countries like Japan and West Germany put too many of ours to shame. Our competitiveness has begun to slip.

The American free enterprise system has always been vigorous enough and able enough and dedicated enough and well-supported enough to prevail. I have no doubt that it still retains those capabilities.

We must nurture an environment in which the new idea and the fresh approach are put to use. The Federal Government bears a large share of this responsibility. We must change government practices that thwart innovation, while enhancing government policies which encourage the development of new products and new processes.

Last year, I directed the Secretary of Commerce to begin a major study of industrial innovation. That study, involving some 30 Federal departments and agencies and consultations with industry, labor, and the universities and the public, will soon be completed. I look forward to reviewing the recommendations and to acting on them, hopefully with your help.

Many of you in this room today are leaders of American business and industry, and I call on you to emphasize innovation

in the companies which you serve. Like Federal support of basic research, industrial development and investment in research, both basic and applied, in new products and new processes, is a practical testament of faith in our own future.

Since Kepler's day and before, scientists have been perhaps the most international of all professions in their outlook. In our own time, the explosion of communications and technology has made international scientific communication both easier and more urgent than ever before.

Albert Einstein himself operated on what even then was a very modest budget. He needed little more than a few sharpened pencils and a quiet place to think. But as you know, the task of building upon his work can be much more expensive. Many of the key experiments yet to be done—in both basic and applied technology—are on a monumental scale.

Our choice in the years ahead will be between carrying out the few large projects we can afford on our own, as Americans—or by doing many more projects, perhaps even more effectively, in cooperation with other nations. We must continue to choose cooperation—for reasons that go beyond the considerable benefits of sharing the costs and sharing ideas.

With our traditional friends, scientific and technological cooperation can strengthen existing bonds. With others, who may not be quite so friendly, it can help to bridge political and ideological and cultural divisions.

One of the most important purposes of international cooperation in technology and science is to meet the developing needs of the poorer countries of the world.

The future of the advanced countries is increasingly tied up with that of the developing world. Yet, only about 1 percent of the world's civilian research and development is devoted directly to the problems of the poorer half of humanity—problems such as poverty, disease, hunger, education, and resource development. We should be doing more.

A year ago, I proposed the creation of a new Institute for Scientific and Technological Cooperation to mobilize the talents of scientists and engineers in this country and in the developing world to address these critical problems. Instead of providing relief, we would aid the Third World in building its own corps of development scientists and decisionmakers. And we would join them in mutually beneficial projects in agriculture, medicine, industrialization, and appropriate energy systems.

The Institute for Scientific and Technological Cooperation has been approved already by the House of Representatives and is now before the Senate for consideration. It needs your full support.

Let me turn now to the use and exploration in space where, as on Earth, our purpose is human betterment—material, intellectual, and spiritual.

In the coming era, we will reap a good return on the more than $100 billion the United States has invested in space. From platforms in space, we can indeed continue to improve our world. Every year, satellites make new contributions in such areas as agriculture, environmental monitoring, land use, resource discovery, climatology, and communications.

With the advent of the space shuttle, we will have an unmatchable ability to work in space. We will see a flowering of research and industrial activities in space, and we will make quantum jumps in international cooperation, advancing the causes of peace and human development.

Mankind's leap into space has changed human consciousness forever. The era of manned exploration of deep space is still well in the future, but our senses are al-

ready penetrating the outer reaches of the solar system and beyond. No one who has seen those breathtaking pictures of Jupiter and its moons sent back from Voyager I could fail to have been surprised and delighted by them. We can expect many more such surprises, many more such delights, as we probe further into the universe and its mysteries.

And finally, let me say that of all the fruits of science, none is more bitter than nuclear weapons. And of all the responsibilities of nations, none is more urgent than the control of this most terrible menace to our lives and to our civilization.

All of us are thankful that the recent accident at Three Mile Island in Pennsylvania ended without harm to the public. That accident may even have served some positive purpose. It has, of course, led us to redouble our determination to improve the safety of nuclear power. Even more importantly, however, it has reminded us vividly of the dreadful consequences of nuclear war.

We have lived too long with nuclear weapons. We've grown too accustomed to their shadowy presence in our lives. We are too apt to forget what the ultimate horror would be: the instant death of millions and the slow and agonizing death of many millions more; the destruction of the cultural legacy of all mankind; the poisoning of air and soil and water for many dark generations to come. In an all-out nuclear exchange, the victim would be nothing less than the past, present, and future of our own human species.

When President Kennedy addressed this body 16 years ago, the Senate had just ratified the most significant step in nuclear arms control until that time—the atmospheric test ban treaty. The SALT II treaty, now nearing completion, is part of the same process—a long, slow progress of gradual steps toward sanity, based on mutual self-interest. And after SALT II, that process will continue with a comprehensive nuclear test ban and then with SALT III.

SALT II will reduce the risk of nuclear war by lowering levels of strategic arms, by containing development of new weapons systems, and by contributing to a more stable political interrelationship between ourselves and the people of the Soviet Union.

Many of the issues involved in assessing the treaty are very complex technically, and the American people will look to the scientific community to help shape an educated public debate. Many of you devoted much effort to the debate over SALT I, and you played a major role in forming the consensus that developed to support that treaty. Today, I ask for a renewal of that commitment.

If science gave us nuclear weapons, it's no less true that science has given us the extraordinary means of verifying compliance with treaties to control those weapons. In the great SALT II debate, which has already begun, the participation of scientists will indeed be crucial.

Albert Einstein also said these words, "The importance of securing international peace was recognized by the really great men of former generations. But the technical advances of our times have turned this ethical postulate into a matter of life and death for civilized mankind today, and made it a moral duty to take an active part in the solution of the problems of peace, a duty which no conscientious law [man] can shirk."

These words were more prophetic than anyone could know, for they were spoken more than a decade before the explosion of the first atomic bomb. Those words are important. I urge you to heed them as we conclude SALT II, the next step towards

nuclear arms control and
more sure worldwide pea

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Thank you very muc

NOTE: The President spok
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United States Arm
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***Message to the Congress
Report. April 23, 1979***

To the Congress of t

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nuclear arms control and a stronger and more sure worldwide peace.

Americans once had an unquestioned faith in science as a savior. We've grown more skeptical of science, as of so much else in our lives. But we still look to our scientists and to our engineers, our medical researchers and to our doctors, to our inventors and to our thinkers, to improve our lives and to improve the lives of our children.

My concern for the state of American science and technology has made our present efforts a keystone in building a new and a more solid foundation for our common future. I look to the members of this Academy, to the entire scientific and engineering community, to the Members of the Congress, and to the people of our country, to join these efforts through science for a greater America.

Thank you very much.

NOTE: The President spoke at 2:32 p.m. in the auditorium of the National Academy of Sciences building. Philip Handler is president of the Academy.

United States Arms Control and Disarmament Agency

Message to the Congress Transmitting a Report. April 23, 1979

To the Congress of the United States:

There is no more important responsibility for me as President than ensuring the safety and security of our nation. Like Presidents before me, I am meeting this responsibility: (1) by maintaining sufficient military forces to protect ourselves and our Allies; and (2) by seeking equitable and verifiable arms control measures to reduce the risk of war. The attached report is a summary of the actions taken through the U.S. Arms Control and Disarmament Agency in 1978 toward this latter goal.

The SALT process, which has been carried forward by four Administrations since 1967, is the most fundamental of our arms control efforts. A SALT II agreement to limit strategic offensive weapons will serve as the linchpin of all of our other arms control efforts, including: SALT III, where we hope to achieve further strategic arms limitations; a ban on tests of nuclear explosives; mutual and balanced force reductions in Europe; limitations on antisatellite capabilities, chemical weaponry, and conventional arms transfers; and prevention of nuclear weapons proliferation.

To prevent war—and to redirect the resources of nations from arsenals of war to human needs—will be a formidable challenge to all mankind in this last quarter of the 20th Century. It is a challenge that I am determined to meet.

JIMMY CARTER

The White House,
April 23, 1979.

NOTE: The 151-page report is entitled "Annual Report 1978, U.S. Arms Control and Disarmament Agency."

The text of the message was released on April 24.

Meeting With President Aristides Royo of Panama

Announcement of President Royo's Forthcoming Visit. April 24, 1979

President Carter will meet with the President of the Republic of Panama, Dr. Aristides Royo, in Washington on May 10.

The President extended an invitation to President Royo on April 9 to meet in an informal working session to discuss the progress both countries have made in

April 6, 1990

MEMORANDUM

TO: Mark Lange

FROM: Carolyn Cawley

RE: National Academy of Sciences Speech

I spoke with Dr. Fulton, VP of the Academy and he was very helpful. Here is some basic material...I am going over to the Academy on Monday to get more information on their organization, the history of the building and a timeline of advances in science.

Event: The National Academy of Sciences Annual Meeting
April 22 - 25 (POTUS speaks on the 23rd at 2:00)
There will be 3 sessions open to the public, POTUS will be speaking at the first one:

1. Monday p.m.: University Reform
2. Tuesday p.m.: Topics of Current Interest
3. Wednesday p.m.: Voyager Missions

--The Academy was founded in 1863 and Chartered by Congress then, under Lincoln.

--POTUS was there recently, to meet the teenage winners of the Westinghouse Science Talent Award Winners. This event was in the same auditorium.

--POTUS is friends with Dr. Frank Press, President of the Academy. In fact, they received honorary degrees from Ohio State (TBD) at the same time.

--Past Presidents to have addressed the Academy:
Coolidge (dedication of the current building)
Kennedy (1963-at its centennial)
Carter
Bush

--The forum for this event is the annual statutory meeting of members of the Academy. It is mandated in its constitution. (Source for humor??)

--They expect slightly under 600 attendees, though this may change if they have to remove seats for the press platform.

--Dr. Press and Dr. Bromley have arranged this conference and for POTUS to speak. Dr. Press will probably be introducing POTUS.
Also, they'll let us know about acknowledgements.

April 9, 1990

MEMORANDUM

TO: MARK LANGE

FROM: CAROLYN CAWLEY

RE: NATIONAL ACADEMY OF SCIENCES SPEECH

HISTORY

--"A national focus of science and research..." was what George Ellery Hale, a distinguished scientist and officer of the Academy described as his hopes for the Academy.

--The NAS was chartered by Congress in 1863 (under President Lincoln) as an honorific society. Today, membership is an esteemed and prominent honor as it is considered second only to the Nobel Prize.

1600 scientists, in all disciplines, are currently members and each year, only 60 more are elected into membership.

--Motto inscribed in the dome of the Great Hall:

"To science, pilot of industry, conqueror of disease, multiplier of the harvest, explorer of the universe, revealer of nature's law, eternal guide to truth."
(George Ellery Hale)

--The institution has succeeded in enlisting the finest American scientific minds of the century in fulfilling is mandate to "advise the government on science and art" (nowadays the latter is known as technology).

The Academy complex --the National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and the National Research Council -- is unique among the world's science academies in the broad scope of services it renders to our nation's Executive Branch and to the Congress.

--The Academy resided for its first 50 years at the Smithsonian but it was obvious that "American science needed a home". The need became especially urgent at the time of WWI.

The building was chartered on April 28, 1924 ("66 years ago, this week") and was called "a temple dedicated to science". The dedication took place during <u>that</u> year's annual meeting.

--The Public Health Service, the Federal Reserve, and the National Academy of Sciences were all located near each other back then and tour guides referred to the area as "Healthy, Wealthy, and Wise." In 1974, (16 years ago) the Academy building was selected for inclusion on the National Register of Historic Places.

--There are hundreds of varieties of trees, shrubs, and flowers on the Academy's grounds. In fact, this Annual Meeting will kick off with a huge garden party. New plantings are frequently added, and they will be planting trees for Earth Day (the day before POTUS speaks)

--An elaborate cornice runs the length of the building and below it a frieze bears a quotation in Greek from Aristotle. Translated it reads:

> **The search for Truth is in one way hard and in another easy. For it is evident that no one can master it fully nor miss it wholly. But each adds a little to our knowledge of Nature, and from all the facts assembled there arises a certain grandeur.**
>
> from Metaphysics

--Six large bronze panels fill the space between the first and second floor windows. The panels depict the progress of science from Greek to modern times by portraying a succession of the great founders, each accompanied by a symbol of his field of work:

Falton, Gibbs, Darwin, Lyell, Dalton, Lamarch, Watt, Franklin, Galileo, da Vinci, Euclid, Thales, Hippocrates, Aristotle, Archimedes, Copernicus, Descartes, Newton, Linneaus, Cuvier, Pasteur, Mendel...

--The auditorium: (Where POTUS is speaking) is astoundingly modern, compared to the architecture of the rest of the building. Music critics have praised it as "Acoustically stunning". Private concerts are held here weekly, as well as during the annual meeting.

--Einstein statue:

Situated in an elm and holly grove in the southwest grove of the grounds.

Unveiled in 1979 in honor of the centennial of the great scientists birth

The artist, Robert Berks, went to Einstein's home and sculpted ol' Tom from life. In his left hand is a paper with mathematical equations summarizing three of Einstein's most scientific contributions: the photoelectric effect
the theory of general relativity
the equivalence of energy and matter

Three quotations from Einstein are engraved on the bench on which he sits:

As long as I have any choice in the matter, I shall live only in a country where civil liberty, tolerance, and equality of all citizens before the law prevail.

Joy and amazement at the beauty and grandeur of this world of which man can just form a faint notion

The right to search for truth implies also a duty; one must not conceal any part of what one has recognized to be true.

--The Academy is involved in MANY facets:

- International affairs
  - security and arms control
- Education
- Industry
- Agriculture
  - biotechnology
- Environment
  - biodiversity
  - acid rain
- Social and community issues
- Health
  - health care
  - infant mortality
  - AIDS

NATIONAL ACADEMY OF SCIENCES

- Monday - April 23; 2:00
  in the auditorium
- approx. 600 attendees
- probably introduced by Frank Press (Academy President)
  ... TBD, could be Bromley
-

--POTUS was recently at the Academy for the 1990 Westinghouse Science Talent Search for high school students.
Might be nice to mention this...an example of how the Academy helps science by encouraging young people

- also recently presented the Draper Engineering award from the National Academy of Engineering (sister of Nt'l Academy of Sciences)

- moving atoms ⇒ "IBM"
- Hubble telescope
- supercolliders

- history of bldg
- luminaries/Nobel winners
- Einstein

ASTRON

:463361

298-8686
Mida Brown
Saturday

Man's place and man's potential
↳ in the cosmos.

Bob Sea starting

Science — conscience

consciousness

4/15 JASTROW 298-8686

((We have been witn. in last years the corruption of the community by pol. force that are using science to further agendas (sometimes they agree w/pols.)

Acad. stricken in this regard
↳ been accustomed to its objectivity.
(Acad 1960's Pres. + Jastrow drafted graphs...)

Summers & Harman will be allies

Acad's imprimatur was on publ. TV film of global warming apocalyptics (Jim Hansen)

NO REVIEW

Natl Research Council (recently) came out w/ report on
↳ NRC - agent of the establishment - just put out a puff piece

(linked to Acad. to do studies on request)

NASA's EOS system and observing

Big ticket boondoggle

(the big ticket item in Mission to Planet Earth)
2 satellites - dev. tech. ea. (more than $10B)

$30 bil.

massive data processing challenge - people in military

on line @ end of decade (i.e., w/ NASA's own sched., info 21st C)

— By then values in global warming

— we should do something sooner, cheaper.

Is there an Assn (or society) of
independent scientists

~~Brent Cantrell, PhD~~

Dr Jeanette

INTRO

Thank you, Dr. Brandy / Dr. Press.

!*! Annual meeting mandated by the Constit. of the Acad.

!*! Pres. of Acad., Dr. Frank Press
specialty is study of plate tectonics earth most.
"I say ah."
1986 - Pr & ASTRUS @ same time Received Hon. Doctorates
from Ohio State U.
(V.P. offered Press role Jack on AF II)

private conversation?

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1ST STORY of Level 1 printed in FULL format.

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January, 1990

SECTION: Vol. 262; No. 1; Pg. 116

LENGTH: 4877 words

HEADLINE: Stress in the wild

BYLINE: Sapolsky, Robert M.

BODY:

Stress in the Wild

The year was 1936. Hans Selye, a young physician just starting off in research at McGill University in Montreal, had a major problem. He had been injecting rats daily with a chemical extract to determine the extract's effects and had identified consistent changes in the animals: peptic ulcers, atrophy of immune-system tissues and enlargement of the adrenal glands. To his surprise, however, the rats in the control group, which had been injected with saline solution alone, showed identical changes.

Most scientists would have thrown up their hands at this paradox. Instead Selye focused on what the two groups had in common: the repeated injections. He wondered if the trio of changes he had identified was actually a generalized physiological response to unpleasantness per se.

He then tested that idea and found the same three effects regardless of whether rats were made too hot or too cold or were exposed to pathogens, toxins or loud noises. Selye borrowed a term from engineering to describe the body's nonspecific response to an insult. What the rats were undergoing, he decided, was stress. Thus, the field of stress physiology was born.

Since 1936 important details have been added to Selye's initial characterization of the stress response, which is now known to involve the secretion of perhaps a dozen hormones and the inhibition of various others. Many studies have also demonstrated that chronic acctivation of the stress response can impair health. Moreover, some people seem to be more vulnerable to stress-related disorders than others. What accounts for the difference in susceptibility? Is it simply that some people are exposed to more stress in their daily lives, or do people actually differ in how their bodies respond to stress?

I am approaching these questions in an unusual way--by studying stress in free-ranging baboons. My ongoing research program has added strong support to a growing body of work suggesting that people's psychological and social characteristics (for example, their emotional makeup, personality and position in society) can profoundly influence their physiological response to stress.

Although chronic activation of the stress response can be harmful, few individuals could live for very long if their bodies were unable to invoke it. In fact, the stress response enables an organism to withstand immediate threats to its homeostatic balance, or physiological equilibrium. The response can be

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triggered by an actual insult (a physical stressor), such as extreme cold or the attack of a predator, or by the mere expectation (a psychological stressor) that an insult is about to be delivered.

In essence, the stress response prepares the body for "fight or flight." Glucose, the body's primary source of energy, is mobilized from storage sites. Blood, which transports glucose and oxygen, is diverted from organs that are not essential for physical exertion, such as the skin and intestines, and is delivered quickly to organs that are crucial--namely, the heart, the skeletal muscles and the brain. The shift in blood flow is accomplished in part by constricting some blood vessels, dilating others and increasing the heart rate. Meanwhile cognition is sharpened (perhaps to facilitate the processing of information), and the perception of pain is blunted. And physiological activities that are not of immediate benefit are deferred; hence, growth, reproduction, inflammation and digestion--all of which are expensive, optimistic processes--are inhibited.

Chronic activation of the stress response can damage health by various means. If glucose is constantly mobilized instead of being stored, then healthy tissues atrophy, and fatigue sets in. With enough time, the cardiovascular changes promote hypertension, which in turn can damage the heart, the blood vessels and the kidneys. Moreover, when constructive processes are deferred indefinitely, the body pays a price in the form of impaired growth and tissue repair, reduced fertility and, as Selye's results suggested, diminished immune function and increased susceptibility to peptic ulcers.

As new links between stress and disease emerge, it sometimes seems miraculous that anyone can function in the modern world without being incapacitated by stress. Still, most people do just fine. The question of why this is the case has been addressed from several perspectives. Some investigators study the effects of stress on human beings directly. For example, people who have classic, hard-driving, Type A personalities have been found to be at increased risk for hypertension and heart disease. Yet the physiological events translating personality traits into diseases that take years to develop are difficult to trace in human beings, who, after all, have complex emotional lives and cannot be caged in laboratories for controlled, long-term study.

Taking a different approach, some investigators study such subjects as laboratory rats. For instance, in the 1960's Jay M. Weiss, then at Rockefeller University, showed that a sense of control or predictability can strongly influence an animal's physiology. For example, rats who receive a warning before they are exposed to an electric shock have a lesser stress response and less pathology in comparison with subjects who receive the same sequence of shocks but without warning. Yet the psychology of human beings is (hopefully) more complicated than that of rats, and so the subtlety of the psychological variables that can be studied in such animals is limited.

Captive primates are a reasonable alternative to both human and rodent subjects, but captivity, which is stressful in itself, can distort an animal's behavior and baseline measures of physiological functioning. Thus, it may compromise the applicability of any findings to non-captive populations.

I have tried to circumvent some of the problems associated with captivity by studying olive baboons (Papio Anubis) living freely in the Masai Mara National Reserve in Kenya. These intelligent animals are good stand-ins for human

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subjects in part because their primary sources of stress, like those of humans in modern society, are psychological rather than physical. Food is plentiful; the baboons spend only a few hours each day feeding. Predators are few, and infant mortality is low. With the luxury of plentiful resources and free time, the animals can devote themselves to distressing one another.

I study the males, who are quite adept at that activity. Violence itself is actually rare, but the hint of violence is ever present. Consider what can happen to a suitor who forms an association with a female in "heat," staying close during the courtship period to prevent other males from taking his place. Often a rival male will shadow the couple for days, thereby disrupting the mating attempts of the initial suitor. The interloper may never formally provoke a fight but will inexorably maintain pressure on the courting male. It is not uncommon for these chess matches to result in surrender by the exhausted first suitor.

In other competitive situations, one male might form a coalition with a second male against a third. If these partnerships are stable, they can be quite successful. Long-term stability is rare, however. After spending hours establishing a coalition, a baboon may find himself abandoned in the middle of a fight or, worse, double-teamed, as his erstwhile colleague opportunistically switches sides.

Some animals are victimized more than others. The males form dominance hierarchies, and the lives of the animals who occupy the most subordinate positions are filled with a stressful lack of both control and predictability. Dominant males have easier access to food, to safe resting places and to shady spots at midday. They often have easier access to sexual partners and will be groomed more readily by other baboons. In contrast, subordinate males may laboriously dig tubers from the ground only to have the food nonchalantly seized by dominant males. Dominant males who lose a fight often seek a subordinate on whom to vent frustration, and they are likely to displace aggression onto the innocent bystander without warning.

Thus, the olive baboons occupy a social landscape of Machiavellian dimensions. Alliances shift unpredictably; threats range from days of harassment to sudden bursts of violence, and a baboon bent on avoiding the turmoil may still fall victim to another animal's problem.

When I began studying the olive baboons in 1978, one of my first tasks was to determine whether two baboons exposed to an identical stressor can in fact have different physiological responses. When I considered that a male's rank profoundly influences what he does in a day and how he is treated by others, I began to wonder whether rank might somoehow also affect how the males respond to stress. Would the physiological response of dominant and subordinate males differ?

It turns out that the stress response does differ in the two groups. I have therefore explored the nature of these differences in some detail, along with their possible causes.

Every year I spend three months in Kenya, where I study the baboons according to a standard routine, usually with the help of a Kenyan assistant, Richard Kones. We begin by determining the males' social rank that season, which essentially involves evaluating how often the animals get what they want. For

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instance, we rate the animals according to whether they win most of their fights, are more often the harasser rather than the harassed, and are able to supplant another male (who might be, say, resting in a desirable spot, feeding or being groomed). I consider males in the top half of the hierarchy to be dominant and those in the bottom half, subordinate.

Once the males' social positions are known, I assess their baseline hormone levels and measure their metabolic responses to a physical stressor: anesthesia. I anesthetize the animals by "darting" them with a syringe shot from a blowgun. Before the animals lose consciousness, they become momentarily disoriented, which seems to trigger the stress response. The anesthesia not only stresses the animals, it also makes it possible to obtain repeated blood samples over the course of the day and thus to track changes in the animals' hormone levels.

In carrying out the darting I have to adhere to many constraints. The baboons must all be injected at the same time of day, to control for rhythmic fluctuations in hormone levels. No animal can be darted if he has been injured or sick recently or if he has mated or had a major fight; such experiences will distort resting, or baseline, values of hormones. For the same reason, I have to be sure the animals have not eaten before they are anesthetized. Animals must not sense they are being stalked, or the data might be confounded by anticipatory stress. Finally, an initial blood sample (which establishes the baseline levels of the hormones to be studied) must be obtained within a few minutes after anesthesia sets in; if too much time elapses, the levels of the hormones of interest will have changed.

With this approach I have found that when the dominance hierarchy is stable (as it usually is), the workings of nearly every physiological system I have examined differ between the dominant and subordinate males. It also turns out that the physiological profile of the subordinate animals is closer to the type that is thought to predispose humans to stress-related disease.

The hormonal system that controls the secretion of testosterone (the principal reproductive hormone in males) offers a good example of how the stress response differs between dominant and subordinate olive baboons. Although the average esting levels of testosterone are essentially the same in both groups, the levels diverge markedly when the animals are stressed.

Testosterone is normally released as the final step in a cascade of hormone secretion that begins at the brain. There, the hypothalamus releases a substance known as luteinizing hormone-releasing hormone, which stimulates the pituitary gland to release luteinizing hormone. This hormone, in turn, triggers the testicular release of testosterone.

In both dominant and subordinate baboons, as in human beings and rats, testosterone levels plummet in response to stress. Yet the similarity between dominant and subordinate males ends there. After the baboons are darted, the testosterone levels of subordinate males decline promptly, whereas those of dominant males actually rise and remain elevated for perhaps and hour before declining.

Theoretically, the rise in testosterone could give dominant males a survival and social advantage, because the hormone increases the rate at which glucose reaches the muscles. Such changes would be expected to help dominant baboons withstand a physical challenge. (Testosterone also regulates sexual behavior

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and aggression, but the magnitude and duration of the testosterone increase found in dominant males during stress would not be enough to improve sexual performance or to make dominant males more aggressive than others.)

What causes testosterone levels to decline during stress, and by what mechanism are the levels elevated for a time in dominant males? I have discovered that the decline is driven in part by the stress-induced secretion of the opiumlike substance beta-endorphin, a pain suppressor that is best known for causing the so-called runner's high. Beta-endorphin, which is secreted by several organs, suppresses the hypothalamic secretion of luteinizing hormone-releasing hormone, which in turn suppresses the pituitary secretion of luteinizing hormone, leading to a decline in the amount of luteinizing hormone that reaches the testes. I determined that beta-endorphin accounts for the decline in luteinizing hormone by administering a drug to the baboons that blocks the access of the opioid to its receptors in the hypothalamus. When the activity of beta-endorphin was thus blocked, there was no stress-induced lowering of the levels of luteinizing hormone.

Another cause of the decline in testosterone levels is a decrease in the sensitivity of the testes to luteinizing hormone. This change is caused by the hormone cortisol, or hydrocortisone, which is released in quantity by the adrenal glands during stress.

The initial rise in testosterone levels after darting in dominant males cannot be explained by changes in the activity of either the brain or the pituitary gland, because the levels of luteinizing hormone released by the pituitary decline equally in high- and low-ranking males. Nor are cortisol levels involved; they are the same during stress in both groups. The explanation, then, must lie elsewhere.

I have found that a two-part mechanism seems to be responsible. In one part the testes of the dominant males somehow become less sensitive to the testosterone-inhibiting effects of cortisol. Yet, if decreased sensitivity to cortisol were the only mechanism operating, it would merely slow the decline of testosterone levels but would not lead to their elevation.

The rise itself probably results from the stress-induced release by the sympathetic nervous system of what are called catecholamines, such as adrenaline and noradrenaline, which affect blood flow. For unknown reasons, the testicular vascular system of dominant males is particularly sensitive to the dilating effects of the catecholamines, and so the testes of dominant males probably receive more blood during stress than do those of subordinate males. Hence, although the output of luteinizing hormone from the pituitary gland declines in both groups, any luteinizing hormone in the blood is probably delivered fater to the testes of dominant males. Such enhanced delivery would lead to a temporary increase in the amount of luteinizing hormone reaching the testes and so to an increase in the testicular output of testosterone.

My work has also identified rank-associated differences in the organ system responsible for increasing the release of cortisol into the blood during stress. The secretion of cortisol, like that of testosterone, is the final step in a cascade of hormone secretion that begins in the brain. In this case, when the animal is stressed, the hypothalamus steps up its secretion of corticotropin-releasing factor and related hormones. These hormones cause the pituitary gland to release adrenocorticotropic hormone, also known as

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corticotropin. Corticotropin, in turn, stimulates the adrenal glands to release cortisol.

Cortisol is responsible for much of the double-edged quality of the stress response. In the short run it mobilizes energy, but its chronic overproduction contributes to muscle wastage, hypertension and impaired immunity and fertility. Clearly, then, cortisol should be secreted heavily in response to a truly threatening situation but should be kept in check at other times. This is precisely what occurs in dominant males. Their resting levels of cortisol are lower than those of subordinate males yet will rise faster when a major stressor does come; exactly how this speedier rise is accomplished is not understood.

I determined the cause of the higher basal cortisol levels in subordinate males by separately studying each part of the cascade that leads to the hormone's release and clearance from the blood. Working backward from the blood to the brain, I deermined that the cortisol is cleared from the blood of subordinate and dominant males at the same rate. Therefore, the high cortisol levels of subordinates must stem from the excess secretion of cortisol by the adrenal glands.

This excess cortisol secretion could result from an increased sensitivity of the adrenal glands to corticotropin, excess secretion of corticotropin by the pituitary gland, or both. I found that the adrenal glands of subordinate males are not more sensitive; therefore, they must be exposed to more corticotropin.

The overproduction of corticotropin could similarly be caused by enhanced sensitivity of the pituitary gland to corticotropin-releasing factor and its relatives, excess secretion of these substances by the brain, or both. I found that the pituitary's sensitivity is actually diminished in subordinate animals. Thus, the brain probably hypersecretes corticotropin-releasing factor and its relatives, ultimately giving rise to high cortisol levels in the blood. the release of hormones by the hypothalamus cannot be measured noninvasively, but my conclusion is supported by the fact that Philip W. Gold and his colleagues at the National Institute of Mental Health came to essentially the same conclusion when they traced the causes of elevated basal cortisol levels in humans who were depressed.

Why would the brains of subordinate male baboons trigger excess cortisol release when the animals are at rest? No doubt part of the answer has to do with the animals' stressful lives, which would lead to frequent stimulation of cortisol secretion. In addition, the animals have difficulty regulating the system responsible for the secretion of cortisol.

In any chain of command, the chief needs feedback, an indication that the commands have been obeyed. In this system, the levels of cortisol--the final hormone secreted in the stress-response cascade--must be sensed by the brain. The brain should continue to evoke cortisol secretion until some threshold level of hormone has been reached, and it should inhibit secretion when the threshold is met. I wondered whether the brains of subordinates sense blood cortisol levels appropriately and found they do not.

This discovery was made by administering a synthetic version of cortisol called dexamethasone to a number of baboons. In dominant male baboons, as in most people, the brain senses the presence of dexamethasone and responds by curtailing the secretion first of corticotropin-releasing factor, then of

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corticotropin and then of cortisol. In contrast, subordinate baboons (and depressed people) are dexamethasone-resistant, that is, their brains are insensitive to the shut-off signal. As a result, cortisol production continues unchecked.

Whether subordinate males are in fact being harmed by their high basal cortisol levels remains to be seen, but certain danger signs are already evident. For instance, Glen E. Mott of the University of Texas at San Antonio and I found evidence suggesting that subordinate males may be at higher risk for atherosclerosis and thus for heart disease. In comparison with dominant male baboons, subordinates have les circulating HDL cholesterol, which is the "good" kind that helps prevent atherosclerosis. This difference was not attributable to diet, levels of activity, body weight, genetics or testosterone levels but was attributable to cortisol. We found that the higher a baboon's basal cortisol values are, the lower its levels of HDL cholesterol will be. Moreover, laboratory studies have shown that cortisol can suppress the production of HDL cholesterol.

Cortisol is known to suppress immune function during stress, and so I also compared a measure of such function in the two groups of baboons. Indeed, subordinate males have fewer circulating, lymphocytes (white blood cells) than do dominant males. Although the HDL cholesterol and lymphocyte signs are ominous, the determination of whether subordinate baboons are at greater risk for heart attacks and infections can only be made by studying the same animals throughout their lives. Complicating such analyses is the fact that social rank can change over time: dominant males weaking havoc today may have been cringing subordinates when I first met them in 1978.

Even considering this caveat, I initially interpreted my data to suggest that the physiology of subordinate males predisposes them to stress-related disease. Rank is physiological destiny, the data seemed to say, and the other physiological systems I have studied in these males gave the same impression.

What aspect of rank might influence physiology the most" My own observations and others' studies of captive animals led me to suspect that the psychological benefits of having a high rank could be particularly important. My firs hint that psychological factors might be crucial came in 1981, when the dominance hierarchy of the olive baboons became unstable. The highest-ranking, or alpha, male in my study group had passed his prime and had no heir-apparent; usually there is an obvious second-ranking animal exerting pressure on the alpha male to step aside. Instead, in this year, half a dozen young males formed a coalition to oust the alpha male. In the aftermath of the successful coup, however, the coalition disintegrated promptly. Any of these males dominated the rest of the troop's males, but among themselves, no clear hierarchy emerged. Instead months of instability ensued: coalitions formed among subgroups of dominant males and then fell apart; the amount of aggression and the number of interactions meant to test dominance increased; and ranks shifted constantly.

During this turmoil, the advantageous physiological correlates of dominance seen in other years disappeared. In contrast to males who were dominant in other study seasons, males dominant in 1981 were physiologically more like subordinates: they had elevated basal cortisol levels and sluggish secretion of cortisol in response to stress; they also no longer had a transient rise in testosterone levels during stress. This finding suggested to me that the "better" profiles seen in dominant males in other years derived in part from

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the sense of control and predictability that comes with sitting atop a stable hierarchy. Although the dominant males in 1981 had the same high rank and power observed in dominant males in other years, they did not have the same sense of security.

Similar results have been found by many investigators who study captive primates, such as rhesus and squirrel monkeys. When new social groups are forming, dominant males are found to have high basal levels of both cortisol and testosterone and to be highly aggressive. Once a dominance hierarchy is stabilized, a picture emerges that resembles my sketch of the olive baboons in stable times.

The research on captive animals also indicates that the optimal hormonal profile seen in dominant males during stable times is an effect and not a cause of one's high rank. If hormonal traits accounted for dominance, the captive animals would have had different profiles even before new social groups were formed, but they did not. Thus, the beneficial physiology seen in dominant males seems to emerge from, instead of giving rise to, dominance and to arise only when dominance brings with it certain psychological advantages.

My most recent studies have altered my thinking about the influence of rank on physiology. They indicate that the advantageous physiology enjoyed by dominant males in a stable hierarchy is not a result of dominance after all. Rather, the "better" physiology found in the dominant males as a group is accounted for by a subset of animals that have certain personality traits. The traits apparently enable the animals to take full psychological advantage of their high rank and may, in fact, have helped the animals become dominant in the first place.

My student Justina C. Ray and I discovered the importance of personality when we analyzed the behavior of dominant males, formalizing as many distinct elements of "style" as we could imagine. (Similar studies of subordinates are now under way). We found low basal cortisol levels--our marker of optimal physiology--only in males who have at least one of the following characteristics: they differentiate well between the neutral and threatening actions of a rival (as evinced by acting differently after each of these events); when a rival is in fact threatening, they control the situation by initiating a fight; they behave differently after winning and losing a fight; and they displace aggression onto a third party if the fight is lost. Dominant males who lack such abilities have basal cortisol levels similar to those of subordinate males.

The general thrust of these findings is consistent with the advice routinely delivered by stress-management mavens, who say that being able to predict and control the outcome of social interactions and to find outlets for tensions can go a long way toward blunting the long-term effects of stree. The wisdom of this advice is underscored by the magnitude of the difference in basal cortisol levels between dominant males who have such traits and those who do not; the difference between these two groups is actually greater than the difference between the cortisol levels of the dominant males as a group and those of the subordinates. This finding indicates that the number of social stressors to which an individual is subjected is less important to physiology than is the emotional style with which one perceives and copes with the stressors.

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Studies of human subjects too have shown that a sense of control and outlets for distress are beneficial to physiology. For instance, in one classic study parents whose children had cancer were shown to have elevated cortisol levels. The amount of elevation varied, however, depending on the parents' coping style. Far lower cortisol levels were found in parents who had psychological defenses against anxiety, including religious faith, an ability to deny the seriousness of the child's illness, or a tendency to displace anxiety by becoming engrossed in the details of caring for the child.

It is perhaps platitudinous to conclude that attitude counts, that one must differentiate between what can and cannot be changed (and accept the latter), that one should find footholds of control and predictability in difficult circumstances. And yet my studies as well as many others have shown that stress-related physiology is remarkably sensitive to these platitudes and that the psychological filters through which external events are perceived can alter physiology at least as profoundly as the external events themselves.

For humans and animals as clever as humans, the stressors of life are predominantly socially generated ones that are both subtle and ambiguous. To the extent that so many of our stressors are the inventions of the mind, so too must be the means of coping with them.

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GRAPHIC: photograph; Graph; Chart; Caption: Testosterone levels in dominant & subordinate baboons differ under stress.; Causes of differing testosterone levels in subordinate & dominant males.; Mechanism regulating the release of cortisol is disrupted in subordinates

SUBJECT: Olive baboon, behavior; Stress (Physiology), Endocrine aspects; Stress (Psychology), physiological aspects; Baboons, physiology

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HEADLINE: Trembly's polyps; Elegant experiments done on hydras in the 1740s by Abraham Trembley

BYLINE: Lenhoff, Howard M.; Lenhoff, Sylvia G.

BODY:

Trembley's Polyps

Any biologist knows that certain primitive animals reproduce asexually by budding, that complete animals of some species can regenerate from cut pieces of a whole one and that tissues from two individuals of the same species can be grafted together. Yet few investigators stop to think that these facts were not always obvious. Fewer still know that the discoverer was Abraham Tremebly of Switzerland, an obscure tutor whose many startling revelations about the curious invertebrates called hydras disturbed and intrigued Enlightenment Europe in the early 1740's and, in the eyes of some authorities, earned him the title "father of experimental zoology."

It is not surprising that Trembley is relatively unknown today. Reference books, if they mention him at all, usually say little about his life, his innovative methods, the impact of his work on his contemporaries or the considerable significance of his approach and his discoveries for modern science. We believe the time has come for Trembley to emerge from anonymity.

Who was Abraham Trembley and what led him to take an interest in hydras, or as he called them, "polyps of fresh water with arms shaped like horns"? He was a member of a prominent Genevan family. Born in 1710, he grew up in a period when many intellectuals in his native city had turned their attention to natural history. His own academic interest initially centered on mathematics rather than on animals, and as a university student he prepared a thesis on the calculus.

Having finished his education, the young man sought work in Holland. It was there, as a tutor at the estate near The Hague of Count William Bentinck, that Trembley made the observations and did the experiments that were to revolutionize the study of living organisms. Amazingly, he made scores of findings in the short span of four years from 1740 to 1744. Moreover, he did it long before the development of sophisticated tools, relying mostly on a magnifying glass and occasionally on a simple single-lens microscope.

Trembley first became intrigued by hydras--which are members of the Coelenterata, the same phylum as jellyfish and corals--in the course of observing aquatic plants and animals collected from ditches on the count's estate in his spare time. He found his glass jars "populated with little creatures" as "good company with which to relax from more serious occupations."

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At first he was attracted more by the lively moving inhabitants of the jars than by the stationary green hydras there. The organisms, which were less than half an inch long and looked like tubes adorned with a crown of tentacles at one end, were apparently immobile, leading him to assume that they were simle plants. Yet one day in June of 1740 he saw them contract and extend. Astonished, he watched for other evidence of animals behavior until, after observing them for several days, he saw his subjects take steps.

Satisfied that the tiny creatures were animals, Trembley paid them little heed for the next month or so. Then by chance he noted that they had a propensity for light. At a time when many naturalists did little more than describe the organisms they observed, he decided to explore his observation further by experiment. He proceeded to demonstrate for the first time that eyeless animals can exhibit phototaxis, or movement toward light. In one study, for example, he covered a jar of polyps with a cardboard sleeve in which he had cut a small opening. He then rotated the sleeve at intervals and tracked the migration of the speciments, which was always toward the light coming in through the opening.

The tutor's interests were now irretrievably focused on hydras, and he decided to investigate them seriously and thoroughly. One of his first accomplishments was proving that a whole organism can regenerate from a small piece vut from an amimal. He began to study this phenomenon after he noticed that hydras varied in the number of tentacles, or "arms," they had--a decidedly odd characteristic for an animal. The oddity made him think of bisecting a specimen to see whether the halves would develop into complete organisms. If they did, the finding would suggest the polyps were plants. It turns out that Trembley soon found definite evidence that hydras were animals: he saw a brown species seize and eat prey. Fortunately, however, he did not make this observation until after he had conclusively shown that hydras could regrow missing parts. As Trembley said, if he had seen his subjects eat earlier, he might never have decided to study regeneration.

To begin the studies, he divided a hydra transversely and then examined both parts under a magnifying glass several times a day. Within a few days he thought he could detect the excised posterior half regrowing tentacles. Soon he had no doubt: the segment had developed into a whole hydra.

"When I examined the two parts through a magnifying glass with all the attentiveness of which I was capable," Trembley reported, "both of them appeared to be demonstrably complete polyps performing all the functions of these organisms known to me: they elongated, contracted and took steps." In later studies he also saw regenerated specimens eat.

The discovery of regeneration in animals was one of the first major challenges to the accepted "natural law" that mating was required for animals to reproduce. Trembley's finding was arguably even more dramatic than that of his kinsman Charles Bonnet, who in the course of studying aphids the year before had discovered parthenogensis, the development of eggs without fertilization.

At about the time Trembley did the work on regeneration he also observed a "polyp that was beginning to produce a little one" in a manner that was "very closely akin to the way plants multiply when they give off shoots." He became excited as he watched a small protrusion from the body of a polyp grow, develop tentacles and detach to become a small replica of its "parent." Experiments he

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then devised helped to elucidate the nature of asexual reproduction by budding, proving for example that the buds did not develop from eggs.

Trembley's other extraordinary discovery, grafting, was the culmination of a circuitous chain of events. While he was studying regeneration, he noticed that whenever he cut a hydra, many "granules," or grains, oozed out of the cut part of its body wall, which he called skin. For a time the young investigator explored the role of these granules in spreading nutrients through the body. At one point he wondered if he could nourish the hydras by turning them inside out and placing them in a nutrient-rich solution. The granules of the inner skin would then be on the outside, where the nutrients were.

In a truly impressive feat, accomplished while holding a hydra in a drop of water on his palm, he managed to invert the tiny animal without killing it. He pushed a boar's hair against the foot, or base, of the animal so that the foot, followed by the rest of the hydra, eventually emerged through the mouth, an opening at the center of the crown of tentacles. Animals inverted in this way survived and seemed to function normally in all respects, although they could not accept nutrients from the external solution.

It was a complication of turning hydras inside out that led Trembley to observe his first graft. In one instance he saw that the tip of an immature bud that was now inside the inverted parent had poked through a hole that had been cut in the skin of the mother; the bud seemed to be completely united to the mother at the new site. The discovery prompted him to do an orderly set of experiments proving conclusively that pieces of two different hydras from the same species could be grafted together and that grafts between hydras of different species would be rejected. In several such experiments he placed one hydra inside the body of another, gave them time to fuse and then fed prey to the inner animal. When pieces of the prey spread to the outer animal, Trembley knew the bodies had united.

The discoveries we have described were probably Trembley's most important achievements, but they were by no means his only ones. When he was still working with hydras, he invented the first "vital staining" technique, a process by which living tissues are colored for study. Trembley may also have been the first to describe protoplasm, the gel-like material that is fundamental in the cells of all organisms. This accomplishment is usually credited to Felix Dujardin, who worked a century later. While analyzing granules oozing out of a cut hydra, Trembley noted that they were held together by a "viscous material" in which "must be contained all the components that serve to carry out their movements of contracting, flexing, and so forth." He and his contemporaries, however, did not realize that the material might be the basic substance of all living tissue.

The astute investigator uncovered secrets of other aquatic organisms as well. He described for the first time the process of budding in the worm Stylaria and in the bryozoan Lophopus, a colonial invertebrate; he wrote about the anatomy of Lophopus in amazingly accurate and fine detail, and he was the one who pointed out that bryozoans are animals. Few people are aware that Trembley also observed cell division. Although the idea of a cell had not yet been conceptualized, he both described and sketched the multiplication of the single-cell alga Synedra, and he was the first to show that protozoans reproduce by division. The late John R. Baker of the University of Oxford, who published a definitive biography of Trembley in 1952, further credits the Swiss tutor

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with a number of discoveries on other animals, including colony formation and tube building in the microscopic aquatic animals known as rotifers.

Abraham Trembley's findings may be accepted as fact today, but early reports of his discoveries created a furor not only in the universities and scientific societies but also in the fashionable salons of the times. The initial reaction was disbelief, and religious questions were raised, among them: If cut pieces of a polyp could regenerate a whole organism, what then became of the animal's soul?

For many intellectuals negativity soon gave way to enthusiasm for the clues to nature that Trembley had uncovered. For instance, the French naturalist Rene-Antoine Ferchault de Reaumur, with whom Trembley corresponded for 17 years, reacted with mounting excitement as he verified Trembley's results. Indeed, Reaumur was so impressed that he encouraged his young friend to collect and publish the discoveries on hydras--something Trembley accomplished in 1744 with his beautifully illustrated book, Memoires, pour servir a l'histoire d'un genre de polypes d'eau douce, a bras en forme de cornes (Memoirs concerning the natural history of a type of freshwater polyp with arms shaped like horns).

Reaumur also introduced Trembley's discoveries to the intellectual circles of Paris, the king of France and his court and the French Royal Academy of Sciences, which later offered Trembley the honor of becoming one of its Correspondants. In England Trembley was elected to the Royal society of London in 1743 and was awarded its prestigious copley Medal, considered then to be one of the highest accolades in science.

More profound than Trembley's popular acclaim was his immediate influence on serious students of natural history. Trembley's work--together with that of Reaumur, Bonnet and others--validated the importance of basing the study of living organisms on direct, careful observation rather than on preconceived ideas and theory. Trembley believed it was only by observation and experiment that he had been able to reveal phenomena, such as regeneration, that should have been discovered long before. "Nature must be explained by Nature," he insisted, "and not by our own views."

Trembley's successes also convinced many students of natural history to make the important transition from observation of God's minute creatures to active experimentation on them. More specifically, his work encouraged other scientists to devise studies that significantly advanced the understanding both of freshwater and marine invertebrates and of important biological phenomena. His experiments, for example, spurred several leading naturalists to conduct studies on regeneration. As a result, within 25 years after Trembley first cut a polyp in two, the phenomenon of regeneration was broadly recognized as a basic natural process. Some scholars believe the spreading influence of Trembley's work on hydras stimulated the development in 1752 of a precursor to today's dissecting microscope.

The discoveries made by Trembley are now part of every biologist's fundamental knowledge. Why then is the man generally accorded little recognition? One reason may be that he did not propose any theory to which his name can be linked. Such hostility to theory has made it difficult for historians to fit him into any philosophic or historic niche.

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There are other reasons as well. Even in his own time Trembley's scientific prominence faded. He made few systematic contributions to science between the time he completed service with the Bentincks in 1747 and his death in Geneva in 1784. After leaving Holland he undertook a secret diplomatic assignment for the British government, traveled, taught, wrote several books (on education, politics, religion and moral philosophy) and, in his later years, concentrated his efforts on rearing the five children he fathered after marrying at the age of 46.

Even if trembley had continued to devote himself to the study of invertebrates, his star might have fallen in the second part of his century because the European intellectual elite had turned to other subjects--such as electricity and the problem of irritability in living organisms. Late in the 19th century and in the beginning of the 20th century, embryology, evolution and genetics dominated research and theory in the life sciences. An anthropomorphic focus on vertebrates further dampened enthusiasm for Trembley's invertebrate subjects. Finally, as preeminence in biological research shifted across the Atlantic to a generally monolingual society, the fact that his masterwork on the hydra was not--until recently--translated from French into English tended to limit the acquaintance of biologists with the once renowned investigator.

Trembley's prominence in the collective memory of scientists may have faded, but a review of his Memoires provides a quick reminder that he still has much to teach the modern scientist. Today's biologists dipping into the book can gain insight into virtually every aspect of the biology of the hydra, including its structure, behavior, physiology, development and interaction with prey and predators. Moreover, many of the phenomena described in the book invite further study by contemporary developmental biologists.

Which of Trembley's qualities as a scientist might the aspiring biologist emulate? In addition to being an empiricist who insisted on postponing the development of theory until he had sufficient data, he was an observer quick to see the unusual and to report his findings with great accuracy and detail. He was an experimentalist who was not content until he could prove his findings in a number of ways. He was quantitative in his approach, backing up many of his experiments with numbers and repeating the experiments until he was convinced of their validity. He was an organismic biologist interested not in a single problem but in all aspects of an animal, and he was an operationalist who believed an experiment has no lasting value unless the methodology is described in a way that enables others to replicate it. It is not enough to say, he wrote, "that one has seen such and such a thing. This amounts to saying nothing unless at the same time the ovserver indicates how it was seen, and unless he puts his readers in a position to evaluate the manner in which the reported facts were observed."

Trembley had other noteworthy qualitites as well. He worked not only in his study but also in the field, where he was able to discover a number of new species, and he investigated both the structure of organisms and the mechanisms behind the functions he observed. He was a technician par excellence, carrying out complex and delicate operations with hardly more than scissors and a boar's-hair probe as tools. He was, moreover, persistent. "One should not become disheartened by want of success," he wrote in the Memoires, "but should try anew whatever has failed. It is even good to repeat successful experiments a number of times. All that is possible to see is not discovered, and often cannot be discovered, the first time."

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We suspect that Trembley's admirable scientific objectivity stemmed in part from his piety. He believed all marvels were possible in God's magnificent universe. As a consequence he was undismayed by disconcerting findings that did not seem to fit accepted understandings. On December 11, 1742, he wrote to Bonnet: "Your worm with two tails is admirable, but it does not surprise me, because nothing surprises me."

What would Abraham Trembley think about contemporary biology if he were alive today? We suspect that this organismic biologist, who was "swept along, as it were, from one observation to another" to discover phototaxis, whole-animal regeneration, budding and grafting, might be somewhat ambivalent. He would probably marvel at the success of such fields as neurobiology and molecular biology, where organisms are exploited to answer specific fundamental questions. Yet he would undoubtedly be disturbed to discover that individual biologists increasingly study ever fewer phenomena. Nature is too vast, he might well insist, for us to neglect broad and detailed studies of the host of organisms that populate the planet. He might say: Let the organism speak.

GRAPHIC: Portrait; Photograph; Caption: Abraham Tembley

SUBJECT: Coelenterata, research; Biology, history

NAME: Trembley, Abraham, research

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BYLINE: Davis, William C.

BODY:

The Detonation of Explosives

In 1846 the Italian chemist Ascanio Sobrero noted that combining nitric acid and glycerol resulted in a liquid substance with peculiar properties. The substance exploded violently and in a markedly different way from black powder, the most widely used explosive at that time. Whereas black powder does not explode unless it is confined so that its combustion gases can generate high pressures, small quantities of the oily liquid exploded much more powerfully than black powder even when the liquid was unconfined. Sobrero had discovered not only a new compound, nitroglycerin, but also a completely new physical process by which substances can explode, namely detonation.

As the news of Sobrero's discovery spread, others tried to apply it. The tireless Swedish inventor Emanuel Nobel tried adding nitroglycerin to black powder in an unsuccessful effort to increase the powder's effectiveness. In 1863 his son Alfred reasoned that a new kind of explosive deserved a new kind of initiator. Whereas black-powder charges had always been set off by flame, the younger Nobel developed a detonator that reliably set off nitroglycerin "by percussion or sudden pressure," as stated in its patent.

Substances that explode in the same way as nitroglycerin does are called high explosives to distinguish them from such substances as black powder, known as low explosives, which simply burn extremely briskly. Although Alfred Nobel and others after him devised a wide variety of powerful and safe high explosives and detonators, in most cases they relied more on hunches and even on sheer serendipity to guide them than on a clear understanding of the physics and chemistry of detonations.

That trial-and-error approach to the development of high explosives persisted until only a few decades ago, when investigators first began to transform the study of explosives from an empirical science to a science based on a solid theoretical foundation. The transformation is still not complete, but current research efforts are likely to quicken the pace. Progress in theoretical analysis, backed up by new computational methods, are helping to elucidate the structure of the inhomogeneities that seem to play an important role in the way a detonation propagates in an explosive. Advances in experimental techniques, such as laser spectroscopy, are yielding data from which the complex equations can be derived that describe the behavior of materials under the extreme conditions of pressure and temperature found in detonating explosives. These investigative efforts will ultimately provide what is still lacking today: a comprehensive theory of detonation.

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Ironically, it was a completely new type of explosive process--a nuclear chain reaction--that stimulated the modern theoretical study of detonation. Nuclear weapons rely on high explosives for the rapid assembly of key reacting components. Hence the assembly process calls for chemical explosives whose blast effects can be precisely controlled. The stringent requirement brought about a radical change in the explosives industry. All the attributes of a sophisticated technology--accuracy, predictability and tailoring to fine gradations--were suddenly demanded of explosives.

Engineers soon began to see precision explosives as compact energy sources of exceedingly high power that, although of short duration, are safe, reliable, controllable and, best of all, inexpensive. Thereafter it did not take long for a variety of new applications to be devised. Explosives are attached to the support columns and beams of old buildings and detonated in precise sequence to demolish the structures into neat piles of rubble. They are invaluable in metalworking to harden, form, weld and clad metal sheets or tubes. Indeed, in certain situations explosive welding is the only practical way to bond incompatible metals, such as aluminum and steel.

In some devices explosives are set off so that they force metal plates to collide violently, causing a high-velocity jet of metal to shoot out from between the plates. Such explosive-generated jets are capable of piercing the hardest materials and are used to penetrate armor, perforate oil pipes and cut up steel structures. Explosive cutters operating on the same principle are installed in structures that have to be sheared instantly while they are under great stress, as in the separation of missile or rocket stages.

Explosions can also be applied to generate the pressures and temperatures needed to make diamonds from graphite, to fuse metal and ceramic powders and to cause some otherwise impossible chemical reactions to proceed. Perhaps less well known is the development of explosive-driven magnetic field compressors that attain field strengths up to 10 million times the strength of the earth's magnetic field. Such magnetic fields can generate enormous pulses of electricity.

In spite of the variety of modern applications of explosives, detonation science has not yet reached maturity for several reasons. First of all, the theoretical calculations are intrinsically difficult. Whereas tractable, linear processes are common in many fields of classical physics, detonation is an exquisitely nonlinear process. Nonlinear processes are much harder to model mathematically than linear ones: the equations are hard to solve and the few solutions obtained are usually of no practical importance.

Second, detonation problems operate on two widely different dimensional scales: the region in which critical chemical reactions take place in the explosive, called the reaction zone, is usually between 100 and 1,000 times smaller than the region in which the explosion products deposit their energy. Yet the way explosion products transfer their energy to inert surrounding material affects the way the explosive chemical reactions proceed, and the study of the two processes cannot be easily uncoupled.

Third, there is a dearth of information about the chemical and physical properties of materials subjected to the extremely high temperatures and pressures that prevail in an explosion. The relation between pressure, volume and temperature for a given chemical mixture (known as the mixture's equation

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of state) and how the mixture reacts to form new chemical mixtures under such conditions are virtually unknown. Without that knowledge one is reduced to constructing theories devoid of a description of the actual material properties; the theory's inherent defects must then be corrected by adjusting artificial parameters according to experimental results.

Yet experiments are costly and are tricky to carry out. The explosive components are unavoidably destroyed and must be painstakingly built for each measurement. Needless to say, most such experiments cannot be done indoors; they require a large area of isolated land into which people are not likely to stray. To make matters even more complicated, the conditions that need to be measured in a detonating explosive approach the limits of the measurable. Peak pressures in explosives can reach values 500,000 times ambient air pressure and the detonation propagates through the explosive at velocities of up to 10 kilometers per second (30 times faster than the speed of sound in air). The chemical reactions involved in detonation are timed in nanoseconds (billionths of a second) and take place in a layer between .01 and one millimeter thick. Instruments that have the necessary time and spatial resolution have only recently become available, and their proper operation in the midst of an explosion is, to say the least, difficult to achieve.

It is therefore not surprising that the first significant steps toward a theory of detonation were taken in the last quarter of the 19th century with the study not of explosions but of a closely related phenomenon: shock waves. In formulating the basis for a theory of shock-wave propagation 19th-century investigators considered a simple construct: a long cylinder filled with a fluid and fitted with a piston at one end [see top illustration in box on page 110]. If the piston is instantaneously accelerated into the fluid, the fluid immediately in front of the piston will move at the same velocity as the piston. Hence at the start of the piston's motion the plane that separates the moving fluid from the stationary fluid will be close to the piston. Because the thickness of the layer of moving fluid rapidly increases as the piston travels down the cylinder, however, the plane does not remain near the piston but quickly outdistances it. Indeed, the plane travels faster down the cylinder than the piston (whose velocity is equal to the velocity of the moving fluid), since for every unit of distance the piston travels, the plane has traversed that distance and the increment of thickness added to the layer of moving fluid by the piston's motion.

Such a moving plane, which separates stationary material from material that is in motion, constitutes a shock wave. When the fluid velocity is very low, the shock wave is weak and its velocity approaches that of a sound wave in the stationary fluid. For higher fluid velocities, however, the shock wave travels faster than the speed of sound in the stationary fluid.

Clearly, as the piston advances, the fluid occupying the volume between it and the shock wave (the so-called shocked fluid) becomes compressed and its pressure increases. By applying the fluid's equation of state (which describes the way its pressure, temperature, volume and composition affect one another) and the fundamental physical principles of conservation of mass, energy and momentum across the shock wave, it can be shown that the pressure in the shocked fluid is uniquely determined by the material constituting the fluid as well as by the material's velocity. On the other hand, the shocked fluid's pressure and material velocity are uniquely determined by the shock-wave velocity. Hence the velocity of the shock wave fixes the state of the shocked fluid.

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Investigators who studied explosive gases noted that a detonation propagates as a wave through gas much as a shock wave does, and in 1899 the English chemist David L. Chapman proposed that a detonation wave sweeping through an explosive gas could actually be considered a self-sustaining shock wave. Chapman maintained that a shock wave traveling through a high explosive precipitates in its wake chemical reactions that supply enough energy to drive the shock wave forward through the explosive.

If this was the case, the equations that describe shock waves could also be used to describe detonation waves-- as long as they reflect the state of the exploded rather than the unexploded gas. Some further analysis, however, revealed an important difference between shock and detonation waves: while weak, low-velocity shock waves are possible if the illustrative piston is moved quite slowly, detonation waves are always strong and always propagate at a high velocity. The slowest detonation wave is still a very strong wave. For it the shock-wave equations yield a single solution for the pressure and material velocity of the detonated gas, but for faster detonation waves there are two possible solutions.

Chapman resolved the indeterminacy by relying more on aesthetics than on rigorous analysis: since a detonation wave was observed to travel at a single characteristic velocity depending only on the explosive through which it propagated, he reasoned that the conditions for detonation likewise had to be defined by a singular state. He therefore postulated that the pressure and material velocity for the detonation state of an explosive gas were defined by the unique minimum detonation-wave velocity. Chapman calculated detonation velocities according to this proposition and compared them with measured velocities; they showed remarkable agreement.

At about the same time in France the physicist J.-C. Emile Jouguet, who had been working along similar lines, showed that the minimum detonation-wave velocity corresponds to the velocity of a sound wave in the hot, compressed, moving detonation products found in the shocked explosive. This meant there was a physical explanation for the fact that a stable detonation wave propagates under the condition described by the minimum detonation velocity, as Chapman had conjectured: if a detonation wave were made to travel at a velocity greater than the minimum detonation velocity by a sufficiently strong initiating shock wave, a rarefaction would eventually travel through the detonated explosive and catch up with the overdriven wave to slow it down.

The process can be understood by referring back to the cylinder example. When the piston driving the shock wave in the cylinder is stopped, the velocity of the material just in front of the piston quickly slows to zero and the pressure correspondingly drops to a low value to form a rarefaction. The rarefaction propagates forward as a sound wave. From its lagging position the rarefaction weakens the shock wave, enabling it to draw closer. The closer to the shock wave the rarefaction approaches, the more the shock wave is slowed down, until it too is traveling at the speed of sound in the shocked material.

Jouguet's arguments about how a shock wave might speed up to attain the minimum detonation velocity, called the Chapman-Jouguet velocity, were more complicated and not as convincing. Nevertheless, investigators could not dispute the experimental data, which seemed to confirm the theory's accuracy of predication. Indeed, the theory outlined by Chapman and Jouguet is still the framework on which the most widely accepted theories of detonation are

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constructed.

The Chapman-Jouguet theory was unsatisfactory in that it lacked a detailed explanation for what takes place physically in a detonation wave. Nevertheless, the fact that it adequately predicted the final state of a gas right after it has been detonated satisfied practical-minded engineers. Knowledge of the final state of a detonation reaction was of great importance to them, because this state is the initial one from which to calculate the expansion of the explosion products (primarily nitrogen, water vapor, carbon monoxide, carbon dioxide and solid carbon in the form of soot). The expansion of the explosion products, like the expansion of steam or hot combustion gases in an engine cylinder, is the means by which energy is transferred to the surrounding medium (whether it is the casing of a hand grenade or the rock in a quarry face) to do what is technically known as work.

Strictly speaking, calculations based on the Chapman-Jouguet theory were valid only for the detonation of explosive gases, because only for them were equations of state known. Nevertheless, explosion engineers assumed that the theory would be applicable to liquid and solid explosives, if a reasonable approximation to an equation of state could be found for a high-density mixture of solid and gaseous materials. Such an equation can theoretically be derived from fundamental principles by considering the forces between molecules, the shapes of the molecules as they are subjected to high pressure, and the way different molecules mix in the product gases. The investigators of the first half of the 20th century, however, could derive these equations of state only empirically, that is, by directly measuring how the various properties of a material are affected if one of the properties is varied. Empirically derived equations of state, while they were not scientifically enlightening, nonetheless enabled engineers to calculate the state of a shocked explosive with a degree of accuracy sufficient for most engineering purposes at that time.

The first significant attempt to explain the underlying physics of how chemical reactions are initiated by the shock wave and how they transfer energy to the overall flow of the explosion products came from the theoretical work of Yakov B. Zel'dovich in the Soviet Union, John von Neumann in the U.S. and Werner S. Doering in Germany. The three investigators arrived at the same conclusions independently and more or less simulaneously in the early 1940's. Their key insight was to take a shocked material's temperature and pressure as givens and to concentrate on how chemical reactions in the shocked material proceeded. In other words, a shock wave in an explosive material is treated simply as a discontinuity in the material's properties: the material behind the infinitesimally thin shock wave is at high pressure and temperature, whereas the material in front of it is not. The explosive's chemical reactions, in contrast, are treated as taking place behind the shock wave in a short but finite time and in a steady reaction zone of small but appreciable thickness.

This notion compelled the three investigators to reconsider the Chapman-Jouguet theory, which takes only an explosive's final, detonated state into account. They maintained that directly behind the shock wave the explosive is in a state where no chemical reaction has yet taken place; farther back, at the end of the reaction zone, a state is reached in which all energy-releasing chemical reactions have been completed. Between the shock wave and the far end of the reaction zone must lie other states for partially reacted explosive. Hence there is actually a sequence of chemical states in the reaction zone, and each state has its unique pressure and material velocity.

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The Zel'dovich-von Neumann-Doering (ZND) model for detonation finally enabled scientists to give a fair description of how a detonation proceeds: a shock wave propagating into undisturbed explosive material instantaneously compresses and heats it enough to initiate chemical reactions that, over the course of several nanoseconds, release energy. The energy in turn preserves the conditions of high pressure and temperature necessary to drive the shock wave forward. When the reactions have run to completion at the end of the reaction zone, the gases expand to do work. The reactions are only slightly perturbed by the expansion that occurs behind the zone.

The velocity of the detonation wave must at least be equal to the Chapman-Jouguet velocity. If it is equal, the final state of the explosive (and the initial state from which the explosive products expand to do work) is identical with the final state specified by the Chapman-Jouguet theory. If the velocity is greater, two possible final states could result, one with higher pressure and material velocity than is stipulated by the Chapman-Jouguet theory and one with lower pressure and material velocity. (These two theoretically allowable detonation states are essentially the ones Chapman had avoided dealing with by arbitrarily limiting himself to uniquely defined detonation states.) Although its equations allowed two final states, the ZND theory rejected the physical existence of the state with the lower pressure and material velocity because there appeared to be no reaction pathway to it; all reactions had run to completion by the time the state with higher pressure and material velocity had been reached. A detonation that produces a final state with a higher pressure and material velocity than the state expected from the Chapman-Jouguet theory is said to be a strong detonation.

In the event of a strong detonation, however, Jouguet's argument of a half century earlier (that a rarefaction can catch up with an overdriven detonation wave to slow it down) still applies. The detonation wave therefore eventually slows down, reaching the minimum possible detonation-wave velocity for the completely reacted explosive, that is, the Chapman-Jouguet velocity. The ZND theory seemed to confirm that the Chapman-Jouguet state was in fact the appropriate state from which to start the expansion of the explosive products in calculating the energy transferred to the surrounding material.

The ZND theory was initially received with disbelief and incredulity by detonation scientists. It seemed to go against common sense. The theory held that pressure should fall while the reaction proceeds as a result of the fact that the propagating detonation was treated as a steady-flow problem, for which the equations balancing momentum and energy across the detonation wavefront required such an effect. Most investigators were convinced that the pressure ought to rise. Since the predicted drop in pressure was an extremely rapid effect (lasting on the order of a nanosecond), detonation scientists, who at that time were able to measure detonation phenomena only in terms of microseconds (milionths of a second), had to judge the theory on the strength of its underlying arguments. After much initial debate the ZND model of a detonation became widely accepted, and about a decade later experiments finally confirmed the fleeting pressure drop predicted by the ZND theory.

Even as he was first laying out the principles of his theory, however, von Neumann pointed out a major "loophole,' through which could be reached the disallowed state of a detonation with a greater-than-minimum velocity. Although it took most physicists about 20 years to figure out what von Neumann meant, the point is actually easy to understand if one considers a small refinement in

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the details of the energy, or heat, released by the explosive.

According to the ZND theory, account had to be taken of the states of the partially reacted explosive. Consider what could happen if an explosive reaction proceeds in two steps, the second of which absorbs part of the heat released by the first. In other words, the first step is exothermic and the second is endothermic. If the first step is much faster than the second, the heat released by an explosion would increase as it does in a one-step reaction, but it would eventually reach a maximum and then drop to a lower, final level. During the time of maximum heat release, momentary states could be attained that provide a pathway for the explosive reaction to proceed to a state with a lower pressure and material velocity than the state specified by the Chapman-Jouguet theory, which considers only the final heat-output level of such a reaction and ignores the way heat output may have varied in getting there [see box on preceding page].

Studies done by William W. Wood, Zevi W. Salsburg, Jerome J. Erpenbeck and others at the Los Alamos Scientific Laboratory in the early 1960's showed that this type of detonation reaction, variously called a weak, eigenvalue or pathological detonation, can also be achieved by coupling energy-absorbing processes other than endothermic chemical reactions to a primary, exothermic reaction. For example, real detonations (as opposed to the idealized types I have been discussing so far) do not experience smooth, regular combustion in the reaction zone. Instead the reaction zone is heavily crisscrossed by pressure waves propagating at a right angle to the direction in which the detonation wave is traveling. Such crisscrossing waves set up turbulent flows that drain energy from the explosive chemical reactions. The net result is much like the chemical system of exothermic reaction followed by endothermic reaction: chemical reactions release heat, which is then dissipated in turbulent flow. It is probably because of turbulence that the final state of detonated gases has been shown to be different from a Chapman-Jouguet state and closer to the one predicted by assuming that a weak detonation occurs.

There is yet another way to produce a weak detonation, and this one probably manifests itself more often in everyday detonations (as opposed to experimental detonations, which are often initiated as plane waves). An unconstrained detonation wave expanding from its point of initiation attains a curved shape, much like the ripples that arise when a pebble is dropped into a pond. This type of expanding detonation wave can in fact be considered to have a heat-absorbing mechanism, because the diverging flow of material diverts energy in directions different from the direction of motion. In practical applications almost all detonations are initiated at a point (or in some small region) and expand, so that in fact almost all real detonations are weak ones and not Chapman-Jouguet detonations.

Although it is clear that there is in reality an intimate relation between the chemistry and the fluid mechanics of detonations, both the Chapman-Jouguet and the ZND models treat the two processes as distinct and independent in order to make the analysis of a detonation more tractable. It had been thought that even if turbulence or other similar small-scale perturbations arose from the mechanical flow of material in the reaction zone, the effects of such perturbations on the chemical reactions would be small enough not to warrant any qualitative change in the detonation models.

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Most workers now believe that the effects are not negligible and that detonation theory must be extended to take into account the effects of turbulence and of curved detonation waves, both of which are influenced by the type of inert material that surrounds the explosive. In addition, experiments have revealed that the reaction rate of an explosive (and therefore the thickness of the reaction zone) can be varied by mixing inert or catalyzing particles in the explosive material. Hence the chemical purity and homogeneity of an explosive can significantly affect its detonation behavior.

Other small-scale effects also have to be treated as significant contributors to the dynamics of detonation. Small pockets of unreacted explosive can become trapped behind the detonation front as transverse pressure waves interact with the shock wave. Tiny fluctuations in density or temperature in an explosive can produce regions of higher temperature called hot spots, which disturb the propagation of the shock wave by detonating before the surrounding explosive does. These localized perturbations are difficult to model, because they operate on a dimensional scale that is even smaller than the scale of the reaction zone. To make matters even more complicated, recent equation-of-state calculations have suggested that the dense explosion-product gases may not mix in the expected way; the gases may separate into two distinct fluids during detonation. If this turns out to be correct, yet another dimensional scale would have to be considered.

Fluid mechanics is just now advancing to a stage where real progress in computing these important details can be made. In this context the development of more powerful computers and new methods for averaging the effects of intricate microscopic events will contribute greatly to the understanding and prediction of complex fluid flows arising from the interactions of shock waves and the explosive material at the detonation front. Similarly, theoreticians who apply the equations of statistical mechanics and chemical kinetics to derive respectively equations of state and chemical-reaction rates must rely on experimentalists to provide raw data and to verify predictions. In this connection laser spectroscopy, which makes it possible to probe chemical phenomena on time scales of less than 100 trillionths of a second, will be a major help to both the experimentalists and the theoreticians.

Scientists who study explosions are spurred on by being constantly reminded that current detonation theory is incomplete. An important example of the need to refine the theory is a mode of explosion called low-velocity detonation, which workers first noted many years ago. If an explosion is initiated with a strong detonator, the detonation wave proceeds through the explosive charge at high velocity, typically between 6,000 and 8,000 meters per second in an ordinary dynamite. This high-velocity mode seems to be the one that current theory seeks to describe (at least in an idealized way) as either a Chapman-Jouguet detonation or, more probably, a weak detonation. In contrast, if the detonator is weak, the wave proceeds at low velocity, between 2,000 and 3,000 meters per second, and only part of the explosive reacts quickly. Clearly, factors other than those covered by the ZND theory are at work in such detonations.

Another type of behavior the current theory does not describe is the transition from burning to detonation. If a large pile of explosive at a manufacturing plant is ignited accidentally, it will burn briskly but quietly for a while—just as many nonexplosive materials do. If the pile is big enough, however, the flame front will accelerate into the material and the pressure in

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the material will increase. As the pressure increases, the explosive material begins to flow, compressing and heating the material at an appreciable distance ahead of the flame. Then the explosive suddenly undergoes high-velocity detonation--without an external initiating shock wave. So far no one has come up with a convincing theory that accounts for this process.

The problems I have cited are just two samples of those facing physicists and chemists who study high explosives. They will be difficult to solve, but their solution could increase the safety and efficiency of explosives so as to keep pace with the ever more demanding specifications of modern explosion engineering.

Photo: DETONATION WAVE moving from left to right through an explosive gas in a tube is depicted by colored zones in this set of computer-generated pictures. Navy blue represents low-temperature, unreacted gas; turquoise and red represent high-temperature, completely reacted gas. An intermediate-temperature, partially reacted state is depicted in pink. The detonation wavefront --actually a shock wave--has a transversely propagating component that causes a pocket of incompletely reacted gas to form behind it. The pictures were generated at the Laboratory for Computational Physics of the Naval Research Laboratory.

Photo: MODERN APPLICATIONS of high, or detonating, explosives inclu de the forming, cladding and perforation of metals. In explosive forming the powerfu l pressure pulse generated by an underwater detonation forces a metal sheet to conform to the sh ape of a die. In explosive cladding a metal plate that is lined with high explosiv e

and buffer material is set at an angle to a thicker metal plate. Detonating the explosive a t the juncture of the two plates lays the thinner plate down on the thicker plate with suc h

force that the plates are welded together. A by-product of the cladding process is the cre ation of a high-velocity jet of metal that shoots out from between the colliding plates. Suc h

a jet can cut through the hardest materials. It is the operating principles of a p erforation charge, which generates a pipe-puncturing jet by forcing a conical metal liner to c ollapse explosively.

Photo: VISUALIZATION of a detonation wave varies according to theory. The Chapman-Jouguet theory treats a detonation wave as a discontinuity between two distinct pressure and chemical states: the low-pressure, undetonated explosive and the high-pressure, detonated explosive. The Zel'dovichvon Neumann-Doering theory separates the discontinuous pressure increase from the energy-releasing chemical reactions (green), which proceed in a zone of appreciable thickness. Moreover, the transition from unreacted to completely reacted explosive is accompanied by a fall in pressure. Although the final detonation state can be identical with that predicted in a Chapman-Jouguet detonation, other states are also possible. In a strong detonation, greater initial and final pressure states are exhibited. In a weak detonation an energy-absorbing reaction (red) coupled with the energy-releasing reactions allows a final state with a lower pressure to be reached.

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Photo: LASER-SPECTROSCOPY experiment at the Los Alamos National Lab oratory provides data on the composition and vibrational states of material at extrem e

pressures and temperatures. Such data are required to understand the behavior of detonating explo sives.

Photo: FIREBALL of a nighttime explosion of a 50-pound mixture of a mmonium nitrate and fuel oil results from the afterburning of the explosion products; paraffi n

and sulfur have been added to the mixture to enhance the effect. The streaks at the base of the fireball are tracks made by turbulent burning during the expansion of the explosio n-product gases.

GRAPHIC: Photograph; Chart; Caption: Visualization of a detonation wave varies according to theory; Hugoniot curves and Rayleigh lines

SUBJECT: Explosives, research; Detonators, analysis; Explosions, research

LOAD-DATE-MDC: March 31, 1988

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Big Science in the Sky

THE SPACE TELESCOPE
A Study of NASA, Science, Technology, and Politics.
By Robert W. Smith.
Illustrated. 478 pp. New York:
Cambridge University Press. $39.50.

By Leon M. Lederman

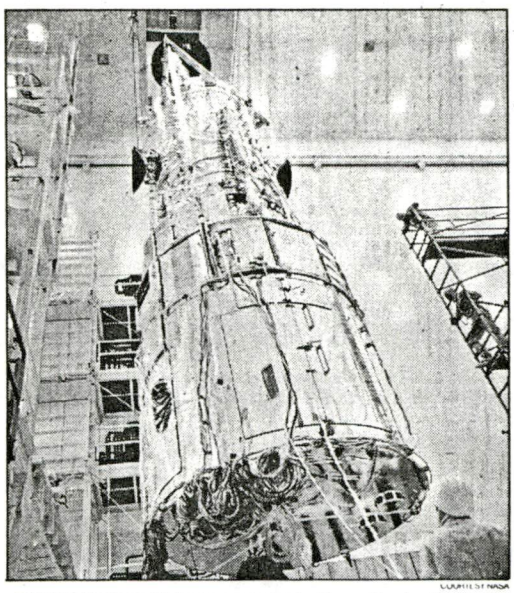
WHICH of us has never looked up at a particularly clear night sky and wondered about what is up there? For millenniums people speculated that the universe was about as simple, and as serene, as it looked. But discoveries made in this century reveal that what is up there is not so simple. It is a place of immense distances, enormous violence, a cosmic maelstrom in which countless stars are born and die and they and their galaxies are constantly moving "away" — the whole universe expanding from its origins in the big bang billions of years ago. Yet all our discoveries have made what is up there even more tantalizing than it was in the past; mysteries remain because there are numbers that are too imprecise, patterns that are not really decipherable, phenomena that, in spite of all our technology, are too dimly seen.

What is not up there yet is the Hubble Space Telescope, an instrument designed to solve some of the most baffling problems of modern astronomy. It has been in the planning for a quarter of a century, and its designs were started more than a decade ago. It was first scheduled to go into orbit in 1983, then 1984, then 1986. Now, if the schedule holds, it will finally be sent aloft from the space shuttle, perhaps as early as this week. That will be an exciting moment for science. And yet, the space telescope that will finally fly several hundred miles above us, to peer into the universe without the distortions imposed on our vision by the earth's atmosphere, will not be quite the instrument any of its original planners envisioned. For the space telescope is the work of big science, and in big science, we are learning, the result is changed along the way by influences far outside the fields of the scientists who make the first plans, outside science altogether.

"The Space Telescope" by Robert W. Smith is a big and important book that tells the story of this instrument and focuses a strong light on one case study of big science. "Big science" is a term coined by Alvin Weinberg in the 1960's when he was the director of the Oak Ridge National Laboratory in Tennessee. Big science involves the collaboration of large numbers of scientists, Government officials, university faculty members and administrators and industrial contractors, and large sums of money, to produce new instruments to advance our understanding of nature. Examples of big science include the space sciences, particle accelerators, oceanographic vessels, research in fusion energy and the project to map the human genome. It is apparent that, the more deeply we look into nature, the more big science we are going to need. So the effort to understand it becomes more important all the time, even though it may not be quite so enchanting as the effort big science organizes to understand the universe. Mr. Smith's book is a large contribution to both. It should be required reading for anyone involved in science policy.

Mr. Smith, a historian at the National Air and Space Museum of the Smithsonian Institution, who also teaches history at Johns Hopkins University, began working on this book in 1982, along with a group of historians and political scientists from several institutions who were involved in the Space Telescope History Project. They had unusual access to the people making the space telescope through an agreement with NASA, as well as to many closed meetings and briefings. But under the agreement their conclusions, and the account Mr. Smith has written, were not interfered with by the agency. The history project is indeed a rare opportunity to study what one of Mr. Smith's colleagues calls "the new techno-politics."

Leon M. Lederman, who received the Nobel Prize in Physics in 1988, is a professor of physics at the University of Chicago. He was the director of the Fermi National Accelerator Laboratory in Illinois from 1979 to 1989.



COURTESY NASA

The Hubble Space Telescope, covered with a reflective thermal shield, at the Lockheed Missiles and Space Company, Sunnyvale, Calif., 1988.

In the brief, 2,500-year history of scientific thought, astronomy has always played a crucial role. And advances in astronomy to a very large extent generated the astonishing advances in our understanding of the universe in this century. They began with the construction of large telescopes such as the one on Mount Palomar in California and were accelerated by the development of sophisticated instruments for reducing distortion and examining the color content of the light from distant stars, by electronic and computer-aided information processing that greatly improved the quality of the data. Ground-based radio wave observatories also added a new component to the data stream. Finally came space-based observatories contained in satellites that, employing a bewildering variety of instruments, collect information from invisible portions of the electromagnetic spectrum: gamma rays, X-rays, infrared ultraviolet rays and more.

From the beginning such instrumentation bore the mark of big science. Long before there was any possibility of launching a telescope into space, the successful construction of a facility like the Hale Telescope on Palomar, near San Diego, required the intimate collaboration of astronomers and other scientists with engineers in a wide set of disciplines. Glass mirrors had to be polished to a precision of a fraction of the wavelength of light (about one hundred-thousandth of an inch) over a diameter of hundreds of inches, and the relative positioning of mirror components had to be true to one ten-thousandth of an inch. The 14-ton mirror had to be firmly supported and steered with smoothness and accuracy far exceeding that of the works of a fine watch. In the case of a space telescope, all this precision will have to be preserved as the instrument is subjected to the great forces experienced in the launching of the vehicle that will lift it into orbit. The complexity of such an undertaking, and then of operating the instrument once it is aloft, is daunting.

Serious astronomers have mused about the value of large telescopes in space for more than five decades, but the state of rocketry before 1940 was such that only Astounding Science Fiction magazine would publish such speculations. It took World War II to focus resources on the technology of rockets that eventually became our space vehicles and made a space telescope possible. The first cogently argued case for a space-based optical telescope was made by Lyman Spitzer in 1946, when he was a 33-year-old astronomer at Yale University. He later moved to Princeton, and he kept on moving and shaking the world outside the university and outside astronomy for 40 years as he pushed the project. A telescope orbiting the earth at an altitude of a few hundred miles would be free of the burden of atmospheric dust, glow and distortions and would profit from the fact that crucial portions of the spectrum of light hitting the earth cannot penetrate through the atmosphere to earth-based telescopes. The seeing power of a telescope above the atmosphere was predicted to be about 10 times greater than even the largest ground-based telescopes. This would extend the observable universe by over 100 times that which could be observed from Palomar. The sharpness of the image of a star would also be about 10 times better than could be obtained on the ground. So here was a vision of a superb instrument waiting for the appropriate technology and circumstances.

MR. SMITH gives a quick account of developments from early rocketry to the Apollo manned space program as preliminary history. The space telescope story, however, as he says, really starts with the launching of a satellite known as OAO-2 in 1968. It contained a small optical telescope and a package of ultraviolet telescopes. They sent data back for over four years and established the new domain of astronomical observations. The success of this satellite gave great impetus to the advocates of a large telescope in space, who had been at work since the early 60's. Powerful scientists and powerful scientific groups became engaged in the plans. By the early 70's both laboratories of the National Aeronautics and Space Administration, the Marshall Space Flight Center and the Goddard Space Flight Center, were working on design concepts, as were several corporations. NASA headquarters was planning a management structure and formulating the campaign to sell the space telescope to Congress — on its merits but also as an important use for NASA's much-loved space shuttle. One curious omission in Mr. Smith's history is an almost total blackout on the impact of military and intelligence satellites on the space telescope design. Only occasionally do we get a hint that an instrument that can photograph a blemish on the nose of a man in the Kremlin from 100 miles up in space may be relevant to the technology of orbiting a telescope.

In the skirmishing among competing interests — Goddard and Marshall, NASA and the astronomers, cosmologists and planetary astronomers, and many others — the design of the space telescope changed greatly from the time of the first designs proposed in 1973 and those agreed on in 1977. The program was much diminished; it was still capable of excellent, exciting science, but it was far more modest than the one the astronomers had envisioned. Mr. Smith says: "The telescope designs of 1973, and the program to turn those designs into reality, were very different from the designs and programs that emerged in 1977. The 1973

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Big Science in the Sky

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design . . . had a primary mirror three meters in diameter; the 1977 telescope had a 2.4-meter mirror. In 1973 there were seven specific instruments; in 1977, five. In 1973 the Support Systems Module sat behind the primary mirror; in 1977 it surrounded the primary."

Mr. Smith gives a detailed account of the pressures NASA exerted to produce changes that would lower costs and make the project "acceptable," in its view, to the White House and Congress. Obviously those changes had to also be acceptable to the scientists, and reaching agreement was by no means an easy task. He quotes a program manager: "I was stunned. I couldn't believe that this was the most technically advanced program . . . and that it was being done on a shoestring. . . . We weren't doing life testing on the mechanisms, and environmental testing was cut back drastically. . . . This was supposed to be the big leagues, yet I knew we had done more testing on other little programs that weren't as important as this one. I was really shocked." This was the period when science policy, as it was carried out in practice at NASA, had its most serious impact on the scientific aims of the astronomers.

The construction phase, from 1977 to 1986, is again painted in fine detail, with its vastly underrated technical problems, its cost overruns, mismanagements and schedule slippages. The plan was to fly the telescope in 1983, but the launching was then pushed back in steps to 1986. Then the Challenger exploded in January 1986, and the schedule fell back another four years. Mr. Smith takes us through crisis after crisis, especially the great ones in 1980 and 1983 when the entire project almost died. A meeting of all those involved in building the telescope, on July 26, 1980, was so grim and so crucial that it has become known in space science circles as "Black Saturday," and Mr. Smith gives a vivid account of it, as he does of the months of severe fiscal crisis in 1983 when the project's managers were finally able to persuade Congress to vote extra emergency funds to save it. He takes us from seemingly insuperable technical problems to brilliant solutions and lets us be there for the building of the telescope and the research detectors that go with it.

The image of the scientist as lonely scholar in his laboratory is fading fast. Inevitably, as the mysteries of nature become ever more subtle, more complex apparatus are needed to penetrate them, and big science is the order of the day. And members of Congress, science specialists in the Office of Management and Budget and in the Office of Science and Technology Policy, as well as scientists and people throughout Government and industry who are concerned with science policy, have to deal with such issues as: What is the proper balance between supporting large facilities and supporting individual investigators? How do we measure out the support between one science and another, or that given to people in major universities and those in lesser institutions? And, underlying all, what is the proper level of support of scientific research in our society?

"THE SPACE TELESCOPE" manages to illuminate all of these subjects. The writing is spare and clear. Technical matters are explained and described, and will give no trouble to the general reader. The cast of characters is huge. Astronomers come in many flavors: the ground-based astronomers concerned about their own funding, the planetary scientists in competition with the cosmologists, and those who choose to ply their science within the NASA bureaucracy. Rivalry between the Goddard and Marshall laboratories plays a crucial role in the drama, and the industrial contractors, with their technical strengths and managerial weaknesses, are great characters. Mr. Smith marvels at the residue of scientific exhilaration that remains after so many years of frustration. The lesson is that big science doesn't necessarily erase the traditional joys of intellectual engagement.

A widely held view in Government now is that this nation must handle its science more coherently. In the executive branch, science is done in a variety of agencies: NASA, the National Science Foundation, the National Institutes of Health and the Departments of Defense, Energy and Commerce, to name a few. Even the most courageous and forceful of science advisers to the President must be daunted by the prospect of trying to bring coherence to the aims of the lords of so many executive strongholds.

"The Space Telescope" tells of how a lack of coherent science policy produces decisions that are only in part driven by science and are often dictated by such extra-scientific factors as Governmental agency expansionism, the desire of Congress to spread Federal spending equitably around the country and less noble aims. When such forces come to bear on a big science project like the space telescope, the consequences can be devastating. With exquisite clarity, Mr. Smith exposes penny-wise strategies that lead to less science, and more expense, in the long run. That is why "The Space Telescope" is so valuable. As a case history, it touches on all the issues, but with the drama of specific incidents involving real people and institutions. One cannot but compare the space technology story and the still unfolding play of the superconducting super collider. The super collider is a huge particle accelerator for which initial construction funds have been appropriated. It is to be built in Texas, and it is scheduled to be completed by the end of 1998. Before one shovel of Texas soil is dug, the project is in its ninth year. Recent news items indicate new cost estimates, and the super collider may be facing its "Black Saturday." It was conceived in the same system of chaotic science policy procedures as the space telescope, and anyone familiar with it will feel secure in saying that the lesson to be drawn from Mr. Smith's book can be generalized.

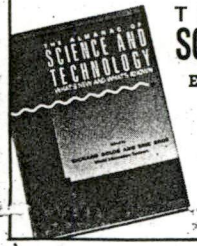
We need big science if we are to continue to be an industrial society. However, if we don't clean up our act — in the executive branch, in the Congress and in the scientific community — we will continue to have projects that fail (Mr. Smith mentions a few) or, at best, we will see scientific objectives compromised and costs escalating and we will find it increasingly difficult to maintain in the scientists that hot flame of awe, mystery and joy at the doing of science. One fault that can be found with this book is that the author does not exult enough in the fact that, after all its troubles, the telescope is complete, assembled and waiting for its mission, to begin the exciting task of providing humanity with a new window on the universe. □

1) Which of the following gases contribute to the greenhouse effect?
a. nitrogen
b. carbon dioxide
c. methane
d. a and b
e. b and c

2) About how many acres of tropical forest are cleared each year?
a. 30 million
b. 5 million
c. 1 million
d. 200,000
e. 10,000

3) How much hazardous waste is generated in the U.S. each year?
a. 50,000 tons
b. 4 million tons
c. 250 million tons
d. 2 billion tons
e. 100 billion tons

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ANSWERS: 1) b, 2) b, 3) c

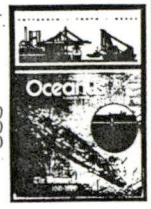
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BODY:

THE TRANSPORMING PRINCIPLE: DISCOVERING THAT GENES ARE MADE OF DNA, by Maclyn McCarty. W. W. Norton & Company, Inc. ($ 14.95).

Between 1604 and 1618 Johannes Kepler published the results of his lifelong studies of the motion of the planets, based on the remarkable naked-eye observations made by his teacher Tycho Brahe. Kepler's work established the heliocentric view of the planetary system and formulated its geometrical interpretation in the laws that go by his name: Kepler's three laws of planetary motion.

Thinking about Maclyn McCarty's The Transforming Principle, and reflecting on the history of the discovery it describes--the DNA nature of the gene-transforming substance of the pneumonia bacillus--I was struck by an analogy between Kepler's achievement and that of Oswald Avery, Colin MacLeod and Maclyn and McCarty. Both advances provided factual and logically satisfying pieces of evidence that explained many converging but confusing observations. In both cases the factual conclusions were reached before they could be explained in terms of mechanisms.

More than half a century elapsed between Kepler's proclamantion of the laws of planetary motion and Newton's interpretation of them in terms of forces acting at a distance and universal gravitation. Only nine years separated the classic 1944 article by Avery's group of the DNA nature of the transforming principle and the discovery of the double-helix structure of DNA by James Watson and Francis Crick. Science moves faster in the 20th century.

Newton's gravitational theory and Watson and Crick's double-helix model of DNA had an aura of abstract finality, of all-encompassing "revelation," that put them beyond the range of normal discovery --they were the leaps with which science breaks into new states of integration. In contrast, the achievements of Kepler and Avery were ordinary science--intelligent, stupendous, but not exceptional as feats of the human intellect--and neither of them took the scientific world by storm. Kepler's laws were probably unknown to Galileo in 1632; the discovery of the DNA nature of the extract that transformed the pneumonia bacillus got a mixed reception. It was disputed by biochemists, more or less ignored by bacteriologists, and was welcomed only by those geneticists who had been flirting with thoughts of genes and DNA. The background of this discovery, the history of its reception and the personalities of its reception ad the personalities of the participants make a fascinating story.

Maclyn McCarty's book is a genuinely intimate and knowledgeable account of the transforming principle's discovery and its bearing on the later deciphering of the DNA double helix. Of the previously published histories of

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the achievement it is complemented in these respects only by Rene Dubos The Professor, the Institute, and DNA. The sytles of these two authors are as distinct as one might find in the writing of two serious scientists. Dubos' prose is sensitive, vigorous and assertive. His narrative is marked by worship of Louis Pasteur and a devoted if puzzled admiration for Oswald Avery. McCarty's book is both a dry, low-key autobiography and a precise step-by-step report of the research that led to the discovery. It is a model of sober restraint, presenting the author and his colleagues as well as their critics without sentimentality. McCarty is almost touchingly precise in assigning to each statement and recollection the degree of certaintly or uncertainty with which he can warrant it.

Out of the two books--Dubos' and now McCarty's--there emerge, painted with different palettes, the personalities in the story, particularly that of Avery, who was known as the Professor to most colleagues (an appellation that was shortened to Fess among his closest associates). The McCarty book also makes it clear that the TP discovery was outside the main lines of genetic and biochemical research, at the limit of the almost pathetically primitive (by 1986 standards) technology of the time. Simultaneously McCarty illustrates in a paradigmatic way the opportunistic process of research at the frontiers of science: the shrewdness required to grasp at disparate leads and approaches.

The story of the discovery can be summarized in a few paragraphs. It began in 1928 when the British bacteriologist Fred Griffith, puzzled by the frequent occurrence of multiple "types" of pneumococci--the pneumonia bacilli--in the lungs of a single patient, wondered whether the virulent types, each of them characterized by specific reactivity with an appropriate serum, could interconvert. Griffith injected mice with a mixture of nonvirulent bacilli together with heat-killed virulent bacilli of a specific "type." Some mice died, and in their lungs Griffith found live virulent bacilli of the type that had been killed. Many careful controls persuaded Griffith that the virulent pneumococci (referred to as S, for smooth colonies) had not just been revived: the nonvirulent ones (called R, for rough) had been "transformed" to virulence and had acquired the "type" of the dead ones.

Griffith's report fell on prepared soil at the Rockefeller Institute's pneumonia laboratory. Pneumonia, in those preantibiotic days, was the worst cause of death in the industrial world. A very, first had isolated the substances that surround virulent pneumococci and are responsible for their virulence. Then he had shown that each type (I, II, III, . . .) is associated with a specific substance and that each substance is responsible for the reaction of a type with its corresponding antiserum. This was a critical advance in pneumonia epidemiology, one that promised the possibility of specific vaccination.

Later Avery had brought Michael Heidelberger into the pneumococcus field and together they had proved that the specific capsular substances of pneumococci are complex sugars called polysaccharides. The discovery of the capsular substance had revolutionized immunology by proving that molecules other than proteins could elicit antibody responses in animals. At this point Avery had brought Rene Dubos to the Rockefeller Institute to search for enzymes that degraded the pneumococcal polysaccharides--and CUBE can generate images much like the ones shown in Banchoff's graphic sequence. With successive rotations through small angles in the third and fourth dimensions, readers may see the two crude toruses balloon, pinch off and regenerate much like their smoother

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cousins in the illustration of the rotating hypersphere. Dubos had succeeded: his enzyme specifically degraded type III polysaccharide and could protect mice from an injection of virulent bacilli.

When Avery read Griffith's report, he saw its importance and promptly got one of his colleagues, Martin Dawson, to repeat Griffith's experiments; Dawson's work confirmed Griffith's conclusions. Then Dawson and Richard Sia went further: they succeeded in proving that transformation of R pneumococci into specific S types could take place in a test tube rather than only in a living animal. This opened the way to precise experimentation. The next step, also taken in Avery's laboratory, was Lionel Alloway's finding that transformation did not require whole killed S bacterial cells: extracts of dissolved pneumococci, for example type III, could transform R cells derived from type I or II into live S cells of type III. The problem thereby became a biochemical one: the separation and identification of a "transforming principle" (TP) from the mixture of substances in the bacterial extract. Avery's name does not appear in any of the articles published by Dawson or Alloway, yet it is clear that Avery was and remained the driving force in the research.

Remarkably, no other investigative group jumped in to exploit Alloway's promising finding. At the Rockefeller Institute the TP research project moved at what by today's standards appears to have been a surprisingly leisurely pace, driven by Avery's conviction of the importance of identifying the transforming principle and constrained by the career requirements of a series of young medical researchers. Avery's laboratory was a most desirable center for the training in research of scientifically minded physicians, several of whom followed Alloway on the TP project. At times progress was also slowed by Avery's health problems, which led to a thyroidectomy for Graves' disease.

Enter finally Colin MacLeod. With him the effort to purify TP began in earnest, and yet it still progressed at a heartbreakingly slow pace. In their search for the transforming principle MacLeod and Avery methodically excluded one by one most components of their S-cell extract. Neither Dubos' enzyme, which broke down the polysacharide, nor any of several enzymes that destory proteins affected the TP activity. Tons of bacterial cultures had to be prepared for these tests and MacLeod invented the needed instrumentation as he went along.

By the time MacLeod left Avery's laboratory in 1941 many things had happened. For one thing, the arrival of sulfonamide drugs had made research on pneumoccocci less urgent if not altogether obsolete. He and Avery had to persuaded themselves, as well as the institute's administration, of the desirability of continuing the study of TP. By then they had become convinced that TP must be nucleic acid--either RNA or DNA, substances then distinguishable only by uncertain chemical tests. MacLeod moved a mile and a half south from the Rockefeller Institute to the New York University Medical School. He remained in close contact with Avery but, surprisingly, did not pursue TP research in his own laboratory. It seems reasonable to assume that Avery was jealously keeping complete control of his pet project.

When McCarty replaced MacLeod, he may already have heard about the TP problem, but he was naive with respect to the substance of the work. His previous experience had been in pediatric bacteriology; still, he brought to the TP group the fresh drive and solid competence of a well-trained medical investigator. Methodically he and Avery refined the purification of TP,

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perfecting their techniques and pursuing every clue, such as the "stringy" appearance of the active fraction in an alcohol precipitate and the loss of activity on drying. Enzymes that degraded RNA did not affect this transforming activity. Most important, they proved that the transformed bacteria and their descendants became permanent sources of more TP of the same kind. The TP reproduced itself.

By 1943 McCarty and Avery felt certain that TP was DNA--in fact, pure DNA. It was not an easy certainty: in 1943 no one knew what pure DNA really was. Geneticists, particularly chromosome experts, had expected DNA to have something to do with genes, but they were outnumbered by chemists who claimed it could not. The chemists believed DNA was only a monotonous polymer, a molecule without importance, at most a dull portion of something that was called "nucleo-protein." And McCarty still had no reliable test for DNA. Altogether the proof of the DNA nature of TP was anything but "rigorous," the term by which Horace Judson described it in his summary of the TP story in The Eighth Day of Creation. Yet Avery and McCarty, joined by MacLeod, decided to go public.

No pressure or competition or sudden emergence of irrefutable data precipitated the decision to publish. In retrospect it appears that at this point Avery may have decided to exert the prerogative of the experienced leader. He exhibited the assertiveness that comes from the habit of success: a willingness to impose on a still confused mass of data a certainty that is emotional as well as rational. Such a source of certainty in science is unrecognized by those who believe certainty comes only after innumerable controls and attempts to disprove. The certainty Avery exhibited is more akin to illumination, a sudden vision projecting the possibility of an intellectual leap. What happened in the TP research at this point may have been the maturing of the conviction that the transformations observed in pneumococci were not just an idiosyncratic phenomenon of bacteriological interest but a stupendous lead to the chemical basis of hereditary specificity.

The article by Avery, MacLeod and McCarty, which appeared in the February 1, 1944, issue of the Journal of Experimental Medicine, is cautious in its conclusions but revealing in its opening sentence: "Biologists have long attempted by chemical means to induce in higher organisms predictable and specific changes which thereafter could be transmitted in series as hereditary characters." Note the precise wording, which could have satisfied any card-carrying geneticist.

Earlier in 1943 Avery had written his brother a letter, which fortunately became part of the public record because Avery showed it to Max Delbruck, who after Avery's death insisted that it be published. In the letter, reproduced in part in the McCarty book, Avery sounds cautiously but deeply stirred: "After innumerable transfers and without further addition of the inducing agent, the same active & specific transforming substance can be recovered far in excess of the amount originally used to induce the reaction. Sounds like a virus--may be a gene . . . the problem bristles with implications . . . It touches genetics, enzyme chemistry, cell metabolism & carbohydrate synthesis, etc."

Whether or not Avery and his colleagues were aware of it, there was something in the air at the time those words were written. Just as the classical biochemistry of energy metabolism reached its apogee, marked by Fritz Lipmann's great review article of 1941, genetics was entering new and greener pastures. In December, 1940, George Beadle and Edward Tatum had reported their first

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results on the biochemical genetics of the bread mold Neurospora crassa--the work that was soon to lead them to put forward the one-gene, one-enzyme hypothesis. And in 1943 Delbruck and I had published in Genetics the first demonstration that bacterial variants originate by spontaneous mutation.

Bacteriologists were then by and large oblivious of genetics. Many of them accepted uncritically hypotheses such as one put forward by the physical chemist Cyril Hinshelwood, which ascribed heredity and variations in bacteria to complex flow equilibriums in chemical reactions. In his 1976 book on Avery and the Rockefeller Institute, Dubos, one of the most biologically minded bacteriologists, remarks that as of 1945 he "could find in the literature only a few sketchy experiments to support the view that . . . some phenomena of bacterial variability nevertheless probably fall within the fold of classical genetics." It is a fact that most bacteriologists did not read Genetics.

Yet people such as Avery, MacLeod and McCarty certainly knew or sensed what was in the making. Theodosius Dobzhansky, in the second edition of Genetics and the Origin of Species, published in 1941, gave an account (the first one to come to my attention) of the transforming-principle story and its possible bearing on the study of gene mutations. In the summer of 1941, at Cold Spring Harbor, Dobzhansky developed a close intellectual relationship with Alfred Mirsky. Mirsky was a Rockefeller Institute biochemist who, in 1942, gave McCarty some useful leads on handling DNA and even collaborated with him in one set of experiments. Mirsky later became one of the severest critics of the Avery group and of their conclusion that TP consisted of DNA. He was critical partly on grounds of rigorous biochemical standards and partly, perhaps, because of a grudge over his abortive participation in the research.

Thus the Rockefeller Institute must have been abuzz with talk of biochemical genetics. It is reasonable to suppose (the supposition is not contradicted by anything in McCarty's book) that the profound biological significance of their TP work may, sometime between 1942 and 1943, have become so urgently clear to Avery, MacLeod and McCarty that the realization induced even the supercautious Avery to publish what was a fact--even though a fact validated as much by conviction as by hard evidence, a fact less fully convincing to experimentally minded critics than Kepler's laws might have been to Huygens and Newton.

Here I shall take a closer look at the authors of the 1943 article and its fateful statement. I have known all three of them personally. It is ironical to say that Avery stood out among the three. He was a "petite," gnomelike man with piercing but kindly eyes under an enormous forehead and a bald top, which he constantly stroked while he delivered to visitors his customary recitations of the pneumococcal transformation story (McCarty refers to these discourses as the "Red Seal Records"). His professional stature was apparent, as Dubos pointed out, in his complete lack of self-importance. He was unfailingly gentle, courteous in an unaffected way, yet prim and restrained. He had a sharp, teasing wit: I was told of his habit of greeting any colleague who had published a short preliminary note with the remark, "I have seen your advertisement." One day in early 1946 he walked into the Rockefeller Institute library before lunch just as I had found in the current issue of Experientia an article by the French bacteriologist Andre Boivin reporting DNA-mediated transformation in the bacterium Escherichia coli. When I showed Avery the article, he read it quickly, asked me to join him for lunch, and when a few of his co-workers sat down with us he whispered to them, "We seem to have continental support."

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I visited Avery's laboratory at least three times between 1943 and 1945. I was interested in the connection between the TP work and my own research on bacterial mutations, wondering if the DNA might not transform a special class of mutant bacterial cells. (I worked for a few months on this topic and quit when later work in Avery's lab made my idea untenable.) Avery insisted that first of all he had to be absolutely sure of the chemical nature of the transforming principle.

So did McCarty, who by that time was searching for further proof of DNA involvement. McCarty's personality was radically different from Avery's. Intensely serious and alien to discourses, rather shy, laconic in explanation, he was a model of the serious medical researcher.

Jollier and more easygoing than McCarty was MacLeod, whom I came to know much better when, after the TP discovery, he became actively interested in bacterial genetics. In 1946 MacLeod asked Vernon Bryson and me (I was then spending a year at Cold Spring Harbor) to lead a genetics seminar at N.Y.U., where he headed the microbiology department. This turned out to be a delightful experience with a group of bright, intensely interested young people. In those few years bacteriologists had discovered genetics--thanks to the transforming principle. Dobzhansky was encouraging his best students to work in bacterial genetics (one of them, Harriett Taylor, joined Avery in 1945). And Tatum and Joshua Lederberg had discovered mating between E. coli cells.

The response of biochemists to the identification of TP with DNA was more cautious. Their bias was anchored in the belief that DNA, which when degraded yields just four components--the four "nucleotides" called A, G, T and C for short--had a simple repetitive structure (AGTC-AGTC or some other repeated sequence). Therefore, the chemists reasoned, DNA could not serve to encode any specific genetic information.

It is remarkable that this hypothesis, which had been proposed by P.A. Levene without any clear analytical evidence, had taken root in the mind of the few biochemists interested in nucleic acids--an unquestioned assumption that reminds me of the equally unchallenged assumption of astronomers before Kepler that planets should move in circles, whether around the earth or around the sun. The circle, according to Greek philosophers, was the ideal geometric figure. Levene's hypothesis, like that of Greek astronomers, appears to have been initiated by an unconscious desire to impose an ideal order of the simplest possible kind on another aspect of nature. The "sacred rage for order" (to use words from a poem by Wallace Stevens) when carried too far can generate hidden assumptions. The unmasking of such assumptions may in turn become the key to new advances.

Apart from Levene's specific model of DNA, a major obstacle to the acceptance of Avery's conclusion by biochemists, even after more solid evidence was provided by McCarty and by other Avery associates, was the lack of a plausible DNA "structure" on which to hang the specificity required of a genetic material. Proteins were "proteic," that is, multiform in structure. Their specificity was demonstrated, for example by serological tests. DNA instead remained mysteriously amorphous in the mind of biochemists. Bacteria, particularly pneumococci, might, it was suggested, be a freak class of organisms. Even if bacterial genes contained DNA, what did this prove about genes in fruit flies or human chromosomes?

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The relatively long delay between Avery's discovery and its generalization to other genetic materials encouraged all kinds of questioning. It is still a tormenting recollection in my own scientific life that I (who had been so close to the TP story, had written a detailed report about it in 1947 and had even briefly worked on it) could in a 1951 paper suggest that the genetic material of a bacteriophage might be protein--a few months before Alfred Hershey and Martha Chase reported their brilliant experiments identifying DNA as the phage genome.

Geneticists had for years been told by some of the shrewdest cytologists, who were examining chromosomes by means of dyes more or less specific for protein or for nucleic acids, that DNA might be part of the genetic material. And yet others (besides myself) did not fully internalize the idea of the possible universality of Avery's discovery. Our hesitation is even more puzzling in retrospect when we consider that within months after the publication of the Luria-Delbruck test for mutations in E. coli, several genetic laboratories had taken up that lead. The failure of the Nobel committee to recognize the Avery work is particularly puzzling since one of the major experts in the chromosomal location and distribution of DNA was a member of the committee. Perhaps it was thought to be unseemly that the gene's identity should emerge from bacteriology.

The story of the fortunes of the TP discovery took a curious twist later when Gunther Stent, a molecular biologist and philosopher, suggested that Avery's discovery had failed to be appreciated because it was "premature." The doctrine of prematurity in discovery has provided a prime subject for arguments among historians of science in spite of the obvious circularity of the concept: is a discovery premature because it is not appreciated, or vice versa? More simply, does a discovery seem premature to those who missed its significance or failed to read or learn about it? The identification of TP as DNA was neither ignored nor unrecognized. It was questioned by some and embraced by others, and the universality of its impact remained uncertain. What Watson and Crick provided in 1953 was the chemical underpinning for the generalization.

Avery's work was unknown to Watson (he tells me) when, at the age of 18, he came to Indiana University as a graduate student. There he heard of pneumococcal transformation in my virology lectures and in Tracy Sonneborn's genetics course. Watson's fascination with DNA, which was both a rational and an emotional commitment (note the two key ingredients of science), dates from those days. It was this fascination that years later led him (with my encouragement and in spite of Delbruck's misgivings) to pursue the biochemistry of DNA. He ultimately stirred Crick to enthusiasm for that substance and drove the two of them to their great discovery, the DNA double helix: two complementary polynucleotide chains, each bearing complete directions for replication and each providing precise information for protein synthesis. DNA can be "transcribed" into RNA, which directs the synthesis of proteins.

This discovery stands at the center of biological science; it has both a towering finality and an aesthetic beauty that give it a stature comparable to the stature Newton's dynamics has enjoyed for the past three centuries in physics. Out of the double-helix model came a transformation of biology--the vision of a unity even more convincing than the great Darwinian synthesis. The clarifications of protein synthesis and of its regulation through control of gene action (a control itself mediated by specific protein-DNA interactions) are the high points of the new biology and now promise to solve the mystery of the development of complex organisms.

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Reflecting on the prospects for further advance, one may be tempted to take an attitude of romantic pessimism: all that remains is either applications or epistemological disquisition. Such was the mood in physics around 1900--after Maxwell and Boltzmann, and just before Curie, Planck, Rutherford, Einstein and Bohr entered the picture. And so there is hope for the young biologists who dream of discovery.

Where might the "new" come from? I can think of two sources: areas that are today beyond the pale of molecular biology and areas where the current paradigm may again be found incomplete, as it was in physics. History, at least, offers the possibility that unwarranted hidden assumptions may be recognized in the present framework of molecular biology.

One area of persistent obscurity is the "cell theory." Can genes make a cell? Is the organization of a cell as a domain defined by a closed membrane fully coded in the genes, or does the membrane represent a self-priming pattern of organization? An answer to this question will require evidence for or against the possibility of synthesis of cells from subcellular elements. It may be sought by inquiring into the origin of polyphyletic cell types such as cyanobacteria or eukaryotic cells, which appear to have arisen from the merger of elements having different evolutionary origins.

The paradigm of molecular biology has already withstood several challenges that superficially seemed to bring into question its original formulation: the role of DNA as the genetic material and that of protein as the stuff of catalysis. Several viruses have RNA genomes, which are reproduced either through an intermediary DNA or directly as RNA. This, however, simply means that both kinds of nucleic acid can embody in their nucleotide sequences information capable of being copied. In fact, it now appears that a substantial portion of the DNA genome of animals probably originated with the copying of RNA into DNA sequences that were subsequently incorporated into the chromosomes. As for catalysis, the recent finding that an RNA molecule can in some instances catalyze its own restructuring does not shake the central notion that not genes themselves but only their products--mostly proteins but exceptionally also RNA--can function as catalysts for specific steps of cellular chemistry.

There is another twist beyond the simple picture of heredity based on mutation-prone but otherwise stable DNA sequences. It is the discovery that the response of the animal body to the innumerable variety of foreign substances involves a reprogramming mechanism for creating new DNA sequences--new genes--in the cells of the immune system. This discovery illustrates a subtle complexity of heredity based on DNA structure. The genetic endowment of an animal is more than a set of genes; it is a range of possibilities actuated during life by influences that selectively amplify clones of immune cells with the appropriately responding genes.

Molecular biology would be truly revolutionized by proof that substances other than nucleic acids can have a genetic role, that is, serve as molecular templates for the replication of themselves or for the production of nucleic acid chains. It has been suggested that amino acid sequences, primitive proteinlike molecules, might have had roles as templates in precellular stages of the evolution of life.

Whether a revolution in molecular biology is forthcoming, and whether any such revolution will emerge from novel findings at the molecular level or from

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resolution of epistemological quandaries, perhaps in dealing with the biology of the human mind, is for the future to tell. Avery and his co-workers were not after a revolution in science. They sought the answer to a specific question, the nature of TP, and it turned out to be a profoundly important answer. This is the normal path of the scientific enterprise: putting together the pieces of a puzzle whose design comes into existence only as the pattern grows.

Max Delbruck, speaking with Horace Judson, once pointed out that "science pretends that the scientist is immortal," a thought that caused him to worry lest it make scientists less human, less concerned about the mystery of human life. Is there for a biologist any true immortality other than having put into place, as Avery, MacLeod and McCarty did, a fragment that illuminates the overall pattern of the puzzle of life?

TYPE: ReviewThe transforming principle: discovering that genes are made of DNA; Book reviews

SUBJECT: Books, reviews, etc.; DNA, research; Genetic research, history

LOAD-DATE-MDC: June 17, 1988

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HEAVEN'S SCOPE

STARS

By Riccardo Giacconi

When the Hubble Space Telescope (HST) lifts off with the space shuttle *Discovery* next year, it will take with it the hopes of thousands of people who have dedicated their lives to it.

The HST is the first of the great observatories that NASA plans to put into space within the next decade. It will be the largest civilian observatory ever lofted. The size of a school bus, it weighs all of 12.5 tons on the ground.

The HST possesses a 94-inch reflecting telescope and five other major instruments: two cameras to image pictures in the visible, ultraviolet, and infrared ranges of the spectrum; two spectrometers that record data in the optical and ultraviolet bands; and a photometer that measures visible light. Software programs, run on banks of computers, control the HST and manage its data collection.

By placing the HST above the obscuring blanket of the atmosphere, we will be able to see images 10 to 30 times sharper than ever before. This improvement is equal to the one achieved by Galileo when he first used lenses to examine the heavens in 1609. To illustrate the HST's potential impact, consider my own interest, cosmological research. One of the biggest questions in astrophysics today concerns the formation and evolution of the universe after the Big Bang. At the moment the life span of the universe has been determined only with the precision of about a factor of two. That is, it could be as short as 10 billion years or as long as 20 billion.

Why do we want to know the universe's age more precisely? Because knowledge of this cosmic clock is necessary to understand how the galaxies, the stars, the planets, and, finally, life itself formed and evolved. The HST should be able to zero in on the universe's age to within 10 percent.

The HST's flight was first scheduled for 1984. This holdup, caused almost entirely by the *Challenger* tragedy, has created problems for a generation of astronomers. Because of the delays—in the HST and the space program in general—there has also been something of a hiatus in space astronomy.

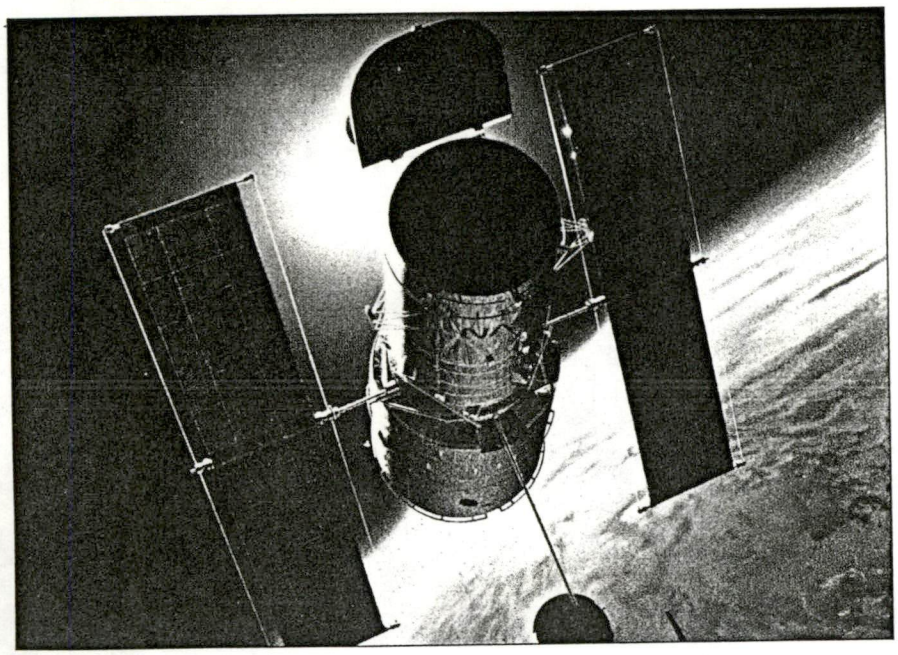
This has meant that the computer hardware aboard the telescope is old technology. There is a joke going around that today's personal computers are more sophisticated and powerful than the computers aboard the HST. In fact, this is true. But while the HST is a little dumb, that will not be a real impediment to the science we want to carry out. We just need to do more thinking on the ground to help it.

The flight of the HST will provide a great challenge to the Space Telescope Institute's staff. We are the first members of the scientific community NASA has entrusted to conduct one of its own programs. This will test our ability to change our viewing targets when unexpected opportunities arise, such as a newly exploding supernova or the uncharted arrival of a comet.

The funding we will disperse on behalf of NASA to the user community will aid greatly in making the best scientific use of HST. These funds are roughly equal to the current level of National Science Foundation grants for all of astronomy. They will be for analysis of the telescope's data. What's more, there will be about 50 postdoctoral fellowships run by the institute as well as 50 junior faculty positions funded by NASA.

Finally, we expect the participation of amateur astronomers, who will get some of their own observing time on the HST. We hope this will lead many young people to become curious about astronomy and science.

During the next 15 years of the HST mission we will discover much. A future generation of astronomers will be looking to answer even more difficult questions than we are posing today. This will lead them to build a more powerful space telescope, perhaps even to create a new astronomy. For me, all of this is riding on the launch next spring.



Hubble, Hubble, toil, and trouble: Next year the telescope will finally soar.

Riccardo Giacconi has been the director of the Space Telescope Institute since its creation in 1981.

Angel

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Adjusting Man's Eyes on Heavens

■ **Astronomy:** The Hubble Telescope will improve man's vision in space from 20/200 to 20/20.

By LEE DYE
TIMES SCIENCE WRITER

Charles F. Bolden, 43, who served as a combat pilot with the Marine Corps in Vietnam, knows exactly what he will be doing as the world's most pampered piece of hardware is lifted slowly out of the shuttle Discovery's payload bay this week.

"I will just sit there and hold my breath," says a man who flew more than 100 missions over Vietnam, Laos and Cambodia in the early 1970s.

As the Discovery's pilot, Bolden's main job will be to look over everybody else's shoulder—"chor-eographing," as he puts it, the delivery to space of the most sophisticated and most expensive satellite ever built, a jewel of a telescope that was created out of the desire to probe the deepest secrets of the universe.

The Discovery is scheduled to lift off at 5:47 a.m. Tuesday (PDT), and the telescope is to be deployed about 23 hours later.

The $2-billion-plus instrument, named for Edwin P. Hubble, the astronomer who in the 1920s discovered that the universe is expanding, is destined to forever change humankind's perception of itself and its place in the universe, said Lennard Fisk, chief scientist for the National Aeronautics and Space Administration.

That's a tall order, but the Hubble, as it is called, is no ordinary piece of equipment. The satellite is a nearly perfect testament to engineering excellence and a window onto worlds never seen before.

And it's not just for the scientists.

Pictures: HUBBLE, A16

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HUBBLE: Putting 25,000-Pound Telescope in Place Is Delicate Task

Continued from A1

"Everybody who has ever looked up at the nighttime sky and seen a star or a planet can relate to this thing," observed Bolden.

"The Hubble is a half billion times more sensitive than the human eye," Fisk said.

Free of atmospheric interference, it will see objects billions of light years away with up to 10 times the sharpness of ground-based telescopes.

"It's as though we currently have 20 over 200 vision and we are about to be given a pair of glasses that brings the universe to 20/20 clarity," Fisk explained.

The Hubble, years behind schedule, has already been assigned a long list of astronomical targets, but most experts predict that the orbiting telescope will turn up a few surprises.

"You can be sure that what we anticipate today will not be the fundamental discoveries of Hubble," Fisk said. "Nature is much more imaginative, and very much more clever than we are, and it is bound to amaze us."

But before all that happens, the Hubble must first be delivered to space 380 miles above the Earth, and that's no simple task.

The entire mission, for example, would be jeopardized if the Discovery failed to reach that record high orbit. But beyond that, the deployment of the 25,000-pound telescope is an extremely delicate operation fraught with potential problems. The huge solar arrays, or panels, that will supply the telescope with the power to run its instruments could fail to open, or the lens cap that is designed to protect the delicate telescope from solar radiation could jam. And there is always the possibility that the 43.5-foot-long satellite could bang against the side of the shuttle during deployment.

These or other problems could require Discovery's astronauts to venture outside the shuttle for telescope repairs. It would be America's first "spacewalk" since 1985.

The telescope, which is about the size of a school bus, will have to be lifted gently out of the Discovery's cargo bay by the shuttle's remote manipulator arm. Astronaut Steven A. Hawley, 38, must perform the difficult task of running the arm perfectly because there is very little clearance between the precious cargo and the sides of the payload bay.

The difficulty of Hawley's task stems in part from the fact that the telescope will block his view as he lifts it out of the payload bay, forcing him to rely on remote television cameras to guide him through his chore. Furthermore, the robotic arm is like a giant extension of the human arm, except it doesn't always work perfectly.

Hawley will have to manipulate two hand controls simultaneously, one to lift the telescope and the other to keep it from yawing or pitching back and forth. He will have to move it very slowly, because tolerances are about one inch on each side in the early stage.

"The complexity arises because with large payloads and slow rates the arm doesn't really give you pure motion," Hawley said. "You get some cross-coupling because it's a mechanical device and it doesn't do purely what it is supposed to do."

Some of the arm's joints will slip slightly, and the telescope is so massive that it will tend to drift as Hawley lifts it out of the cargo bay. So if he doesn't know exactly where it is, and if he doesn't compensate for any drift, he could bang the instrument into the side of the shuttle as he lifts it up.

"The part that is tricky for me is to make sure that I am able to monitor which way it is going rather than the direction I am asking for, and if necessary correct that," Hawley said. "But the tolerances are very tight when (it is down low in the cargo bay)—I mean an inch."

It is fitting that this job should fall to Hawley. He is an astronomer by training, and he spent years at the UC Santa Cruz, studying the distant celestial objects that will be the Hubble's richest playground.

"I'm not an objective observer," Hawley said during a recent interview in Houston.

Many of the scientists at the Space Telescope Science Institute in Baltimore were classmates of Hawley's.

"I know these guys, and they will be watching me," Hawley said. "I will confess to more nervousness about this" than anything he was asked to do on his two previous flights "because I feel so close to it. I have the opportunity to do this right or not. That bothers me a lot more than the other things I have done."

Hawley's role should end—if all goes according to plan—after he has lifted the telescope up to the point where it can be released, a chore that should take about an hour.

But that doesn't mean the Discovery's crew will be finished.

Astronaut Bruce McCandless, 52, one of NASA's most respected engineers who has been working on the space telescope for 12 years, and Kathryn D. Sullivan, 38, the first American woman to do a "spacewalk," will be ready to lend a gloved hand if they are needed. Their job, if anything goes wrong, will be to go outside and fix it.

McCandless, who was the first man to do an untethered spacewalk in 1984, is a celebrated bird watcher and he admitted he would like to venture outside the spacecraft and try his wings.

"But I would not like the reason for it to be that there is a failure with the telescope," he said in an interview.

Over the last several years McCandless and Sullivan have spent many hours in a wet tank at the Johnson Space Center in Houston, practicing every maneuver that is likely to be required if the deployment encounters difficulties that can only be solved by sending someone outside.

The training has prepared McCandless and Sullivan for a possible spacewalk, and it has paved the way for future generations of astronauts who will be asked to return to the telescope many times over the next 15 to 30 years to do everything from changing its batteries to adding major instruments.

The Hubble is the first satellite designed to be maintained on orbit by shuttle crews, but the working environment in space is quite different than it is on Earth. So these two veterans have spent years making sure that if something does go wrong, somebody can fix it.

"We have been doing the unselfish job of making sure that someone other than ourselves gets a good setup when they are assigned to a maintenance mission," said Sullivan, of Woodland Hills. "We have taken a look at everything that isn't welded on."

As a result, a number of features, including the electrical connectors, were modified to make the Hubble "user-friendly" for future astronauts.

"We've tried to make it so that when some future crew goes up there they will not find any showstoppers," McCandless said.

This week, however, Sullivan and McCandless could be called upon to make sure there aren't any showstoppers themselves.

Once the telescope clears the cargo bay, experts around the world will sit on the edge of their seats until the next crisis is passed.

During its trip to orbit aboard the Discovery, the telescope's batteries will be charged by the shuttle's electrical system, but the "umbilical" connecting the telescope to the shuttle will have to be disconnected so that the instrument can be deployed.

When it is on orbit, the telescope will use solar panels to collect energy to keep its batteries charged, but the solar arrays must be folded alongside the telescope when it is in the shuttle. So while it is still dangling from the end of Hawley's robotic arm, the arrays are to unfurl and lock in place, and there are many things that could go wrong during that period.

Experts believe they will have no more than about six hours to get the solar arrays deployed and oriented toward the sun before the batteries run too low. Low batteries could endanger some of the instruments aboard the telescope.

"It'll be wringing my hands" during that period, said William Taylor, the telescope's chief engineer, a veteran of many years at NASA.

McCandless and Sullivan will be partially suited so they can leave the relative safety of the shuttle quickly if the solar arrays fail to deploy. They could also be asked to do a number of other chores, like manually remove the telescope's "lens cap," called the aperture door.

Once the telescope has been successfully deployed, the Discovery's commander, Loren J. Shriver, 45, a former Air Force test pilot, will fire the shuttle's smaller maneuvering jets and drop slowly back from the satellite. The Discovery's larger jets cannot be used because they might contaminate the area around the telescope, thus negating one of the main reasons for putting it on orbit.

The Discovery will drop back about 40 miles and baby-sit the telescope for a couple of days, just in case it should have to rendezvous and make emergency repairs.

But in Shriver's view, by that time he will be able to rest a little easier. He is more concerned about the earliest phase of the mission.

"The most disappointing thing for me would be if we couldn't reach the minimum altitude to set the telescope out and would have to bring it back," Shriver said in an interview.

Scientists want the telescope to be in an orbit 380 miles above the Earth, thus forcing the shuttle to fly higher than it has ever flown before. That will leave the telescope within reach of future missions, but far enough in space to minimize the contamination from Earth's atmosphere.

But what if, for any number of technical reasons, the shuttle doesn't get that high? There is no way for the telescope to boost itself to a higher orbit because it does not carry rockets, which would contaminate its environment.

Scientists say they could live with a lower orbit, about 310 miles, that would allow them to maneuver the telescope and use it scientifically while waiting for a future shuttle mission that could push it higher.

Shriver has argued, however, that any orbit that would keep the telescope up for at least a year would be preferable to bringing it back and trying again later. Reentry would severely contaminate the telescope, he said, and the delicate instruments could be damaged on landing.

"The scientific community tends to think in terms of the kind of data they want," Shriver said, "but if they could get on altitude where the Hubble could survive, and if they could get up another flight within nine months to a year, I suspect they would leave it there."

"Are they going to risk bringing it back and maybe never getting it back up there again?" he asked. He suspects, however, that such a decision would be made only at the level of the White House.

Such is the nature and importance of this extraordinary instrument on which so many careers now depend.

When it is all over—the telescope is projected to operate for 15 to 30 years—Hawley expects the Hubble to have accomplished "things that are unique."

"It will be nice," he said, "to be able to say, 'gee, I helped do that. I had a role to play in that.'"

He said that as an astronomer the mission has special significance for him and he does not rule out the possibility that when his days as an astronaut are over he may return to astronomy.

But that depends on what happens this week, he quipped.

"The opportunities that will be presented to me will be profoundly different depending on how the flight goes."

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All Systems Are 'Go' for Tuesday's Shuttle, Telescope Liftoff

By Kathy Sawyer
Washington Post Staff Writer

CAPE CANAVERAL, Fla., April 8—All signs appeared favorable for a Tuesday morning liftoff of the shuttle Discovery and the Hubble Space Telescope, as technicians finished installing the instrument in the orbiter's cargo bay early today.

"This is a very important day for us," said William Taylor, the telescope's chief engineer. "Some of us who have been on the project for a while wondered if we would ever see this day."

The launch of the 43-foot telescope, the most complicated and costly science payload ever carried by a shuttle, is scheduled for 8:47 a.m. EDT Tuesday, almost seven years later than originally planned. Even the weather is expected to cooperate, officials said.

It was 6:24 a.m. EDT when the ground crew at the Kennedy Space Center closed the space plane's cargo bay doors on the complex telescope, which along with its ground facilities cost $2.1 billion.

Named after American astronomer Edwin P. Hubble, the telescope is expected to bring into 10 times sharper focus corners of the universe close to the beginning of time. Its long list of tasks includes searching for the first planet outside of the solar system.

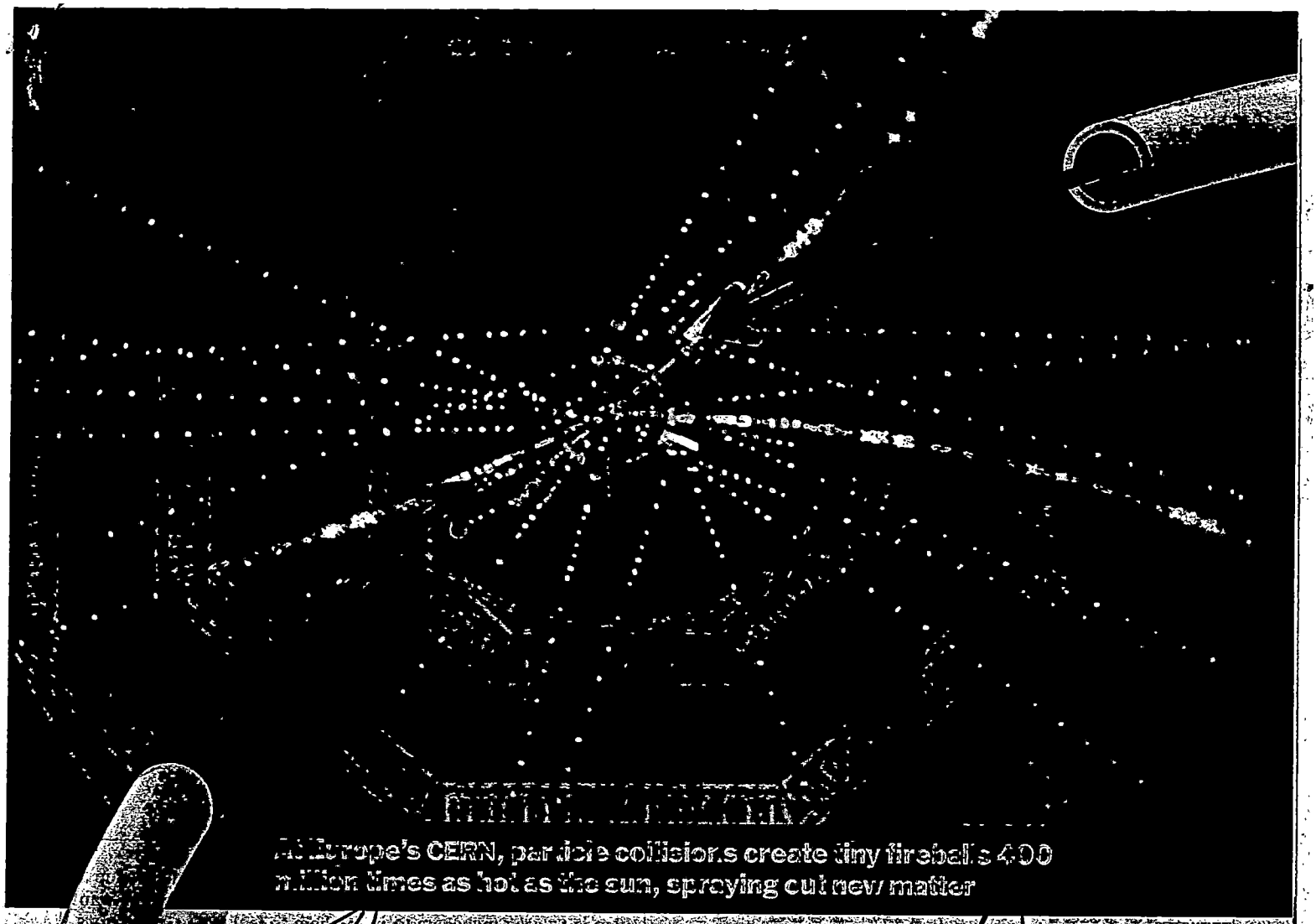
"This instrument has been built to the limits of what technology can provide," said Charles Pellerin, director of NASA's astrophysics division. "This is a voyage very much perhaps like the voyages of Columbus and Magellan, except that it's a voyage of man's intellect into the universe."

The Hubble is to be released 380 miles above the Earth 29 hours after liftoff, following an extensive checkout at the end of the shuttle's robot arm.

Discovery's crew consists of commander Loren Shriver and co-pilot Charles F. Bolden Jr., and mission specialists Bruce McCandless, Steven A. Hawley and Kathryn D. Sullivan.

McCandless and Sullivan are prepared to take a space walk to fix any problems the telescope might develop as it is deployed.

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At Europe's CERN, particle collisions create tiny fireballs 400 million times as hot as the sun, spraying out new matter

PETER MENZEL

Science

COVER STORIES

The Ultimate Quest

Armed with giant machines and grand ambitions, physicists spend billions in the race to discover the building blocks of matter

By MICHAEL D. LEMONICK

The elevator doors opened into a cavernous room in an underground tunnel outside Geneva. Out came the eminent British astrophysicist Stephen Hawking, in a wheelchair as always. He was there to behold a wondrous sight. Before him loomed a giant device called a particle detector, a component of an incredible machine whose job is to accelerate tiny fragments of matter to nearly the speed of light, then smash them together with a fury far greater than any natural collision on earth.

Paralyzed by a degenerative nerve disease, Hawking is one of the world's most accomplished physicists, renowned for his breakthroughs in the study of gravitation and cosmology. Yet the man who holds the prestigious Cambridge University professorship once occupied by Sir Isaac Newton was overwhelmed by the sheer size and complexity of the machine before him. Joked Hawking: "This reminds me of one of those James Bond movies, where some mad scientist is plotting to take over the world."

It is easy to understand why even Hawking was awed: he was looking at just a portion of the largest scientific instrument ever built. Known as the large electron-positron collider, this new particle accelerator is the centerpiece of CERN, the European Organization for Nuclear Research and one of Europe's proudest achievements. LEP is a mammoth particle racetrack residing in a ring-shaped tunnel 27 km (16.8 miles) in circumference and an average of 110 meters (360 ft.) underground. The machine contains 330,000 cubic meters (431,640 cu. yds.) of concrete and holds some 60,000 tons of hardware, including

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nearly 5,000 electromagnets, four particle detectors weighing more than 3,000 tons each, 160 computers and 6,600 km (4,000 miles) of electrical cables. Tangles of brightly colored wires sprout everywhere, linking equipment together in a pattern so complicated, it seems that no one could possibly understand or operate the device. In fact, it takes the combined efforts of literally hundreds of Ph.D.s to run a single experiment.

LEP and other large accelerators have been built to probe the nature of matter on a scale far smaller than that of the atom. The goal is to answer ancient and fundamental questions: What is the universe made of, and what are the forces that bind its parts together? These questions cannot be answered without an understanding of what happened in the Big Bang, the unimaginably hot and dense fireball that 15 billion years ago gave birth to the universe and all it contains.

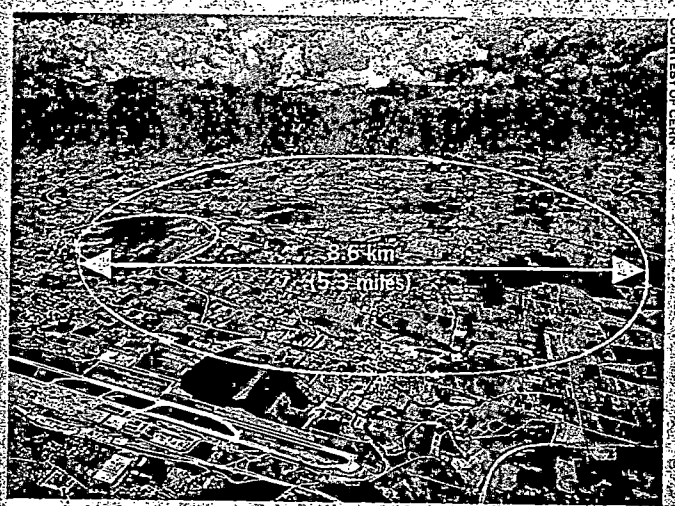
In a very real sense, accelerators are time machines that re-create the primordial fireball in miniature to unlock its secrets. The collision of two accelerated particles releases enormous bursts of energy. But that energy instantly condenses into a new array of particles, some of which may not have existed since the Big Bang.

This power to go back 15 billion years in time has touched off one of the most heated competitions in the history of science, a race that pits Europe's LEP against U.S. entries led by the powerful Tevatron at Fermi National Accelerator Laboratory (Fermilab) near Chicago and the Stanford Linear Accelerator Center (SLAC) in California. Huge teams of physicists at the rival centers are working day and night to discover the next new particle and to explain the behavior of those already found. In recent years, each lab has had its share of triumphs.

But none of the current generation of accelerators are big enough or powerful enough to re-create the very earliest fractions of a second after the Big Bang, where answers to the most intriguing mysteries are thought to lie. So U.S. physicists have embarked on a bold quest: the building of a colossal collider that will dwarf today's accelerators. Called the superconducting supercollider, it will have a tunnel that will circle for 87 km (54 miles) under the cotton and cattle country surrounding Waxahachie, Texas. Expected to be completed around the year 2000, the SSC will cost $7 billion to $8 billion.

That enormous price tag has fueled a growing controversy over how much the U.S. can afford to spend on such megaprojects, especially when the knowledge to be gained is so abstract. Critics complain that the money could be better spent on more practical goals, like fighting poverty and improving education. Some scientists, including many researchers in other branches of physics, fear that funding for the SSC will come out of their own budgets. Cynics have argued that the SSC is just another pork-barrel construction project, being foisted on the public by the powerful Texas congressional delegation and backed by a President from Texas.

Yet the support for a giant accelerator goes deeper than a desire for federal dollars. To many scientists and politicians, national pride is at stake. Proponents insist that the SSC is necessary to keep the U.S. in the forefront of particle-physics research. Americans dominated the field from the mid-1940s to the 1970s, but Europe's CERN started stealing much of the glory in the 1980s. Without the SSC, its proponents contend, many of the best American physicists will emigrate to Europe. In fact, the brain drain has already begun: last year, for the first time, the number of American experimenters working at CERN surpassed the total number of scientists from CERN's 14 member countries who had moved to U.S. research centers.



COURTESY OF CERN

Aerial view of the large electron-positron collider site near Geneva

The international competition has spurred remarkable progress in the effort to understand nature's mysteries. Says theoretical physicist Steven Weinberg of the University of Texas at Austin: "Before, we had a zoo of particles, but no one knew why they were the way they were. Now we have a simple picture." That picture, known as the Standard Model, is based on a set of theories that attempt to describe the nature of matter and energy as simply as possible. The model holds that nearly all the matter we know of, from garter snakes to galaxies, is composed of just four particles: two quarks, which make up the protons and neutrons in atomic nuclei; electrons, which surround the nuclei; and neutrinos, which are fast-moving, virtually massless objects that are shot out of nuclear reactions. These particles of matter are, in turn, acted upon by four forces: the strong nuclear force, which binds quarks together in atomic nuclei; the weak nuclear force, which triggers some forms of radioactive decay; electromagnetism, which builds atoms into molecules and molecules into macroscopic matter; and gravity. An entirely separate set of particles—the bosons—are the agents that transmit these forces back and forth between particles, people and planets.

The basic "family" of particles is supplemented by two more exotic families, each of which has a parallel structure: two quarks, a type of electron and a type of neutrino. These two extra families are all but extinct in the modern universe, but they apparently existed in the searing heat of the Big Bang, and only accelerators can re-create them. In fact, all of the quarks in all of the families have been found or re-created—except for the one called the top, which is believed to be the heaviest of all (its mass is at least 90 times that of a proton). Because it would complete the set and thus vindicate decades of theory building, the top quark has become the object of an intensive international search. And because the top is so massive, it will take the energy of the most powerful accelerators to produce it.

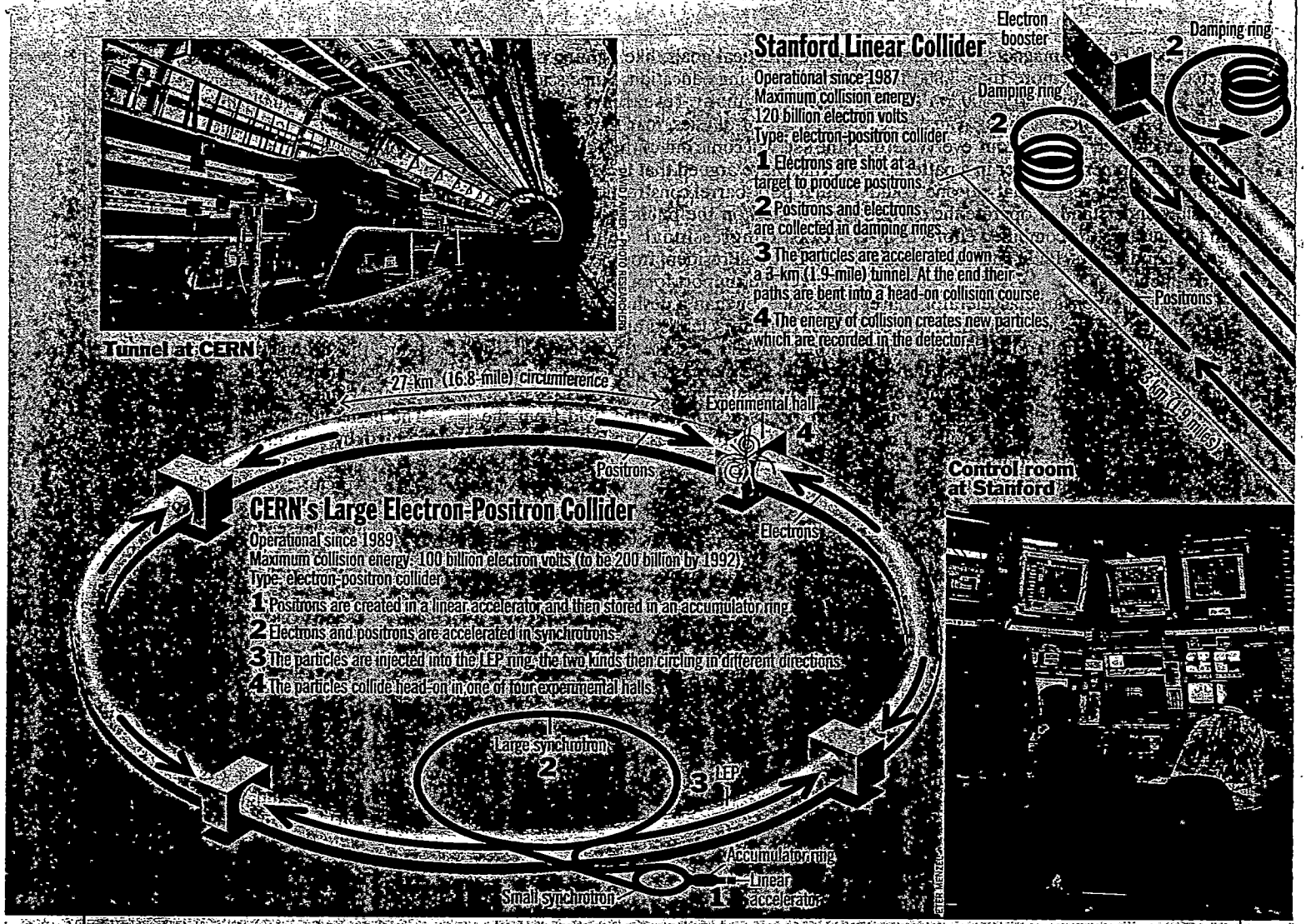
But researchers will be awfully disappointed if all they succeed in doing is to fill out the known family tree of particles. Too much predictability can make science dull. Says Samuel Ting, an M.I.T. physicist and one of the head researchers at CERN: "I will only consider our experiment a success if we discover something really surprising—new types of quarks, for example—that would explode the standard theory."

Anyone able to take particle physics beyond the Standard Model will automatically win prizes, prestige and added power in the profession. The quest has attracted some of the most driven personalities in science. The leaders, including Ting, CERN director Carlo Rubbia and Stanford's Burton Richter, are known for their relentless ambition, feisty competitiveness and monumental egos. All have already won Nobel Prizes, but that seems only to have increased their desire for greater achievements. In the

Electrons and their antimatter counterparts are pulled into the ring and accelerated to light speed

TIME Diagrams by Joe Lertola

Photocopy-Preservation



rush to get results, they push their staffs mercilessly and are furious—at least in private—whenever they come in second.

It is this rivalry that speeds the accumulation of knowledge. Observes Jack Steinberger, another Nobel laureate at CERN: "Competition in science is not always a pretty thing, but it's always stimulating and productive." The search for the nature of matter requires brash risk takers because it is a venture into the unknown and perhaps the unknowable. Explains Roy Schwitters, director of the new SSC project: "The physics we do is like a voyage of discovery. You can imagine you're Columbus. We're setting sail to who knows where—a new world, we hope."

Only a few places are equipped to catch glimpses of that new world. A look at the major explorers:

Fermilab. The machine most likely to find the top quark first is Fermilab's mighty Tevatron, which has been operating for 6½ years beneath the waving grasses of the Illinois prairie. In the Tevatron, strong magnets guide subatomic particles through a circular tunnel that is 6.4 km (4 miles) in circumference. The accelerator is built as a ring so that particles can go around the track again and again, picking up speed with each lap. The ring was built large so that the particles would not have to make sharp turns.

When the machine is running, one beam of particles travels in a clockwise direction while a separate beam goes the opposite way. After reaching maximum speed, the two beams are forced together, and the particles begin to smash head-on into one another, creating fireballs that are 400 million times as hot as the sun—but so tiny and short-lived that they pose no danger to the accelerator. The Tevatron can produce 50,000 such collisions in a single second. In each of these explosions, the original particles are transformed into a shower of new, short-lived particles. The collisions take place in a detector, which contains a giant magnet that bends the newly created particles in different directions. Scientists cannot see the fresh matter directly, but its characteristics are recorded in computers, and the trails it leaves can be pictured as brightly colored streaks on a video display screen.

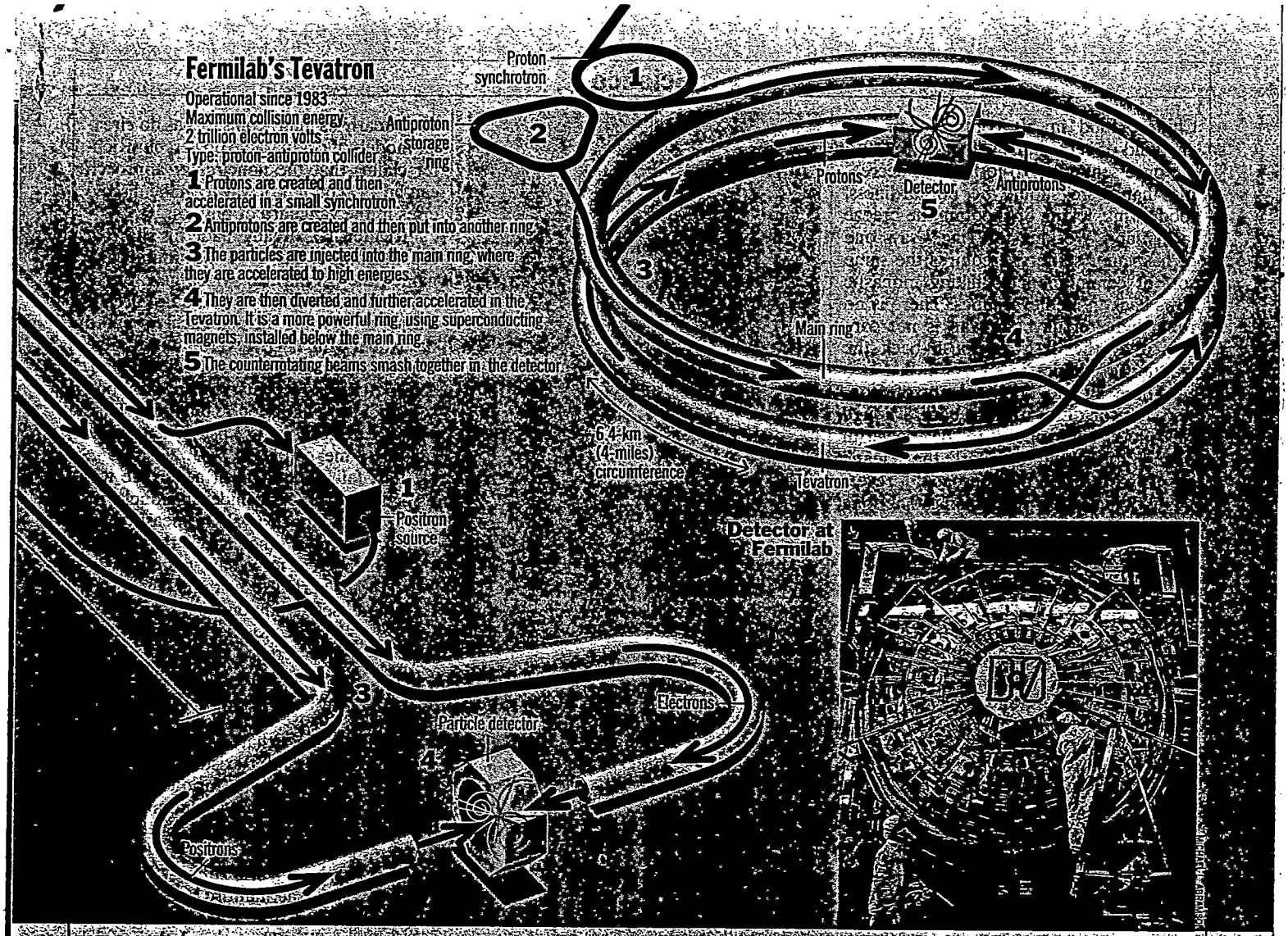
Though the Tevatron is considerably smaller than CERN's LEP, the collisions that Fermilab's accelerator produces are much more powerful. Reason: the Tevatron smashes protons into antiprotons, while LEP uses electrons and positrons. Protons and antiprotons collide with much more force because they pack more energy than electrons and positrons. Think of it as if the Tevatron were crashing Mack trucks together, as opposed to Volkswagens.

The Tevatron collisions produce dense blizzards of particles. Most are uninteresting because they have been observed before, but the chances are relatively good that hidden somewhere in the debris is an exotic new particle. Finding it, though, is no easy task. One reason CERN chose to make LEP an electron-positron machine is because of its comparatively "clean" collisions; though fewer particles are produced, they are easier to locate and study.

Fermilab's physicists believe they have already seen what might be the top quark, but they will have to gather a lot more data to confirm such a discovery. Confidence is already building. Contends James Trefil, a George Mason University physicist: "If the top quark is going to be found, it is going to be found at Fermilab sometime in the next five to six years."

*Antiprotons and positrons are examples of antimatter, a rare set of particles that mirror normal matter. A proton is positively charged, but an antiproton is negative. The counterpart of the negative electron is the positive positron.

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Fermilab is led by director John Peoples, who is widely respected for being a hands-on physicist. But experiments at the lab are not dominated by superstars, such as CERN's Rubbia and Ting. Instead, the atmosphere is one of relative consensus and collegiality. Explains researcher Melvyn Shochet, who commutes to Fermilab from the University of Chicago: "We have pushed to set up a more democratic system, rather than an autocratic system where one person heads up the project." When one team of scientists goes off duty and another comes on, they often share an informal dinner right in the control room. "There's Chinese food with chopsticks, dripping all over the logbooks," says Fermilab physicist Drasko Jovanovic.

It would be a mistake, though, to assume that Fermilab's scientists are any less competitive than their rivals at other labs. The masters of the Tevatron positively gloated last year when they defeated Stanford in a race to measure the mass of the Z^0 particle, a boson that carries the weak force. Says Thomas Devlin, a Rutgers physicist working at Fermilab: "That was fun to beat out our West Coast colleagues. They were hopping mad for a time, but they learned they weren't the only ones to walk on water. It's time they recognized that we also can do good work."

CERN. "Many people doubted that Europe could pull off this venture," said French President François Mitterrand in a speech at the gala official opening of CERN's new accelerator last November, "but the achievement of LEP shows that Europe can harness its cultural diversity." In fact, LEP, which took more than four years and nearly $1 billion to build, is much more than a European showcase; it is a laboratory for the entire world. It has attracted scientists from 29 countries in both the West and the East. More than one-third of the Soviet Union's particle physicists are registered to work at CERN, as well as a quarter of their colleagues from China.

Most of LEP's 2,000 scientists are split into four teams, each of which operates one of the four particle detectors spread around the accelerator ring. The team leaders are Americans Ting and Steinberger and Italians Ugo Amaldi and Aldo Michelini. The groups compete just as fiercely with one another as they do with outside rivals, creating a setting that is more charged with tension than the comparatively fraternal atmosphere at Fermilab.

The tone and pace for the whole CERN operation is set by Rubbia, a pushy director with a thirst for glory and little patience for laggardly performances. Says one senior CERN researcher: "Rubbia is insensitive, abusive, intolerant and high-handed." Yet no one denies his brilliance, energy and vision. "He works incredibly hard," observes a staffer, "and every waking minute is dedicated to physics." Concedes a critic: "If he was not respected intellectually, he would not be able to get away with the way he behaves. The other mitigating factor is that he is rude to everybody, high and low; he doesn't discriminate." Says Rubbia: "This is my life. There are no half measures."

Rubbia's hard-driving style has paid off. In the early 1980s he was leader of a CERN detector team that discovered the W and Z^0 bosons, crucial linchpins in the Standard Model. That earned Rubbia and colleague Simon van der Meer the Nobel. But Rubbia sometimes goads his scientists into announcing results prematurely. In 1984, for example, he said CERN had found evidence of the top quark, but later had to retract the claim.

By all accounts, the toughest team to belong to at CERN is Ting's. The stern leader would never allow chopsticks and

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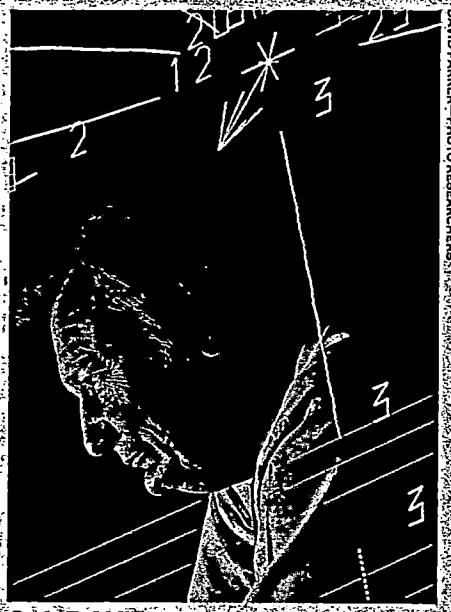
Chinese food in his control room—or any kind of refreshment, for that matter. He once sent a memo to his staff decreeing that there should be no tardiness, food, drink, joking or shooting the breeze in his lab. "Working for Ting," says one of his senior staffers, "requires the same sort of commitment as taking monastic vows back in medieval times. There is no room here for anybody who is not consumed by the desire to push back the frontiers of physics."

There are no doubt plenty of frontiers left for CERN to push back. Though LEP does not appear to be powerful enough to find the top quark, the "clean" electron-positron collisions could reveal many other exotic phenomena. One long shot is the much-sought Higgs boson, named for British theoretical physicist Peter Higgs, one of the first to recognize its importance. According to some theories, the Higgs boson is what gives all particles their mass. The idea is that everything in the universe is awash in a seaof Higgs bosons, and particles acquire their mass by swimming through this "molasses."

But what the CERN researchers really expect, and hope, to find is something totally unpredicted. "In science nobody really knows what is going to come next," says Rubbia. "We always pretend that we know the answers, but nature keeps advising us that we don't."

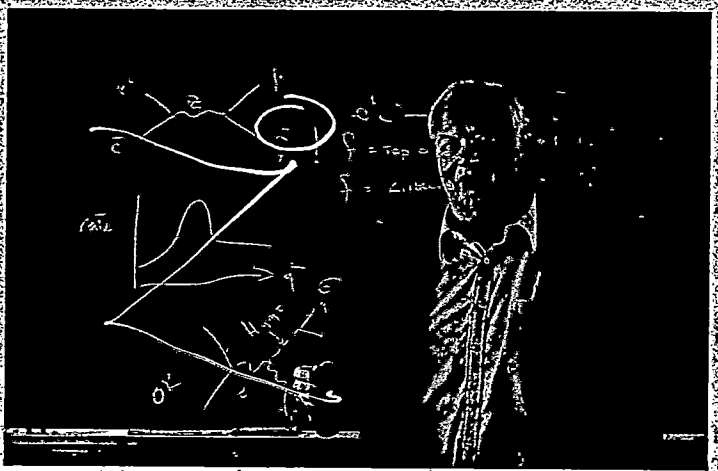
To keep finding new answers, Rubbia is determined to improve CERN's technology. He plans to boost LEP's power 50% in the next year or two. CERN is also trying to persuade its member nations to put up the money to build a proton-proton collider in the same tunnel with LEP. Called the large had ron collider, it would be four times as powerful as the Tevatron and almost half as forceful as the proposed superconducting supercollider in Texas. Rubbia thinks he can finish the LHC several years ahead of the SSC and thus beat the Americans to many important discoveries. If the LHC measures up to Rubbia's expectations, SSC could end up standing for superfluous supercollider.

SLAC. Burton Richter, director of the Stanford Linear Accelerator Center, is the maverick of particle physics. While others have recently concentrated on circular accelerators, he has touted the merits of linear models. His latest machine shoots streams of electrons and positrons down a straightaway and then loops them through two semicircular sections onto a collision course. Linear accelerators cannot produce nearly as many collisions as do circular models of comparable power, but Richter claims that the noncircular approach can be an economical way to make discoveries in the vanguard of physics.



DAVID PARKER—PHOTO RESEARCHERS

Carlo Rubbia, CERN's tough director



STEVE LEIGHTON

SLAC's Burton Richter was the first, by a day, to reveal the Z^0's life-span



MICHAEL L. ABRAMSON

Fermilab's John Peoples inside a detector

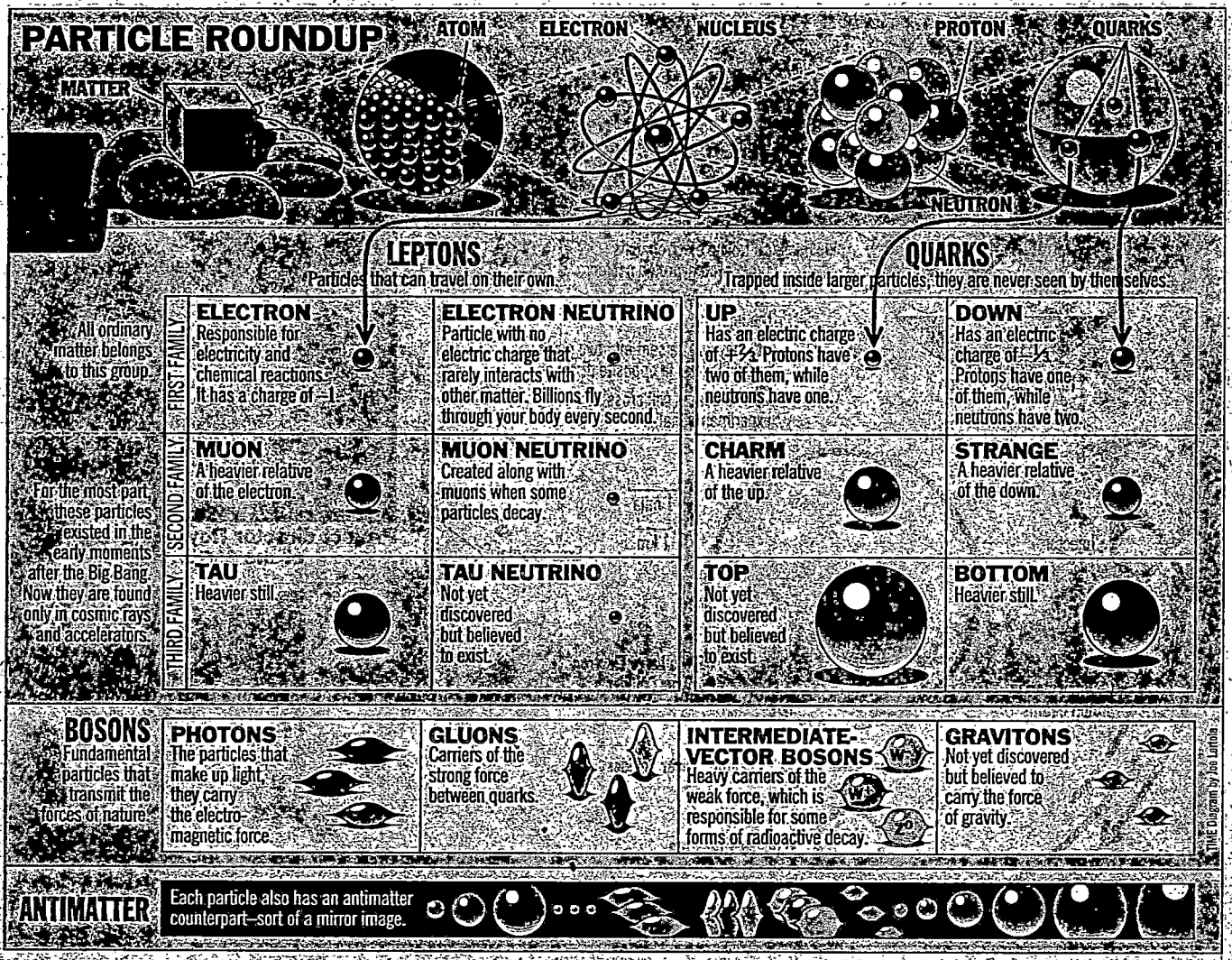
Richter has already made his share of breakthroughs. In 1974 he found and named the psi particle, which gave physicists conclusive evidence that quarks really exist. For spotting the psi, Richter shared the Nobel with Ting, who found the same particle at the same time and called it the J. The particle now bears both names, but, says Richter, "when you're talking to Ting, you'd better call it the J/psi. When you're talking to me, call it the psi/J."

Last fall Richter did it again. He was using his new linear collider in a duel with his better-equipped rivals to measure the life-span of the Z^0, the particle that carries the weak nuclear force back and forth between other particles. Just one day before CERN was set to announce its measurement, Richter called a press conference to put forward his own figure. The calculation was extremely significant because it provided strong evidence that only three families of matter exist. CERN's Steinberger was furious at being upstaged. "I guarantee our results are more accurate than Stanford's," he told the New York *Times*. "The people at Stanford knew perfectly well that we were going to do this. They timed their press conference to get in ahead of us, even though we have ten times as much useful data. They've done some nice work, but I don't like it when they try to beat us by one day."

Richter believes that LEP is the end of the line for circular electron-positron colliders. He once calculated that a LEP-style machine with ten times LEP's power would have to be at least 2,700 km (1,680 miles) around. Thus Richter is convinced that linear colliders are the machines of the future. He is hoping to build a 7-to-8-km (4.4-to-5-mile) linear model that he figures could be five times as powerful as LEP. The only catch: it would require acceleration technology that has not yet been invented.

Superconducting Supercollider. For all Rubbia's and Richter's plans, the SSC will clearly have the best chance of unlocking the deep secrets of the universe. Its scale and complexity will make even LEP look puny. The 10,000 magnets will require as much steel as a battleship and enough superconducting wire to circle the earth's equator 25 times. The counterrotating beams of protons, each as thin as a fork's tine and containing quadrillions of parti-

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cles, will whip around the ring-shaped tunnel 3,000 times, producing up to 100 million collisions, every second.

Building such a mammoth machine from scratch is scary even to Schwitters, a Harvard physicist and leading particle experimentalist who left Fermilab to take charge of the SSC. Says he: "We have to build the equivalent of the Fermilab complex and then the SSC itself." Moreover, since no one has ever built an accelerator of such size and power, each component will have to be reliably mass-produced, which will inevitably cause unanticipated problems. Schwitters is determined to use the best possible designs, even if Congress grimaces at the $7 billion-plus price tag. Former Fermilab director Leon Lederman, one of the early champions of the SSC, thinks it would be idiotic to cut corners on such a complex machine. Says he: "The worst thing in the world would be to build a machine that doesn't work, or one where you have to struggle along."

Another challenge facing Schwitters, who alternates between private fights with Government bureaucrats and public appearances in cowboy boots and a ten-gallon hat, is to recruit hundreds of physicists to work on the accelerator. That may not be so easy. Once it is built, the SSC will be a magnet for young, ambitious scientists. But since Congress will have to appropriate hundreds of millions of dollars each year for the next half-decade for the project, there is always a chance that the money will suddenly dry up, along with jobs. CERN's budget, on the other hand, is shouldered by 14 European governments, thereby spreading the risks and costs.

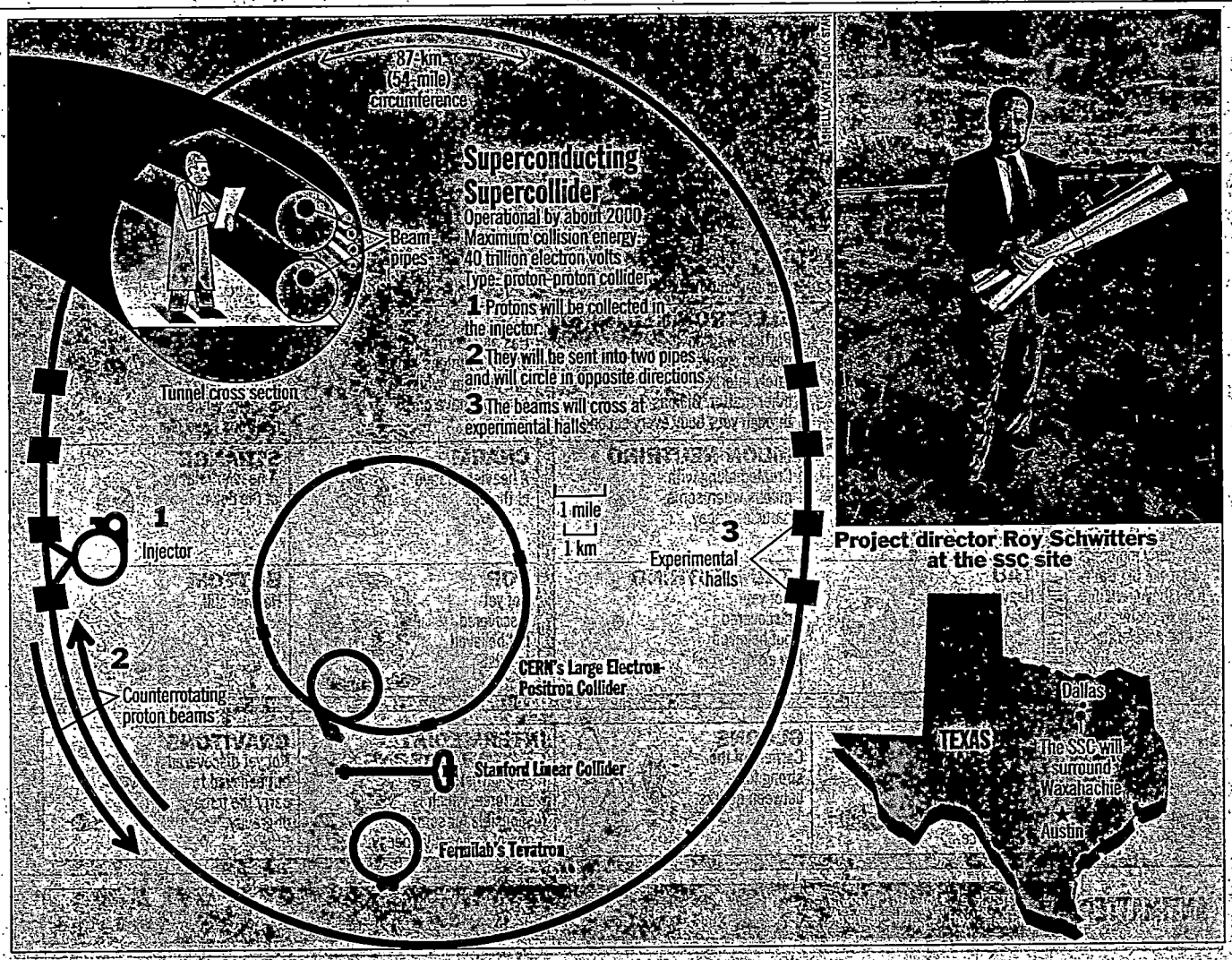
But for the top physicists, who will have no trouble finding jobs even if the SSC construction were to stop suddenly, the lure of the giant collider is irresistible. In fact, the leaders of the 500-scientist teams that will eventually run the SSC's enormous detector experiments are already beginning to organize. One such collaboration is being formed by Ting. Politically shrewd, he has wooed physicists from a number of weapons laboratories and Southeastern universities, which until now have not been powers in the field of particle physics. Observers expect he will run the experiment in the strictly hierarchical fashion he has displayed at CERN. At the same time, physicists from Lawrence Berkeley Laboratory, Fermilab, Argonne National Laboratory and Japan are drawing up a collaboration that will be run along the more democratic lines of Fermilab. The clash of cultures between the CERN and Fermilab styles of management may make the sociology of the SSC nearly as interesting as the science.

The science should be nothing short of spectacular. By the SSC's projected start-up date of 2000, most of the *i's* and *t's* of the Standard Model should long since have been dotted and crossed. Finding the Higgs boson should complete the task. But, contends Columbia University's Frank Sciulli, "there are intrinsic limits to the model, and people believe those limits are going to show up in the SSC, along with a whole new layer of matter we didn't know of before."

The layer that theorists most eagerly hope for is a new class of matter called supersymmetric particles, whose existence is predicated on the so-called grand unified theories now being explored by physicists. Some think that supersymmetric particles are the long-sought components of "dark matter," the invisible stuff that is believed to make up 90% or more of the universe.

Supersymmetric particles could also give a boost to superstring theory, one of the hottest ideas in theoretical physics.

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Superstring theory holds that every particle is really a vibrating loop of stringlike material that exists in ten-dimensional space (most of these dimensions are confined to such a small scale that we never notice them). Whether the string takes on the role of a quark or an electron or a Higgs boson depends simply on how it vibrates.

Or the theorists may be on the wrong trail entirely. While such ideas as supersymmetry and superstrings may be elegant physics, the supercollider could just as easily reveal a subatomic monkey wrench. That could force a crisis in physics, followed by a far more basic set of theories than physicists now dream of. It may be, for example, that quarks are not fundamental after all, but are themselves made of still more basic building blocks. Some forward thinkers have already coined a name for the ingredients of quarks: preons.

But is finding such exotic particles worth the multibillion-dollar price tag of the SSC? Is it a good investment? No one can know what the payback will be, but past breakthroughs in physics have tended to create whole new industries. Radar, X rays, television, microwaves, semiconductors, computers, lasers—technologies that now produce as much as a quarter of the U.S. gross national product—stemmed from discoveries in quantum physics made between 1910 and 1930. "If all of the physics generated by the SSC and its cousins doesn't have a profound effect," says Lederman, "it will be the first time in history."

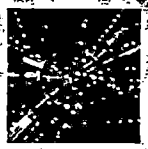
There is no reason for the U.S. to shoulder the full cost of the SSC. When the supercollider was first proposed, it was assumed that other countries would help support the project both scientifically and financially, much as CERN's LEP is backed by its participating nations. Several foreign governments have offered to do just that. The Japanese have made involvement in the SSC a high priority, and even India has offered to donate $50 million worth of goods and services. Unfortunately, nothing has come of these overtures. Part of the problem, insiders say, is lack of follow-through by the staff at the Department of Energy, which is overseeing the venture. But the SSC remains all-American largely because a few key Congressmen still believe that sharing knowledge about subatomic particles is somehow akin to sharing the secrets of the atom bomb.

Whether or not the U.S. pays the entire cost of the of the project, there are no guarantees that the SSC will yield practical results anytime soon or that the physicists will not be back ten years from now asking for an even costlier machine. In the end, the only real justification for building the supercollider is for its value to science, for what it may add to the storehouse of human knowledge. It is difficult to put a price on such a commodity. How much is it worth to know what matter is made of, or what happened in the very first moments after the Big Bang? The answer will vary from individual to individual. Some people think the space program was a big waste of money. Others believe it was worth the cost just for one picture of the earth floating like a fragile island of life in the black void of space.

Particle accelerators have come a long way since the 1930s, when they were literally no larger than a bread box. Since then, each bigger and better machine has pushed physics to a new energy level and has uncovered important and fascinating new facets of matter. If the SSC is built, it should do the same—taking yet another step in a mind-stretching adventure whose end is not yet in sight. *—Reported by Philip Elmer-DeWitt/New York, J. Madeleine Nash/Chicago and Christopher Redman/Geneva*

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Can We Really Understand Matter?



By EUGENE LINDEN

Few tasks are more daunting than standing in the path of a charging theoretical physicist who is hell-bent on getting funding for the next particle accelerator. As practitioners of the hardest of the hard sciences, physicists do little to discourage their aura of intellectual supremacy, particularly when suggesting to Congress that a grand synthesis of all the forces of nature is at hand if the Government will only cough up a few billion dollars more. But what if this confidence is misplaced? What if the barriers to knowledge are higher than many physicists like to admit?

For much of this century, scientists have known that the comfortable solidity of things begins to break down at the subatomic level. Like the Hindu veil of Maya, the palette from which nature paints atoms proves illusory when approached. From afar, this world appears neatly separated into waves and particles, but close scrutiny reveals indescribable objects that have characteristics of both.

Physicists have prospered in this quirky realm, but neither physics nor the rest of science has fully digested its implications. Inside the atom is a world of perpetual uncertainty in which particle behavior can be expressed only as a set of probabilities, and reality exists only in the eyes of the observer. Though the recognition of this uncertainty grew in part out of Albert Einstein's work, the idea bothered him immensely. "God does not play dice with the universe," he remarked.



ILLUSTRATION FOR TIME BY PETER GIS

The set of mathematical tools developed to explore the subatomic world is called quantum mechanics. The theory works amazingly well in predicting the behavior of quarks, leptons and the like, but it defies common sense, and its equations imply the existence of phenomena that seem impossible. For instance, under special circumstances, quantum theory predicts that a change in an object in one place can instantly produce a change in a related object somewhere else—even on the other side of the universe.

Over the years, this seeming paradox has been stated in various ways, but its most familiar form involves the behavior of photons, the basic units of light. When two photons are emitted by a particular light source and given a certain polarization (which can be thought of as a type of orientation), quantum theory holds that the two photons will always share that orientation. But what if an observer altered the polarization of one photon once it was in flight? In theory, that event would also instantaneously change the polarization of the other photon, even if it was light-years away. The very idea violates ordinary logic and strains the traditional laws of physics.

The two-photon puzzle was nothing more than a matter of speculation until 1964, when an Irish theoretical physicist named John Stewart Bell restated the problem as a simple mathematical proposition. A young physicist named John Clauser came upon Bell's theorem and realized that it opened the door to testing the two-photon problem in an experiment. Like Einstein, Clauser was bothered by the seemingly absurd implications of quantum mechanics. Says Clauser, now a research physicist at the University of California, Berkeley: "I had an opportunity to devise a test and see whether nature would choose quantum mechanics or reality as we know it." In his experiment, Clauser, assisted by Stuart Freedman, found a way of firing photons in opposite directions and selectively changing their polarization.

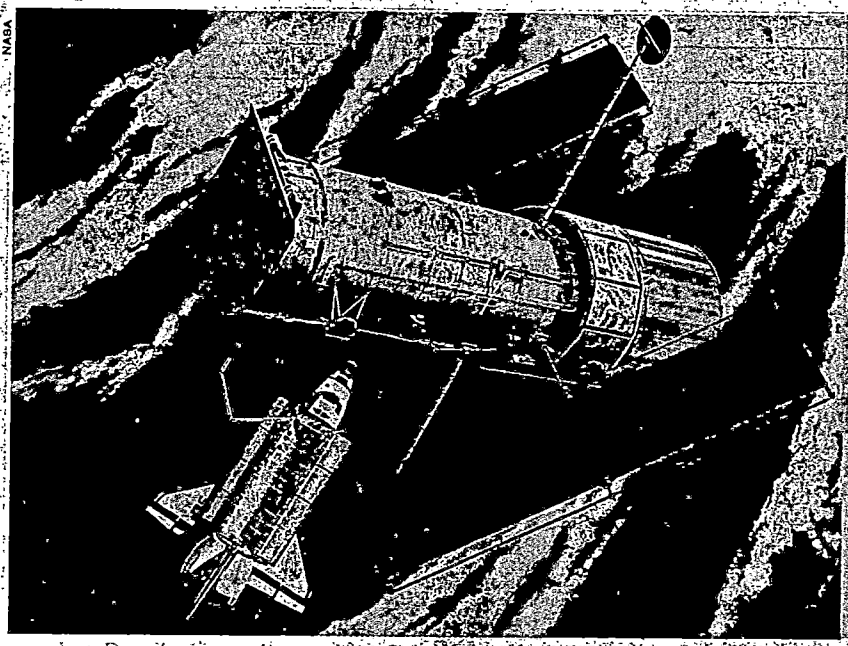
The outcome was clear: a change in one photon did alter the polarization of the other. In other words, nature chose quantum mechanics, showing that the two related photons could not be considered separate objects, but rather remained connected in some mysterious way. This experiment, argues physicist Henry Stapp of Lawrence Berkeley Laboratories, imposes new limits on what can be established about the nature of matter by proving that experiments can be influenced by events elsewhere in the universe.

Clauser's work pointed out once again that the rules of quantum mechanics do not mesh well with the laws of Newton and Einstein. But most physicists do not see the apparent disparity to be a major practical problem. Classical laws work perfectly well in explaining phenomena in the visible world—the motion of a planet or the trajectory of a curveball—and quantum theory does just as well when restricted to describing subatomic events like the flight of an electron.

Yet a small band of physicists, including Clauser and Stapp, are disturbed by their profession's priorities, believing that the anomalies of quantum theory deserve much more investigation. Instead of chasing ever smaller particles with ever larger accelerators, some of these critics assert, physics should be moving in the opposite direction. Specifically, science needs to find out whether the elusiveness of the quantum world applies to objects larger than subatomic particles.

No one worries about the relevance of quantum mechanics to the momentum of a charging elephant. But there are events on the border between the visible and the invisible in which quantum effects could conceivably come into play. Possible examples: biochemical reactions and the firing of neurons in the brain. Stapp, Clauser and others believe that a better understanding of how quantum theory applies to atoms and molecules might help in everything from artificial-intelligence research to building improved gyroscopes. For now, though, this boundary area is a theoretical no-man's-land. Certainly physicists are a lot further from understanding how the world works than some would have Congress believe. ■

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NASA

THREE KEY INSTRUMENTS:

WIDE-FIELD/PLANETARY CAMERA
Covering wide swaths of sky, it is ideal for studying our solar system and the planets around other stars.

FAINT-OBJECT CAMERA
Its forte will be taking ultra-sharp pictures of hard-to-see objects like globular clusters, aggregations of old stars in spiral galaxies.

HIGH-RESOLUTION SPECTROGRAPH
It will analyze rather than photograph the light from galaxies and gas clouds, revealing clues to their exact chemical makeup.

"New Window on the Universe"

With an unclouded view of the most distant stars, the sharp-eyed Hubble telescope will be able to look far back into time

By DICK THOMPSON

Even on a clear night, astronomers cannot see forever. Light from the stars is diffused and distorted by the earth's atmosphere. To the casual stargazer, that produces a beautiful twinkle, but to the astronomer it is a tragic blur. Star watchers have long dreamed of somehow getting above the atmosphere to have an unobstructed look at the universe.

Now their opportunity has come. This week the space shuttle *Discovery* was scheduled to take off and deliver into earth orbit the Hubble space telescope, a bus-size instrument that will see the cosmos ten times as clearly as any ground-based telescope ever has. Scientists have impatiently awaited the historic launch through three years of delays caused by the shuttle's problems in the aftermath of the *Challenger* explosion.

Once aloft in the dark void of space, the Hubble promises a leap in astronomical observing power unlike anything since 1609, when Galileo first pointed a telescope at the heavens. As never before, astronomers have a realistic hope of seeing planets that orbit distant stars, watching tidal waves of energy swirl around black holes and spotting the birth of galaxies. The Hubble, says presidential science adviser D. Allan Bromley, "will open entirely new windows on the universe."

Named for Edwin Hubble, the great astronomer who discovered in the 1920s that the universe is expanding, the space telescope has a mirror 2.4 meters (7.9 ft.) in diameter that will focus light on an array of cameras and instruments. After recording and analyzing the radiation, the instruments will translate it into electronic impulses and beam it down to earth at a prodigious rate—fast enough to fill a 30-volume encyclopedia in 42 minutes. Moreover, the Hubble will literally view the stars in a new light: the space observatory can see ultraviolet radiation that fails to reach ground telescopes because it is largely blocked by the earth's ozone shield.

Building the Hubble and putting it into space has cost the U.S. Government $1.5 billion, and that is only the beginning of the investment, which will likely top $5 billion. The telescope is being run by scientists at the new Space Telescope Science Institute, housed at Johns Hopkins University in Baltimore. The data will be collected by some 380 institute researchers and computer technicians and will be used by scientists all over the world. Over the Hubble's expected 15-year life-span, teams of astronauts will shuttle to and from the telescope to service and upgrade it.

The Government's Hubble budget alone will amount to an annual injection of more than $150 million into the scientific community. No wonder that researchers were awaiting the launch with both excitement and apprehension. "A lot is riding on that pillar of fire," observed institute director Riccardo Giacconi. The Hubble will not make ground telescopes obsolete, since there is a limit to how many scientists can use it and how much light it can gather at one time. The huge new Keck Telescope, which is nearing completion atop Mauna Kea in Hawaii, will complement the space observatory. Privately developed by the University of California and Caltech and financed mainly by the W.M. Keck Foundation, the Keck has a dish 10 meters (32.8 ft.) in diameter. That is nearly twice the size of the next largest telescope, a problem-plagued 6-meter (19.7-ft.) dish in the Soviet Union. The Keck may not see the heavens as sharply as the Hubble, but the bigger, ground-based telescope can take in much more light in a short period of time. By combining high-quality images and a large quantity of data, the Hubble and the Keck will usher in a new era for astronomy.

One advantage of the Hubble is that it will offer the clearest pictures yet of the most distant objects in the universe. And the farther away those objects are, the longer the light has been traveling. So the Hubble is a spyglass that enables astronomers to look way back in time to earlier ages of the cosmos. Says institute astronomer Eric Chaisson: "The space telescope should allow us to see sufficiently far out into space and sufficiently back into time so that we can begin to probe the regions at which galaxies actually formed, and that's the greatest missing link in all of modern astrophysics."

The Hubble will also cast its sharp eye around stars in this galaxy, looking for traces of planets. So far, only dusty disks thought to be planetary precursors have been observed near some suns. "With the space telescope we have a fighting chance of seeing a planet," says European Space Agency physicist F. Duccio Maccheto.

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Another mission will be to focus on planets around the sun and send back pictures as sharp as those from the Voyager spacecraft—with one major difference. "On a flyby, you get one moment in time and look at whatever is looking at you," says institute planetary scientist Robert Brown. Hubble will allow astronomers to study planets over a long period. On Mars, for example, dust storms arise from small regions and eventually cover the entire planet. Now scientists will be able to follow that mysterious phenomenon.

Even with their powerful new tools, astronomers will not be satisfied. While upgrading the Hubble in the 1990s, NASA plans to ring the earth with satellite observatories that can receive and analyze infrared radiation, X rays and gamma rays. "It's as if we never could see at all at the beginning of the decade, and by the end we'll have 20/20 vision," says Princeton's John Bahcall, president-elect of the American Astronomical Society.

The ultimate observatory would be on the moon, a real possibility in the next century. Just as Edwin Hubble used the best instrument of the 1920s to discover that our galaxy was not the only one in the cosmos, perhaps a moon-based telescope would reveal startling regions of space—and time—never seen before. —*With reporting by Michael D. Lemonick/New York*

Petite Payloads

Pegasus puts into orbit the first of a new class of small satellites

The first satellites were tiny, antenna-studded devices that often weighed little more than the men and women who built them. But big was better as the space age progressed. The largest satellites today tip the scales at 15 tons, cost hundreds of millions of dollars and are roughly the size of Mack trucks. They must be put into orbit by giant rockets or space shuttles.

But in the skies over California last week, a launch took place that broke all the rules. A diminutive rocket named Pegasus, built by a Virginia-based entrepreneurial firm called Orbital Sciences, dropped from under the wing of a B-52 and carried into orbit a small 200-kg (450-lb.) satellite, one of a new type of craft that promises to bring space history full circle. Called lightsats, the new payloads pack as much function into a few hundred kilograms as satellites many times their size. At $8 million a launch, they could open space to new military and industrial uses.

The shrinkage has only begun. In July a second Pegasus is scheduled to launch seven 22.5-kg (50-lb.) communications satellites the size of car tires. And scientists are already dreaming about peppering space with swarms of "microspacecraft," each no bigger than a coffee can. ■

Carping over the Catechism

Americans criticize a Vatican text on church teachings

Not since 1566 has the Roman Catholic hierarchy attempted such a project: the summarizing of the church's central teachings on faith and morals in a single document. Four years in the making, a secret 434-page draft of the new *Catechism for the Universal Church* was sent last December to the world's 4,000 bishops. The prelates were instructed to dispatch their comments on the text to the Vatican by May 31, after which work will begin on the final version. Since then there has been widespread grumbling over both the document's old-fashioned conservatism and the rush-rush deadline for responding to it. Last week leaders of the U.S. bishops escalated the debate, sending the Vatican a sweeping and surprisingly blunt 51-page critique of the Catechism. They also pleaded for more time to consult with theologians and educators over what they called the "most significant" project of the church's magisterium, or teaching office, since the Second Vatican Council.



ANN STATES—SABA

Alabama's Archbishop Oscar Lipscomb

"We have given a positive response."

The bishops' critique was the work of a six-member committee headed by Alabama's Archbishop Oscar Lipscomb, 58, the chairman of the bishops' doctrinal committee. (Individual U.S. bishops, like those elsewhere, will also be sending separate responses to the Vatican.) The Lipscomb panel's chief objection is that the *Catechism* has not clearly distinguished a "hierarchy of truths" treating concepts like the meaning of Christ's crucifixion as more important than, say, teaching about angels.

The report chides Rome for ignoring a generation of progressive Bible scholarship. The Roman draft, the Americans say, seems to presume that "New Testament texts are the product of direct historical reporting" and resorts to "proof-texting," quoting Scripture out of context to prove a doctrinal point. In addition, the Americans feel that science has been slighted in favor of an almost Fundamentalist approach to creation.

Another U.S. complaint is that the English version of the *Catechism* seems to back away from some of the key ecumenical language adopted by the 1962-65 Second Vatican Council. While Vatican II declared that the true church of Christ "subsists" in the Roman Catholic Church, implying that there is a place for other Christians, the *Catechism* uses an exclusionary phrase, "has its existence in."

Reflecting the influence of feminism, the report sharply criticizes Rome's relentless use of non-inclusive nouns and pronouns (for instance, in referring to believers as "men" or "sons"), which the American bishops have been trying to banish from their own documents. One problematic passage in the *Catechism,* though it was not specifically cited by Lipscomb's panel, introduces a list of heroic women in the Bible by terming them "weak and feeble." The U.S. bishops did not dispute the text's predictable conservatism on controversial moral issues like birth control, but they did urge that such subjects get a "more positive" treatment rather than an inflexible listing of dos and don'ts.

In spite of the panel's numerous reservations about the *Catechism,* Archbishop Lipscomb maintains that "basically, we have given a positive response." The same could not be said, however, for the 15 Catholic scholars who gathered at Georgetown University last January to discuss the Vatican document. Jesuit Father Thomas Reese, who organized the Georgetown meeting, branded the draft as "fatally flawed." Father William Spohn of California's Jesuit School of Theology characterized Vatican drafters as religious Rip Van Winkles who have slept through a generation of progress in moral theology. Underlying such attacks from liberals is a not-so-hidden fear: that a hard-line *Catechism* will one day be used as a criterion for disciplining theologians and educators. —*By Richard N. Ostling. Reported by Michael P. Harris/New York*

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NAT'L ACAD. – BROMLEY 4/11

van Dorp. DOE's ~~not~~ sci educ. paper as basis.

~~Bromley Dorp. re.~~

Report to Baker of sci. comm. on how followed thru on pledges & promises.

cf. Acad. Decenn. to Bush on sci/tech, make earlier (white paper).

i.e. – NSF be upgraded – done
– Sci Adv. " involved in Cabinet – done
– Pres' Council of Advisors on Sci + Tech – done
(last time in a decade)
– met w/ POTUS twice.
– Freedberg source of info

In past, participation too low in agencies.
Exc
Now restructured, more powerful.

recomm EXT be revitalized

– Ass't Pres. level appointed person in:

Life Sciences
Phys Sci + Eng
Earth + Tech. Res.
Industr. Tech.

(1) What coord. + integrate Fed. govt doing

by – Committee on Earth Sciences
rather than Agency Progs.
acting on their own, integrated.
Best bang for the buck.
Become a model for civil activities.
POTUS asked for 5 to 7% incr. in next budget

Areas to come:
- HE + Educ
- Biotech
- High perf. computing
- Material Sci & Engineering

(2) get priv. sector involved.
Pres. Council.

– New working groups – take gov. that emerge from EXT – that have elements of Econ. + policy

– Trying to treat sci + tech. across entire spectrum of Federal effort.
(i.e. as a whole rather than Fed. recomm)

AEAD. 2

The Fed. Budget
support for R&D as investment in nat'l future.

90-91 12% incr. in basic research
in opening (sec 3) of budget — good prose.

Be prepared — Congress dispose ∴ you decide.
Can help me help you by talking
w/ members about — these national
concerns — call to arms

Space Sta.
SSC
Human genome mapping

Recog. that despite the large req.
incr. & fr sci & tech, more and
diff. for young sci & tchrs to get
the support they need to do
their work.

In budget, were worked for

Balance / indiv. investigator (small)
large facils., large programs.

For 1st time since AWU, fraction of young people's
proposals accepted dropped below 1/3.

Why — more proposals
& 7% of all sci & engrs ever
lived in US are alive today

— were responded increasing both
& size of grants.

— much more would have gone to Bio has
gone to AIDS, for eg.

Coolidge
~~Carter~~ already spoken
said what he did

~~City of Bills Book~~
~~Building Boom~~
~~Budget~~
Promises made, promises kept
for the sake of science.

Oct 25 '87
Ok. Soc. Bookcenter

In lee of limited budgets,
the importance
of (Building a constituency))
for sci & tech in U.S.

a new understanding of intimate
connection between Big Science & American life, good.

Recog. young scientists --
the fellow to spot was Low.
We recog. as Prof.
Will work on small inventions
as backbone
Big Science crucial in frontier.

SMALL SCI / entrep.

Mark-

(A) and (B) are the Soviet approach -- a centralized, planned economy -- or research establishment

I and others believe centralized planning of research will destroy the magnificent creativity and entrepreneurial energy of the American technical community, which have made us -- and other free enterprise societies -- so much more successful than the Soviet model.

Just as nearly all the new jobs in America are created by small businesses based on the ideas of innovative individuals (witness Xerox, Intel, Hewlitt-Packard, Apple), the important research ideas come from talented individual scientists. They don't come from bureaucrats managing the programs in Washington.

The wisest use of government research funding should be to locate individual scientists with talent, and furnish them with the equivalent of venture capital.

Note (C) in the attached article. I didn't know, when I mentioned the IBM superconductor example, that the two IBM scientists had to do their great work in secret because IBM's program planners hadn't approved it.

Frank tells me that through plate tectonics, we've learned that the Himalayas are growing, the continents are drifting, the Atlantic Ocean is steadily widening and the shores of the Red Sea, at any rate, are now parting.

It is computing power, of course, that makes our exponential growth in scientic understanding possible. Vast quantities of information are now mediated through integrated circuits: conceptual spectacles that enable us to see, or model with the mind's eye, phenomena we'd otherwise miss or couldn't comprehend -- from the diffusion of charge in a single semiconductor, to collisions between galaxies.

Science Times

TUESDAY, APRIL 10, 1990

The New York Times

C1

For a Space Visionary, Persistence Nears Payoff

Astrophysicist proposed a space telescope in 1946 and has fought for it ever since.

By JOHN NOBLE WILFORD

Special to The New York Times

CAPE CANAVERAL, Fla., April 9 — At 75, Dr. Lyman Spitzer Jr., professor emeritus of astrophysics at Princeton University, has a string of scientific accomplishments behind him. He had a leading role in the development of sonar in World War II and of early concepts for controlled fusion energy.

But what may be his most lasting contribution is sitting on a launching pad here: the Hubble Space Telescope, set for liftoff Tuesday morning to an orbit where it will view the heavens almost to the edge of the universe. The first detailed ideas for a large space telescope were Dr. Spitzer's, and over the years his tenacious advocacy won over astronomers, fought off budget cutters and sustained the project through adversity and repeated delays.

This tall, lean professor has never shied away from the big problems of science and technology requiring bold and imaginative solutions. "I have a weakness of character — a fascination with the spectacular," Dr. Spitzer likes to say of himself. "But then I have a sort of theory about our weaknesses being our strengths."

To be sure, the $2.1 billion project, the most expensive and complex undertaking in unmanned space science to date, has grown beyond the embrace of any one person. It has become a manifestation of big science, involving vast teams of researchers and technicians, enormous costs, fierce competition and bureaucratization.

But everyone associated with the project acknowledges Dr. Spitzer as the intellectual and political father of the Hubble telescope.

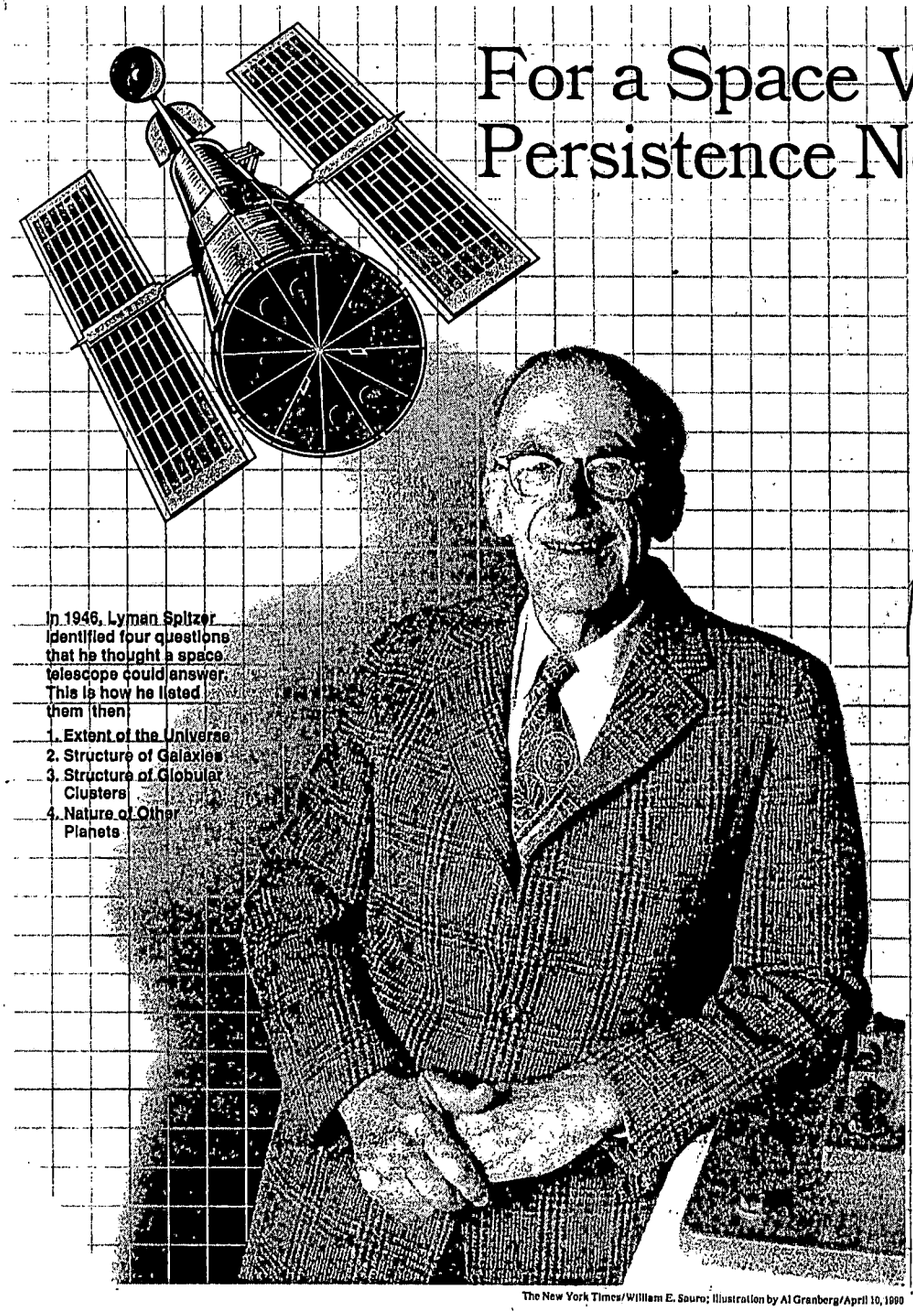
"He's been the driving force from the very beginning," said Dr. Jeremiah Ostriker, chairman of the astrophysics department at Princeton.

In a history of the project, "Space Telescope: A Study of NASA, Science, Technology and Politics," published this month, Dr. Robert W. Smith, a historian at the National Air and Space Museum, writes that Dr. Spitzer's "involvement in arguing for, justifying and then helping to develop the space telescope stretches back longer than the commitment of anyone else."

"Lyman has been the father-spirit of the project," added Dr. Charles J. Pellerin Jr., director of astrophysics for the National Aeronautics and Space Administration.

Forty-four years ago, when the German rockets of World War II had awakened people to the possibilities of space flight, Dr. Spitzer elaborated on the value of placing a large telescope in orbit high above Earth's obscuring and distorting atmosphere. He did this as an addendum, entitled "Astronomical Advantages of an Extraterrestrial Observatory," to a 1946 study of artificial Earth satellites conducted by the Rand Corporation for the Air Force. "Such a scientific tool," he wrote,

Continued on Page C8



In 1946, Lyman Spitzer identified four questions that he thought a space telescope could answer. This is how he listed them then:

1. Extent of the Universe
2. Structure of Galaxies
3. Structure of Globular Clusters
4. Nature of Other Planets

The New York Times/William E. Sauro; Illustration by Al Granberg/April 10, 1990

Photocopy-Preservation

For a Space Visionary, 4 Decades of Persistence Nears a Payoff

Continued From Page C1

"could revolutionize astronomical techniques and open up completely new vistas of astronomical research."

Dr. John N. Bahcall, an astrophysicist at the Institute for Advanced Study in Princeton, N.J., said: "That paper was like Lyman himself. It was simple, very clear but very audacious."

Although Hermann Oberth, a German-Romanian member of the V-2 rocket team assembled by Dr. Wernher von Braun, wrote in the 1920's of the possibility of space telescopes, it was Dr. Spitzer who expanded the concept with specific plans. His outline of the four main research goals for the telescope was especially prescient.

A telescope with a 200-inch mirror, he predicted, could measure the extent of the universe, determine the structure of galaxies, resolve the individual stars now hidden in the hazes of globular clusters and learn the nature of other planets. All four are high on the Hubble's agenda for discovery.

Only in one respect have events overtaken Dr. Spitzer's vision. He predicted the telescope might settle the issue of whether there was intelligent life on Mars. That possibility was ruled out by spacecraft visiting the planet. But the Hubble telescope, astronomers hasten to add, could help identify planetary systems around other stars and thus encourage the belief in extraterrestrial life far beyond the solar system.

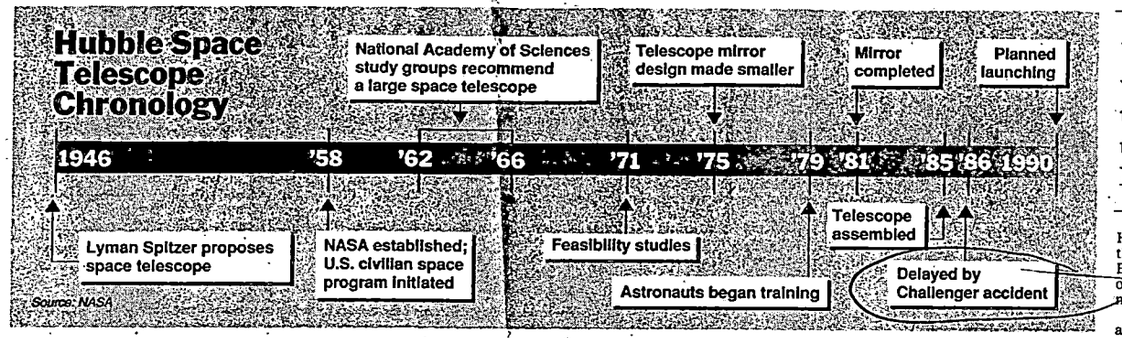
Embodiment of a Struggle

As Dr. Spitzer recalls, the evolution of the Hubble telescope occurred in four stages of roughly one decade each. He worked mostly alone in the first decade, but would come to embody astronomy's struggle to initiate and defend the project through its long, troubled history.

No one paid much attention to the idea at first. Space flight was still futuristic. But Dr. Spitzer left Yale University in 1947 to become head of astrophysics at Princeton, where he had earned his doctorate. One condition of his employment, he said, was that he be allowed to pursue his vision of a space telescope.

Working with Dr. Martin Schwarzschild at Princeton, he sent telescopes into the fringes of space with sounding rockets and balloons in what was called Project Stratoscope. In 1957, a 12-inch telescope was lofted by balloon to 80,000 feet to make revealing studies of the Sun. The information gathered by the telescopes, recorded on spectrographs, was recovered when they were brought back to earth.

That was a few months before Sputnik was launched in October, inaugurating space flight and the second decade of Dr. Spitzer's crusade for the telescope.



> When the Air Force sought ideas for astronomy in space, 'they didn't have to twist my arm.'

"The Air Force came to me with an urgent request for ideas about how satellites could be used for astronomy," he said. "They didn't have to twist my arm."

Ultraviolet Scannings

Manufacturers of optical systems were hired to develop lightweight mirrors. Electronics companies were assigned the task of devising instruments. When NASA was created in 1958 and took over space astronomy, one of the first programs incorporating the new technologies inspired by Dr. Spitzer was the Orbiting Astronomical Observatory.

The two successful observatories, launched in the late 1960's and early 1970's, included 30-inch telescopes designed to observe the heavens in the ultraviolet wavelengths. These radiations are almost entirely blocked out by Earth's atmosphere. With the spaceborne ultraviolet telescopes, scientists were able for the first time to examine the interstellar dust and gases, remnants of exploded stars and the breeding ground for new stars. Dr. Spitzer and Dr. Schwarzschild had been the first, in the 1940's, to realize that stars had to come from somewhere and that it might be possible to observe their birth processes.

Dr. Spitzer's own research with the second observatory, called Copernicus, earned him the Crafoord Prize from the Royal Swedish Academy of Sciences. For astrophysicists, this is the nearest equivalent to the Nobel Prize.

Fear of the Expense

Although many astronomers were skeptical, Dr. Spitzer had prevailed on the National Academy of Sciences to study and recommend proposals for a large space telescope. Even if a space telescope with a mirror more than 100 inches wide might be feasible, the critics preferred a more conservative approach using a number of different smaller telescopes. They feared the big scope would be so expensive it would kill off more modest and more certain endeavors.

Dr. Spitzer was undeterred. In his history of the project, Dr. Smith quoted a colleague as saying, "Lyman is a master of listening to everybody and doing in the end what he wants to do."

Others attribute this dauntless persistence to the mountain-climbing side of the man. Dr. Spitzer has scaled many peaks in his life, and still tries to do some rock climbing once a week. About a decade ago, he was sighted at dawn working his way up the wall of a gothic tower at Princeton and was arrested by campus police.

After a conference of astronomers at Woods Hole, Mass., in 1964, a board of the academy recommended that NASA proceed with the project, to be known initially as the Large Space Telescope. NASA first considered an instrument with a 120-inch mirror. During a preliminary design study, prompted by Congressional resistance, the size was scaled back to 94 inches to save money and simplify construction.

'Great Orbital Device'

By all accounts of his colleagues, Dr. Spitzer is a quiet, gentle and modest man. But he saw the idea through the science and NASA bureaucracies with aggressive vigor that the initials for the Large Space Telescope, L. S. T., were said by insiders to stand for the Lyman Spitzer Telescope.

Reminded of this, he merely chuckled and changed the subject. The adjective "large" did have to be dropped, he recalled, because the telescope was not as large as envisaged and because it was thought to frighten Congressional budget makers.

"A friend of mine," Dr. Spitzer remarked, "suggested that we call it the Great Orbital Device, which would give it an interesting acronym."

A more appropriate and evocative name was conceived in 1983: the Edwin P. Hubble Space Telescope, honoring an American astronomer who discovered 60 years ago that the universe was expanding. It was Hubble's findings that set the stage for modern cosmology's theory that the universe began some 10 billion to 20 billion years ago in an explosion, the Big Bang, that send matter and energy hurtling off in all directions.

Close to Foundering

If the success of Copernicus, demonstrating the benefits of a space telescope, and the design studies by NASA highlighted the third decade in Dr. Spitzer's chronology, the whole project came close to foundering. In 1975 and 1976, NASA's budgets were unusually tight, and Congress was reluctant to authorize any new spending for space. NASA was on the verge of canceling the project. Dr. Spitzer became a lobbyist.

"John Bahcall and I divided up the names of key Congressmen and decided who would see whom," he said. "We spent a lot of time in Washington. We called on other astronomers, who got their friends to get their friends to put on the pressure. The response was overwhelming."

In 1977, NASA received approval to start the project, at a cost estimated to run $435 million. Designs were completed, contracts were let to industry, and fabrication began. The Lockheed Missiles and Space Company would build the spacecraft, and the Perkin-Elmer Corporation would produce the mirror and major telescope components. Launching was planned for 1983.

The project's fourth decade proved even more turbulent. Technical problems with the telescope held up its completion. The General Accounting Office, an investigative arm of Congress, uncovered serious shortcomings in project management, which led to a general shakeup of operations at NASA and the contractors. Costs had escalated, with $1 billion now the conservative estimate.

Chance to Improve Controls

Even the new launching date in 1986 could not be met, but this time it was no fault of the Hubble team. When the space shuttle Challenger exploded in January 1986, all missions were grounded indefinitely. The new delay added another half billion dollars to the expense, but it did give managers a chance to revise entirely what was discovered to be an inadequate computer control system, or software program, for operating the telescope in orbit.

In the last few years, Dr. Spitzer has taken a lesser role in the project, acting only as chairman of the board that oversees management of the Space Telescope Science Institute in Baltimore, the center responsible for planning, executing and processing research with the Hubble telescope.

> With luck, the man who envisioned the telescope will be using it by December.

He has been instrumental in selecting the project's new scientific leaders. But Dr. Riccardo Giacconi, director of the institute, has become the dominant figure in the program.

Even in his heyday, Dr. Spitzer lost a few battles. He had led a campaign to have the telescope science institute situated at Princeton, but Johns Hopkins University won out. His team at Princeton sought the contract to develop the telescope's main camera system, but the California Institute of Technology won with what Dr. Spitzer concedes is a "superior" electronic device.

Telescope of His Dreams

But Dr. Spitzer has the telescope of his dreams. By November or December, if it is functioning properly, he will get to use the instrument for observations of the interstellar medium, the gases and dust between the stars. Other scientists will be looking for answers to the questions Dr. Spitzer raised in his 1946 paper.

"The most important discoveries," Dr. Bahcall said as the countdown for the launching was getting under way, "will provide answers to questions that we do not yet know how to ask and will concern objects we have not yet imagined."

The vision of Dr. Spitzer also incorporated this faith in finding the unexpected.

"It should be emphasized," he wrote in first proposing the space telescope, "that the chief contribution of such a radically new and more powerful instrument would be, not to supplement our present ideas of the universe we live in, but rather to uncover new phenomena not yet imagined, and perhaps to modify profoundly our basic concepts of space and time."

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Proprietary to the United Press International 1988

May 18, 1988, Wednesday, AM cycle

pulsar

SECTION: Regional News

DISTRIBUTION: California

LENGTH: 632 words

BYLINE: By DELTHIA RICKS, United Press International

KEYWORD: Pulsar

BODY:

Scientists have discovered a rapidly whirling pulsar, the second fastest spinning star in the universe and the only one orbiting a companion star big enough to eclipse it, astronomers said Wednesday.

''This is the second fastest pulsar known,'' said Princeton University astronomer J.H. Taylor, who along with a team of scientists, pinpointed the unusual star.

He estimates that the 10-mile-wide pulsar, spinning at mind-boggling speed, makes a complete revolution every 1.6 milliseconds.

''That is why it is called a millisecond pulsar,'' said Taylor. ''You can set the best atomic clocks by them.''

A millisecond is one one-thousandth of a second. Atomic clocks, the most accurate timepieces, are based on the vibrations of atoms.

Pulsars are believed to be neutron stars, thick clumps of condensed cosmic matter. A neutron star is the remnant of a supernova -- or superbright star -- that has exploded, the force of the blast compressing more matter than can be found in our sun into the cosmic spinning ball.

The new pulsar, designated PSR1957+20, orbits a mysterious companion star every 9.17 hours, Taylor said.

While many known pulsars are solitary spinning tops, others, primarily those of the millisecond species, are paired with dense white dwarfs. These are small neutron stars that dump energy into the pulsars, giving them the extra boost to drive their spin.

But the partner star of the new pulsar, measures about three-quarters the diameter of the sun and eclipses the pulsar for about 50 minutes in every orbital cycle, blocking the pulsar's characteristic radiosignal.

''This is the first time that this has happened,'' said Roger Blandford, an astrophysicist at the California Institute of Technology. ''We are not used to having stars eclipse in a binary system. Most (pulsars) are individual stars and the power of their emission is derived from the energy of their spin.

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''It is certainly possible that others will be found because this eclipsing system is important and suggests how some other millisecond pulsars might have evolved.

Scientists have discovered approximately 400 pulsars, spinning in revolutions ranging from 0.1 milliseconds. The stars are noteworthy for their radiosignals which are believed to be caused by highly charged streams of energy emitted at their magnetic poles.

Each time the star makes a complete revolution, it sends out a pulsing radiosignal across the heavens much like Darth Vader's light saber in the movie ''Star Wars.''

Pulsars exist beyond our Milky Way galaxy in the far reaches of deep space where scientists have begun to catalogue a growing variety of astronomical phenomena.

This cosmic zoo includes the new class of superfast pulsars, black holes and quasars which were once believed to exist on the very fringes of the universe.

What most of these phenomena hold in common, astronomers say, is their composition -- collapsed matter. Gravity is the force that that powers these stars and it also is the one that leads to their collapse, which in the most extreme case -- a black hole -- is so dense that even light cannot escape it.

Taylor described the highly unusual pulsar in a paper appearing in the current issue of the British scientific journal Nature, where he wrote ''it is exciting to speculate that we are witnessing the evaporation of the companion (star) by the pulsar. ''

He explained that energy from the companion star apparently is being slowly sucked away by the spinning star.

''If we dare look into the future,'' Taylor said wryly in an interview, ''in 10 million to 100 million years the evidence will be gone. The companion star will be totally evaporated.''

Taylor and his colleagues discovered the highly unusual pulsar during observations at a Puerto Rican radiotelescope.

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December 7, 1988, Wednesday

quark

DISTRIBUTION: TO BUSINESS/SCIENCE/EDUCATION DESKS

LENGTH: 847 words

HEADLINE: UT-DALLAS CONFERENCE DRAWS TOP SCIENTISTS FROM THROUGHOUT GLOBE

DATELINE: DALLAS, DEC. 7, 1988

BODY:

Three Nobel Prize winners, including the discoverer of subatomic particles known as "quarks," will join with 400 other top-level physicists at the 14th Texas Symposium on Relativistic Astrophysics sponsored by The University of Texas at Dallas, December 11-16. The week-long Symposium, returning for the fourth time to Dallas in its 25 year history, will take place in the Doubletree Hotel/Lincoln Center (on LBJ near the Tollway).

Arguably the most prestigious gathering of scientists ever to assemble in Dallas, the Symposium's participants include the director of Israel's space agency, Yuval Ne'eman, and numerous representatives of NASA.

Also present will be William Fowler, awarded the 1983 Nobel Prize in physics, conducting a workshop of the age of the observable universe (Monday evening); Hannes Alfven, Nobel Prize winner in 1970, discussing the theory of a plasma universe; and Murray Gell-Mann, awarded the Nobel Prize in 1969, will lead a discussion on quantum cosmology.

Astrophysicists are scientists who research the various aspects of the universe, seeking insights into the creation of the universe, its age, shape, and component structure. At the first Texas Symposium in 1963, quasars and black holes were presented in scientific discourse; five years later, the Symposium was the site of the first discussions of pulsars.

An introductory session on Sunday evening, December 11, at 7 p.m. will provide an overview of the conference and previous symposia by distinguished physicist Englebert L. Schuking. Schuking and UT-Dallas Professors Ivor Robinson and Ervin Fenyvis, were the original founders of the Texas Symposium.

A later session, Friday at 12:45 p.m., will examine the results of UT-Dallas researcher Carlos Aiken's work in Greenland regarding a possible new gravitational force.

Media Note: For information, contact David Schulz, UT-Dallas News, 214/690-2293. Interested reporters are strongly advised to attend the first introductory session, Sunday, 7 p.m.

Following is an informational essay regarding the 14th Texas Symposium on Relativistic Astrophysics. It may be reprinted.

WHAT ASTROPHYSICS MEANS TO YOU -- An Explanation by David Schulz

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(c) 1988 Southwest Newswire, December 7, 1988

A long time ago, the universe was a whole lot smaller and a great deal hotter.

Imagine a glowing coal in the middle of a campfire. The coal becomes superhot and explodes, leaving tiny pieces of debris scattered about. Time passes, the campfire dies and the debris cools. As more time passes, the debris less and less resembles the original hot coal.

Now examing the cool debris, how do we begin to understand the forces of heat and pressure that were at the heart of the coal? Or, more to the point, so many years after the big bang created the universe, how do we examine the mighty forces present at the time?

At least two methods have arisen. One, demonstrated in the supercollider project, tries to recreate those same primeval high-energy forces in a controlled environment.

The second method is by observing the components of the universe from a distance. Because images are composed of light, which travels at a finite speed, by examining images of very far away objects we are actually observing their distant past. The farther away we can look, the deeper into the past we observe. Beyond "seeing," we can also "hear". Much of the static background noises on the 3-cm. radio band are the echoes of the original big bang.

It is through these observations, and the resulting analyses, that relativistic astrophysicists can piece together the origins and causes of the universe.

What will this tell us, and how will it be of use?

In day to day life, we rely greatly on scientific understandings of natural forces. So far, science identifies four forces -- the electro-magnetic, the gravitational, the strong nuclear force and the weak nuclear force.

When Alessandro Volta first demonstrated an electrical charge in the late 18th century, he would have had difficulty anticipating the electrically lit world of instant communication and automated industry that would ensue. And it no longer takes 200 years for science to become apparent in day-to-day life.

Research in the strong and weak forces of the atom made possible the ability to translate a little bit of matter into a lot of energy . . . as in a nuclear reactor or atomic bomb. Similar harnessing of the other forces can be expected to result in revolutionary changes. Research currently focuses on the force of gravity -- how it works, and why -- and how, if at all possible, we can make a connection between all four forces. This is the grail of modern physics, a "completely unified field theory."

Through research into the origins of the universe, and a more complete knowledge of its makeup, scientists anticipate more clues about the nature of force, and the forces of nature. With these understandings, technology will develop at a much faster pace than we can even imagine.

CONTACT: David Alex Schulz, director of news and information, The University of Texas at Dallas, 214/690-2293.

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19TH STORY of Level 1 printed in FULL format.

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Facts on File World News Digest

December 8, 1989

SECTION: MISCELLANEOUS; Science

PAGE: Pg. 921 A1

LENGTH: 776 words

HEADLINE: 'Great Wall' Found in Space

BODY:

Astronomers mapping the farthest reaches of the universe had discerned the largest structure ever discovered, an enormous sheet of scattered galaxies arrayed almost in a plane, which its discoverers dubbed the "Great Wall" in a report published in the journal Science November 17.

The array consisted of at least 2,000 very bright galaxies stretched across the sky from horizon to horizon, but the galaxies were so distant that they were invisible to the naked eye. But according to astronomers Margaret Geller and John Huchra of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, who discovered the array while preparing a three-dimensional map of the universe, the planar array measured about 500 million light years by 200 light years across but only 15 light years thick. (A light year, about six trillion miles, is the distance light travels in a year.)

The sheet of galaxies formed one side of a huge "bubble" in space that contained little detectable matter, they said.

Geller had earlier discovered that the galaxies in deepest space were not randomly scattered but appeared to be arrayed as if strewn on the surfaces of vast bubbles of relatively empty space. [See 1986, p. 402C3]

The reasons for the apparent clustering were as yet unknown.

In other astronomical research:

* Scientists at the California Institute of Technology November 19 said they had identified the oldest and most distant object yet discovered, a quasar close to the edge of the observable universe. (Quasars were brilliant light and energy sources associated with distant galaxies.) Calculations based on the light it emitted indicated that the object was in existence within one billion years of the birth of the universe in a cosmic Big Bang 10 to 20 billion years ago. The discovery lent support to the idea that galaxy formation had begun very early in the life of the universe. [See 1986, p. 574D2]

* Astronomers August 28 said they had identified what appeared to be a galaxy in the early stages of formation. The object, first sighted in 1988, was a giant disk of slowly rotating hydrogen gas about 65 million light years from Earth. This so-called proto-galaxy as yet contained few or no stars, but current theory assumed that galaxies were created when such hydrogen clouds collapsed under gravitation into billions of stars. Most of the existing galaxies were believed to have been created in the first few hundred million years after the

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Big Bang. The new discovery provided evidence that galaxy formation might still be going on. [See 1987, p. 233F2]

* Astronomers at a meeting of the American Astronomical Society in Ann Arbor, Michigan June 15 reported having identified at least four and as many as nine brown dwarfs, dark objects intermediate in size between planets and stars, in an area of space where new stars were forming. They also said it was possible that such objects were so numerous that they could account for a significant amount of the "missing mass" in the universe. (Known objects accounted for only about 10% to 40% of the gravitation that seemed to be operating in the universe.) Claimed sightings of brown dwarfs had become numerous in recent years, but because they were hard to discern, doubts remained about each. [See 1984, p. 934C1]

* Scientists January 18 measured signals from what appeared to be a pulsar, a rapidly spinning superdense mass and energy source in the location of Supernova 1987A, a star that exploded in the southern hemisphere in 1987. Such a pulsar would represent the collapsed remnants of the exploded star. But the object discerned appeared to be spinning 2,000 times a second -- more rapidly than any known pulsar -- and wobbling slightly. The inability of scientists to repeat the sighting eventually raised questions about what was observed, according to an article in Science March 24. Supernova 1987A-watchers were also intrigued by off-again on-again sightings of what appeared to be a companion object receding from the supernova at high speed. [See 1987, p. 1007B1]

* A ribbon of gas and dust more than 90 trillion miles long was streaming toward the center of the Milky Way galaxy, according to Paul Ho of the Harvard-Smithsonian Center for Astrophysics January 10. Ho theorized that the streamer was the remnant of a cloud of interstellar gas that had been orbiting near the center of the galaxy when it was violently disrupted by a supernova, sending it streaming toward the galactic core. The mass of the cloud could be fueling a black hole at the core of the galaxy a million times as massive as the Sun, Ho said. [See 1985, p. 830D3]

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July, 1986

plate tectonics
Red Sea

SECTION: Pg. 10

LENGTH: 718 words

HEADLINE: Wandering continents

BODY:

Wandering continents

ANYONE who has looked at a world map must have noticed how snugly the coastlines of Africa and the Americas could be made to fit together, if the intervening ocean were removed. Modern geophysics has established that all of the Earth's landmasses were indeed joined together in one supercontinent, Pangaea, hundreds of millions of years ago, and that this supercontinent was broken apart, with the land masses drifting to their present positions on the globe.

This idea took many years to become established. Speculations about the fit of the continents go back to Francis Bacon (1561-1626), but the acknowledged "father' of the idea of continenta l drift was the German astronomer and meteorologist Alfred Wegener, who published the first comprehensive statement of the theory in 1912. Wegener thought that the continents might move through the thinner crust of the ocean floor, like icebergs ploughing through the sea, and he gathered a wealth of evidence showing how well the continents could be fitted together like some global jigsaw puzzle. But the idea of continents moving through the rocks of the sea floor did not seem feasible, and found little favour until the 1950s, when the developme nt of new geological techniques provided conclusive evidence that the continents do move.

The key evidence came from magnetic studies of the ocean floors. These showed that the crust of the Atlantic Ocean floor is arranged symmetrically on either side of a great ridge of volcanic activity which runs roughly down the centre of the ocean bed. The interpretation of this discovery is that new oceanic crust is being created at the mid-ocean ridge, where it wells up through a crack in the Earth's crust and is pushing out on either side, steadily widening the Atlantic.

In other parts of the world the reverse happens. The North Pacific, for example, has no oceanic ridge, but there is a deep trench running down the west of the ocean floor, next to the Eurasian landmass. There the thin crust of the ocean floor is being pushed under the continent, back down into the mantle where it melts and is ultimately recycled. The net effect is that there is no change in the surface area of the Earth--spreading in the Atlantic and at other sites is balanced by contraction of the Pacific. A piece of the Earth's crust that is bounded by spreading ridges and subduction zones is called a "plate', which gives the concept of continental drift its modern name, " plate tectonics' . In some places, two pieces of crust--two plates--rub side by side, with no net creation or destruction of sea floor. This happens today along the notorious San Andreas fault in California.

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The whole process of break-up and re-arrangement of the continents may have happened several times in the Earth's history, and is responsible for building mountain ranges, where continents collide. India, moving northward into Eurasia, has forced up the Himalayas, which are still growing. By contrast, the line of the Red Sea marks a new (by geological standards) crack in the Earth's crust, a spreading ridge which is splitting Africa off from Arabia, and which may eventually cause this narrow sea to expand into an ocean as large as the Atlantic is today.

Overwhelming evidence for the reality of continental drift, or plate tectonics, was collected during the 1960s and 1970s. But the "icing on the cake' has been provided only in the past few years. Using laser beams bounced off artificial satellites in orbit around the Earth, it is now possible to measure directly the steady widening of the Atlantic, calculated at a couple of centimetres every year.

Photo: 200 million years ago

Photo: Present

Photo: 135 million years ago

Photo: In 50 million years' time

Photo: Ocean spreading ridge. Plates are separating; molten rock r ises, adding new material to each plate.

Photo:Oceansubductionzone.Oneplateunderthrustsanother.T h

e edge of one plate is pushed down into the mantle where it melts and is recycled. Some of the molten rock rises to form an island arc.

Photo: Collision zone. An underthrusting plate rams two continent s together, forming a high mountain belt.

Photo: Transform fault. Two plates slide past one another with no addition or destruction of plate material.

GRAPHIC: Map; Caption: South America and Africa; Various tectonic plates around the world

SUBJECT: Plate tectonics, observations; Continental drift, maps; Geophysics, Observations

LOAD-DATE-MDC: March 30, 1988

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BIG BANG - PLASMA THEORY

Acad.

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February 28, 1989, Tuesday, Late City Final Edition
Correction Appended

SECTION: Section C; Page 1, Column 1; Science Desk

LENGTH: 1867 words

HEADLINE: Novel Theory Challenges The Big Bang

BYLINE: By JOHN NOBLE WILFORD

DATELINE: LA JOLLA, Calif.

BODY:

THE Big Bang theory, generally regarded as the best explanation for the origin, expansion and ultimate fate of the universe, is facing the first serious challenge to its validity in more than two decades.

An alternative concept, plasma cosmology, drew physicists and astronomers to a meeting here last week to discuss recent observations that appear to contradict fundamental tenets of the Big Bang theory. Laboratory studies, computer simulations and astronomy's latest findings appear to buttress the heretical position.

Proponents of the newer theory believe that hot electrically charged gases known as plasma, the form in which nearly all observable cosmic matter exists, have played a critical but so far unappreciated role in shaping the universe - stars, galaxies and all. They contend that electric and magnetic forces of plasmas provided the framework and much of the power, along with gravity, to organize matter into galaxies and other large structures seen today. The universe of plasma cosmology has existed forever, without a beginning and with no end in sight.

The Big Bang, by contrast, assumes gravity is the dominant shaping force and rests squarely on Einstein's interpetation of gravity in his general theory of relativity. In this model, the universe began at a single point in one explosive moment as much as 20 billion years ago and has been expanding steadily ever since. Depending on how much mass there is, it will continue to expand forever, dissipating into virtual nothingness, or eventually reverse itself and collapse in a ''big crunch.''

Proponents of the alternative concept, mostly plasma scientists, concede that their numbers are small and their influence slight, especially compared with the titans of astrophysical theory who maintain a firm allegiance to the Big Bang. But their ideas are drawing the attention of some astronomers.

Plasma cosmology's earliest and most ardent advocate is Hannes Alfven, the Swedish physicist who won a Nobel Prize in 1970 for his work in founding the modern study of plasmas. The 81-year-old physicist is a professor emeritus at the University of California at San Diego and the Royal Institute of Technology in Stockholm.

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''The astrophysicists know they have problems with the Big Bang, and they're beginning to study our arguments,'' Dr. Alfven said in an interview. ''They're cautious, of course. A Christian does not go to Mecca and become a convert overnight.''

Dr. Alfven and other proponents held a three-day workshop here to report new evidence for plasma cosmology and to evaluate the implications of recent findings showing concentrations of galaxies apparently too vast to have formed in the time since the Big Bang and also measurements indicating that radiations supposedly left over from the initial explosion may be different than predicted by theory. The meeting was sponsored by the Institute of Electrical and Electronic Engineering and supported by the National Aeronautics and Space Administration.

''Discoveries in space have drastically changed and expanded our concept of how cosmic plasma behaves,'' said Carl-Gunne Falthammar, a physics professor at the Royal Institute of Technology.

With spacecraft and telescopes, scientists have observed huge electrical currents and magnetic fields in the solar system and beyond that resemble on a large scale what they had been seeing in laboratory plasma studies. One result of these forces, scientists reported, were the long filaments of matter that appear to be prevalent, a phenomenon that suggests how plasma processes led to large structures in the universe.

Argument Against Big Bang

In a direct challenge to Big Bang theorists, Anthony L. Peratt, a plasma physicist at the Los Alamos National Laboratory in New Mexico, who was one of the workshop organizers, said: ''We're extrapolating from known phenomena. They're extrapolating from ad hoc assumptions.''

Astronomers reporting some of the observations that seemed to support the plasma cosmology, however, reserved judgment. ''I'm not convinced the Big Bang is out,'' said Rainer Beck of the Max Planck Institute for Radioastronomy in Bonn, West Germany. ''But I'm open to new ideas.''

Leading Big Bang proponents deny that their concept is in serious trouble. They concede that magnetic forces are important in the universe and are including them in their new studies, but they say observations indicate that magnetism is not strong enough to be pushing matter around on a universe-building scale.

Jeremiah Ostriker, an astrophysicist at Princeton University, said: ''I believe there really are missing ingredients to our understanding of the origin of large structure in the universe. But I have trouble understanding plasma as an alternative model. There's no observational evidence that I know of that indicates electric and magnetic forces are important on cosmological scales.''

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at a single point.

But Dr. Alfven, cautioning against faulty reasoning, said: ''If there were a Big Bang, you had to have the Hubble expansion. But it does not follow that because there's an expansion, there was a Big Bang. That's the same logic that says, all dogs are animals, and therefore all animals are dogs.''

Energy Echo From Explosion

The Big Bang still proved to be a successful theory. It explained many of the observations of astronomers and studies of atomic particles. What was regarded as decisive confirmation of the theory came in 1965. Radio antennas detected microwave radiation of seemingly unvarying intensity pervading the cosmos, and this was widely accepted as the energy echo from the explosion.

Problems still taxed scientific ingenuity. Most of the mass required for such a universe is missing, an estimated 90 percent of it beyond present observation; so astrophysicists have invoked something called dark matter, hypothetical exotic particles and perhaps larger unseen objects, to account for the mass. Galaxies appeared to have evolved too early and developed into clusters too large; here, too, the dark matter might have supplied the necessary gravity, or perhaps ''cosmic strings,'' streams of exotic particles generated in the moment of creation, could have acted as the framework for the universe's early clumping into galaxies.

Three years ago, R. Brent Tully, an astronomer at the University of Hawaii, found a host of galaxies that appeared to be clumped in a ''supercluster complex'' about one billion light-years long. If the observations are correct - they are still being debated - astrophysicists conceded that even dark-matter theories could not account for such large structure in the universe. There would not have been sufficient gravity or time.

Then, more than a year ago, Japanese and American scientists reported infrared observations showing that the background radiation, the presumed relic of the Big Bang, had more energy than predicted by the theory. This has yet to be explained, and attempts to confirm the measurements will be made with rocket launchings this summer.

As the problems have mounted, a few scientists began to explore Dr. Alfven's idea of a plasma cosmology and became convinced that there was more than gravity in the evolution of cosmic structure. Since 99 percent of the observed universe is composed of matter in plasma form, they argued, the influence of plasma's powerful electrical and magnetic properties should not be ignored.

Plasma is sometimes called the ''fourth state of matter.'' Neither solid, nor liquid, nor gas, a plasma most closely resembles the latter, except that the atoms and molecules comprising plasma are so energetic that some of them have lost one or more electrons. This makes them electically charged. Plasmas are more efficient conductors of electricity than copper.

The Sun is a gravitationally bound plasma, and the particles streaming out from the Sun as the ''solar wind'' are a plasma. Spacecraft have discovered a torus of plasma around Jupiter and Saturn.

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According to Eric J. Lerner, an independent plasma researcher in Lawrenceville, N.J., the most important aspect of plasma for cosmology is its tendency to become clumpy.

In laboratory experiments, small random motions in electric currents of plasma, caused by the magnetic fields they create, draw them close together in a ''pinch effect.'' The merging currents produce larger currents and magnetic fields and rapidly lead to a network of ever-larger filaments. Once they get big enough, their gravitational fields will exert a major force.

Computer simulations by Dr. Peratt show that galaxies could form along the paths of these currents, like beads on a string. The simulations also show that the spiral shape of many galaxies may result from the effects of these plasma currents and their associated magnetism.

Plasma scientists cite a discovery made in 1984 as crucial evidence that what they see in the laboratory and in simulations is actually occurring in nature. Radioastronomers from Columbia University found real filaments near the center of the Milky Way, the Earth's galaxy. Mr. Lerner said they look like ''textbook examples of electromagnetic vortices.''

Mark Morris, an astronomer at the University of California at Los Angeles, reported at the workshop that recent observations of these filaments reveal behavior suggesting that powerful magnetic fields, not gravity, could be the dominant force at the center of the Milky Way. If this is correct, and turns out to be the case elsewhere, Dr. Morris said, the strange objects at the center of galaxies may not be black holes, which are believed to be tremendous gravitational wells sucking in everything, but magnetic fields.

But it would take an incredible amount of time for filaments of plasma and magnetic fields to create the large structures, clusters of galaxies joining in superclusters, that appear to be common to cosmic architecture.

''If you have a universe that doesn't have a Big Bang, you have plenty of time,'' Mr. Lerner said.

Another Recipe for a Galaxy

Electric current in a charged gas or plasma creates a magnetic field, which in turn bends the current. These actions pinch the plasma into a filament, in a process shown above, and cause it to start rotating.

Computer simulations suggest how plasma forces could produce large structures. The pinching effect that produces filaments (1) also draws them together. Contracting masses (2) rotate around each other. Filaments draw together (3) as embryo galaxy. When they merge (4), gravity is sufficient to attract matter into clumps that evolve into stars that eventually cluster in a classical spiral galaxy like NGC1300.
Source: Anthony L. Peratt, Los Alamos National Laboratory

CORRECTION-DATE: April 12, 1989, Wednesday, Late City Final Edition

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CORRECTION:

An article in Science Times on Feb. 28, about a challenge to the Big Bang theory of the origin of the universe, misstated an interpretation given by Mark R. Morris, professor of astronomy at the University of California at Los Angeles, to phenomena observed near the center of the Milky Way galaxy. He said, in recent correspondence, that the presence of plasma filaments there has not altered his support for the existence in the region of a black hole, a dense concentration of matter whose gravitational force is so strong that light cannot escape. He also said that gravity could be the dominant force in the region.

GRAPHIC: Diagram (pg. C1); photo of Hannes Alfven, a founder of modern study of plasmas (NYT/Robert Burroughs (pg. C11)

SUBJECT: SPACE; MAGNETISM AND MAGNETS; GASES; GRAVITATION AND GRAVITY; STARS AND GALAXIES

NAME: WILFORD, JOHN NOBLE; ALFVEN, HANNES (DR); EINSTEIN, ALBERT (DR) (1879-1955); WILFORD, JOHN NOBLE

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e Holds Area Scientists' Hopes

...unc..as Have Stake in Long-Delayed Hubble Space Telescope

By Lisa Leff
Washington Post Staff Writer

If it succeeds, the Hubble Space Telescope will not only unlock many of the wonders of the universe, it will be one of them. And all the workers who devoted months or years to the monumental project will have hitched their wagons to a star.

"It's sort of like being the chief engineer for the pyramids," said David Skillman, chief engineer of

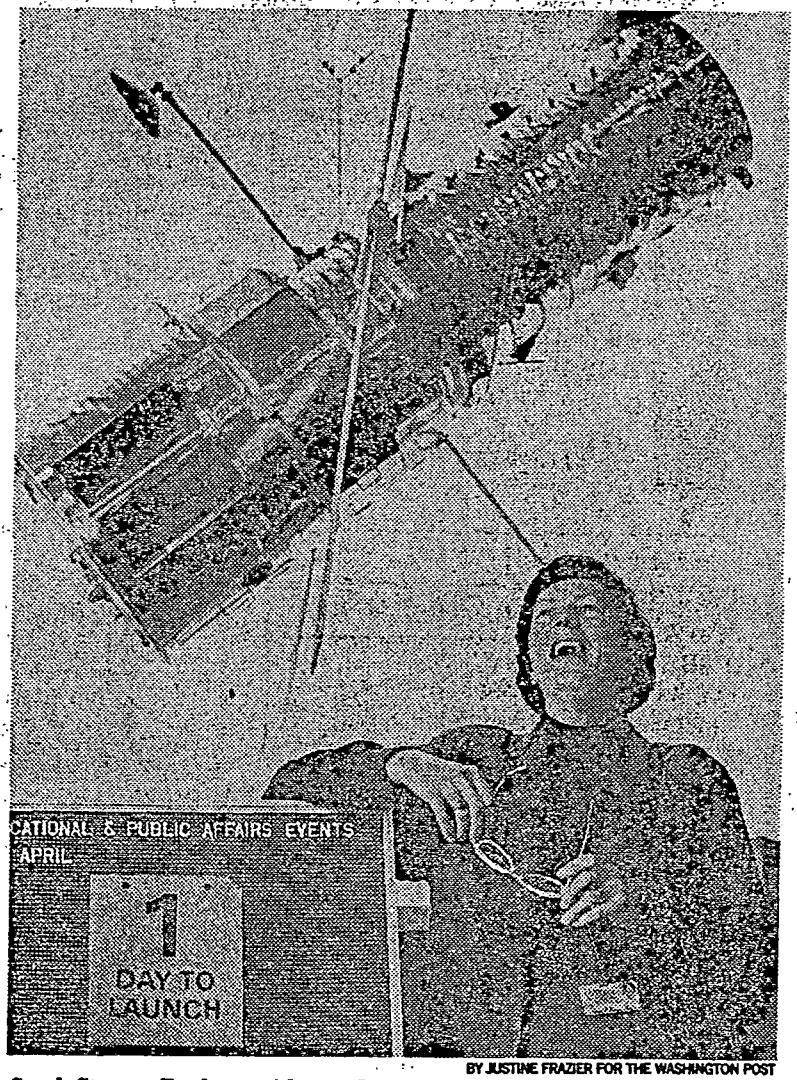
The major networks will broadcast the liftoff live if it happens as scheduled at 8:47 a.m. Story, Page A9.

the Hubble project at Goddard Space Flight Center in Greenbelt. "Building a pyramid isn't that interesting, especially if it goes on too long, but the scale of it is so great that the work is alluring even if you are just stacking bricks on top of one another."

Skillman is one of hundreds of scientists in Washington and Maryland who linked their fortunes to the revolutionary telescope, and then had their painstaking preparations scuttled and patience tested by repeated delays. Hubble's original launch date was in 1983. Now liftoff is scheduled for this morning.

"The running joke here is that

See TELESCOPE, A9, Col. 1



BY JUSTINE FRAZIER FOR THE WASHINGTON POST

Sarah Stevens-Rayburn with a scale model of the Hubble Space Telescope.

Photocopy-Preservation

Photocopy-Preservation

Anxiously Awaiting The Launch

TELESCOPE, From A1

there is no telescope, that this is a psychological experiment on the effects of "delayed gratification," said Sarah Stevens-Rayburn, librarian at the Space Telescope Science Institute in Baltimore.

Stevens-Rayburn, who gave up a job in Charlottesville to come to Baltimore for the telescope in 1983, confessed that anxiety that something will go awry at the last minute caused her to scan the newspaper want ads last weekend "just to see what my options are."

Others staff members at the institute, which is on the campus of Johns Hopkins University, said they long ago abandoned "Two Years to Launch" parties in favor of macabre humor. Launch celebrations are being postponed until they know Hubble is up and running next week, they said.

Their endurance is scheduled to be rewarded when the $2.1 billion telescope gets a lift into orbit, catching a ride beyond Earth's atmosphere with the space shuttle Discovery.

Employees at Goddard and at the telescope institute said they are approaching the Big Moment with excitement and dread. One compared it to a woman's last hours before giving birth for the first time.

If all goes according to plan, the single most expensive scientific instrument ever built will start sending back postcards from outer space in about two weeks and fulfilling its promise of giving mankind new insights into the origins of the universe.

Most space projects are executed within five years of conception, but Hubble has had an unusually large number of setbacks, the most recent being the 1986 explosion of the space shuttle Challenger, Skillman said. Nowhere has the effect of the delays been felt more keenly than at Goddard, which will be responsible for operating the telescope, and at the telescope institute, where the data it collects will be assembled and analyzed.

Although Hubble cannot be claimed as a home-grown Maryland satellite (it was built mostly in Alabama and has been housed in California for several years), it will be very much a Maryland attraction from the moment it is deployed 380 miles in space. Indeed, for the 15 years the telecope is expected to be in operation, much of the world's astronomical research will revolve around Goddard and the telescope institute.

In addition to the 600 people at those facilities who will continue to be involved with the project, 400 to 500 astrophysicists are expected to flock to the institute to scan the heavens and attend conferences.

Not that the years of delay have been unproductive. Skillman and his crew have used the time to update the technology on some of the computers and cameras aboard Hubble, as well as to improve the ground instrumentation. Michael S. Shara, an institute astronomer, said he has continued doing research on ground-based telescopes that should enable him to use his hours on Hubble more effectively.

In some ways, though, the real work is just beginning. And no one is more ready for it than Ray Starner. A Howard County resident who is a mathematician at the Hopkins Applied Physics Laboratory near Columbia, Starner is one of five amateur astronomers selected in a nationwide competition to receive viewing time on Hubble.

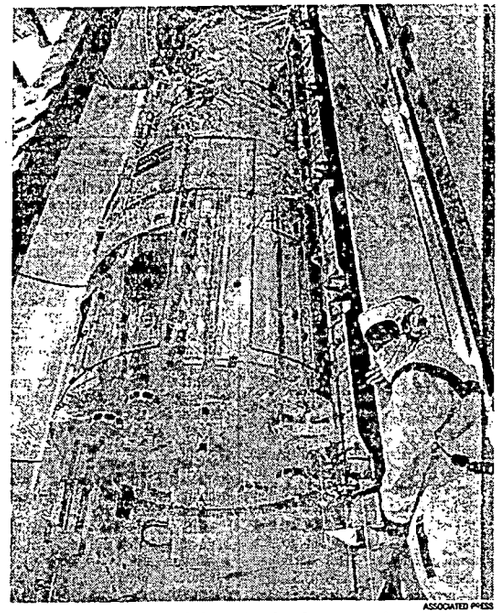
Starner was selected after coming up with a theory, still at odds with most scientific journals, of how a mysterious, arc-shaped object was created. While most scientists agree that it is probably an optical illusion, Starner, using models generated on his home computer, speculated that it was created when two galaxies collided.

Starner, who became interested in astronomy while growing up in rural Pennsylvania, has traveled to Cape Canaveral for Discovery's launch and said he is considering moving away from Woodbine because the light from developments has started to obscure the stars.

"I think the country is really going to hurt itself from having all this light pollution," he said. "The kids are more interested in watching TV because when you go out at night you can't see anything."

Hubble may help change that.

"If everything goes well, there will be tremendous excitement here and around the world about what the telescope will do," librarian Stevens-Rayburn said. "And if it goes up and something untoward happens, our lives will be different from the loss."



ASSOCIATED PRESS

A technician closes Discovery's doors after the telescope covering was removed.

Early Release of Telescope Data Set

NASA to Provide Raw Images Promptly; Countdown Continuing

By Kathy Sawyer
Washington Post Staff Writer

CAPE CANAVERAL, April 9—NASA officials said today they will release raw "engineering" images from the pioneering Hubble Space Telescope a few days after it is launched rather than keeping with the original plan of waiting two weeks or more for electronically processed "pretties."

The decision, apparently made under pressure from news organizations, came as the countdown continued smoothly toward Tuesday morning's scheduled launch of the instrument, the most costly and complex science payload the space agency has ever carried to orbit.

The launch, aboard the space shuttle Discovery, could take place any time within a 2½-hour "window" that opens at 8:47 a.m. Eastern time.

The only shadow on the escalating excitement among scientists and engineers gathered at Kennedy Space Center for the long-awaited launch was a possibility of clouds and high winds at liftoff time.

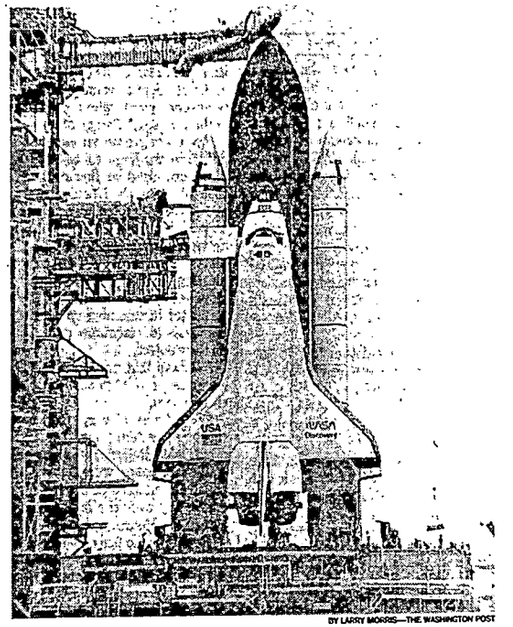
There is a 50-50 chance that weather conditions will prevent the launch in the early part of the window, according to Air Force meteorologist Thomas Strange. He said that should improve to an 80 percent chance of launching before the period ends.

NASA officials, meanwhile, ended a debate about how and when to release to the public the first images from the unique telescope—designed to be the world's first orbiting observatory and to provide 10 times more detailed images of celestial objects at almost the edges of the universe.

Charles Pellerin, head of astrophysics for NASA, said the images from a focus test to be performed on the fourth day of flight will be shown on screens in black and white as they reach the telescope's controllers at the Goddard Space Flight Center in Greenbelt.

The target object, he said, is NGC 3532, an open star cluster in the constellation Carina (the Keel).

According to astronomers on the project, the cluster's brightest star is of the second magnitude. It is located about 1,500 light-years from Earth and is visible to the naked eye from deep in the Southern Hemisphere, slightly "north" of the plane of the Milky Way. (NGC stands for New General Catalogue.)



BY LARRY MORRIS—THE WASHINGTON POST

Discovery is poised on Cape Canaveral pad to take Hubble telescope into space.

This is only an "engineering picture," Pellerin emphasized. "We didn't want to hype this as the 'first picture' because it isn't a scientific picture."

There may be some surface blemishes in the images, he added, because the telescope's electronic detectors, which work best when cooled to the temperature of deep space, will still be warm.

True "first light" pictures, thoroughly processed and indicative of what the telescope will be capable of, are to be released about two weeks after launch by NASA administrator Richard H. Truly, officials said.

The $2.1 billion telescope project has survived decades of technical and management hurdles and a 3½-year delay caused by the 1986 Challenger accident. And two weeks ago, a plague of "no-see-em" bugs, or midges, had to be purged from Discovery's cargo bay in order to prevent any chance of contaminating the telescope's one-of-a-kind mirror, the most optically precise mirror ever built.

If Tuesday's launch is delayed, the ground teams can make two additional attempts to lift off this week, according to launch director Robert Seick. After Friday, there would be an eight-day delay while the telescope's batteries are serviced.

For scientists who have spent a decade or more on the project, finally getting this close to the moment of truth is spine-tingling, they say.

"I can't describe the emotions," said NASA astronomer Edward Weiler, who started work on the Hubble 11 years ago. "I'm on the verge of breaking up half the time walking around here."

California and the West

No Small Feat

Atom Research Could Widen Horizon of Miniaturization

By THOMAS H. MAUGH II
TIMES SCIENCE WRITER

IBM researchers in San Jose have succeeded in moving single atoms around under a microscope, a major step toward the fabrication of atom-sized transistors, exceptionally small integrated circuits and even molecule-sized mechanical devices.

Among other things, these ultraminiaturized electronic components could allow researchers to build microcomputers that operate hundred to thousands of times faster than the fastest supercomputers available today and that store data at densities almost undreamed of now.

The technique should also provide new understanding of the so-called surface catalysts that are used in making as much as 85% of the products of the petrochemical industry.

The researchers report in today's Nature that they manipulated the atoms using an expensive, custom-built scanning tunneling microscope, which is so sensitive that it must be shielded from body heat and the voices of people in the same room.

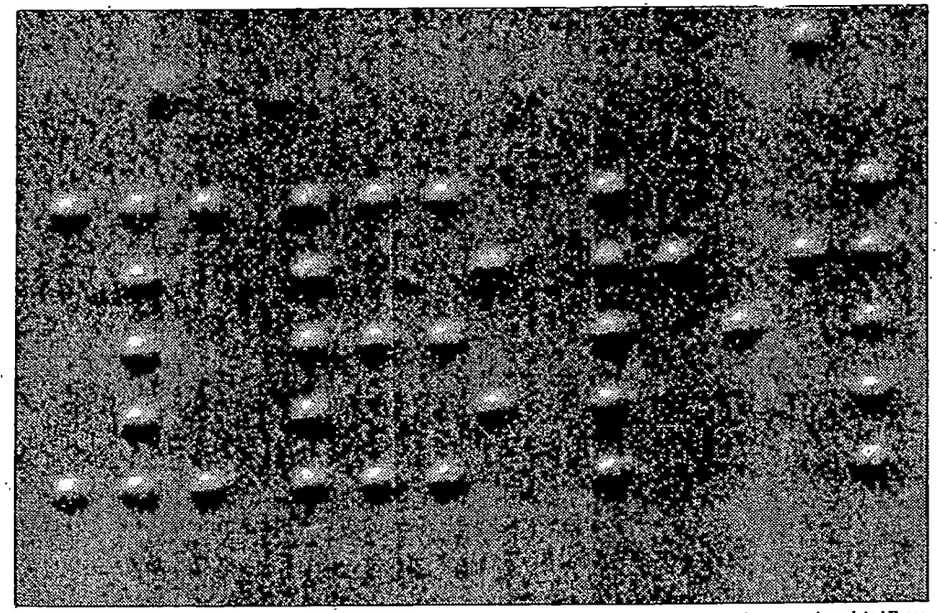
Their prize specimen: 35 xenon atoms painstakingly arranged over a 22-hour period to spell out "IBM" in letters that are one five-hundred-thousandth the size of letters on this page.

But physicists Donald M. Eigler and Erhard K. Schweizer of IBM's Almaden Research Center in San Jose foresee far more practical applications for their technique. They noted that it should be possible to modify or assemble certain molecules by the technique, especially molecules that are otherwise unobtainable.

Manufacturers of synthetic rubber, for example, might be able to use catalysts composed of clusters of two or three metal atoms to produce highly specialized materials. Such clusters are very difficult to produce by chemical reactions, but might be made easily with the new technique.

Physicist Sheldon Schultz of UC San Diego called the work "a real contribution." The IBM researchers, he said, have "demonstrated the ability to place atoms with atomic precision. It's the first time it has been done anywhere near that level. . . . You can't have any more control than that. It is the ultimate resolution."

Please see ATOMS, A29



Associated Press

A magnified look at 'IBM,' written with atoms. It took 22 hours to arrange the atoms.

ATOMS

Continued from A3

The scanning tunneling microscope was invented in the early 1980s by physicists Gerd Binnig and Heinrich Rohrer of IBM's Zurich Research Laboratory in Switzerland, a feat for which they won the 1986 Nobel Prize for physics.

The device works in a manner similar to a phonograph. An extremely small needle, whose tip is formed by a single atom, passes over the surface of an object in a regular pattern. A principle of physics called the tunneling effect keeps the tip of the needle a precise distance from the surface.

As the tip moves up and down to follow the contours of the object, sensitive electronics measure its motion and convert that information into a detailed picture of the surface. The microscope can "see" objects as small as a single atom.

But Eigler and Schweizer, who was a visiting scientist from the Fritz Haber Institut in West Germany when the work was done in November of last year, found that by placing the tip closer to a surface atom than normal, they could drag the atom along with the tip as they moved it.

Eigler said in a telephone interview that he believes that electrostatic attraction caused the atom to follow the tip until electrical current through the tip is reduced, but that they are doing further studies to show precisely how the phenomenon occurs.

"We've made educated guesses about what the mechanism was," he said. "Now, we are trying to go beyond guesses to the point of hard science."

For their experiments, Eigler and Schweizer used a highly purified nickel surface cooled to a temperature of minus 452 degrees Fahrenheit, about seven degrees above absolute zero, and kept under an ultra-high vacuum. The system is so stable, they said, that they can perform experiments on a single atom for days at a time.

To write out IBM, Eigler said, he allowed a few dozen atoms of xenon—a heavy, inert gas—to condense onto the surface, then meticulously moved them around with the microscope tip. The feat took him "22 hours nonstop," he said, "because we would sometimes destroy or partially destroy it [the design] through not being careful."

Now, he said, they have overcome those problems and can do it in "a couple of hours."

The researchers also built a small structure consisting of seven atoms of xenon weakly bound together in a row.

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Ancient Magnolia Leaf Yields Strands of DNA

Scientists' Look Into Past Is Record-Breaking

By William Booth
Washington Post Staff Writer

Scientists for the first time have read the genetic code of an organism that died between 17 million and 20 million years ago, achieving a record-breaking glimpse into the past based on new techniques that could soon be used on other ancient plants and animals, according to a report published today.

Employing powerful new tools developed in the laboratory for use in biotechnology, the scientists extracted delicate strands of DNA from a well-preserved magnolia leaf, which had been buried in the bottom of an ancient lake in northern Utah. The leaves were found essentially mummified and encased in the now-hardened lake sediment. The researchers were able to isolate from the ancient DNA an important and well-known gene that is involved in photosynthesis, the process that turns sunlight into starch.

"This is a stunning achievement," said Mary Clutter, assistant director for biological, behavioral and social sciences at the National Science Foundation, the federal agency that supported much of the research. "Just the very idea that out of rock you could extract enough DNA to sequence a gene is phenomenal. No one could have done this a few years ago. As a biologist, I can tell you this is amazing."

Until now the previous record for extracting and reading ancient genetic information came from 8,000-year-old human brains buried in a peat bog in Florida, according to Michael T. Clegg of the University of California at Riverside, who published his report with colleagues in today's issue of the journal Nature. Other DNA has been found in 13,000-year-old sloths and somewhat older woolly mammoths, but the DNA in these specimens was too damaged to decipher genetic codes.

By examining the genetic information contained in fossils, scientists hope to better understand how plants and animals evolved and how they are related to each other. Ever since the days of Charles Darwin, scientists have been consumed with piecing together an elaborate family tree that shows how each animal and plant arose from earlier ancestors.

Clegg said that he and his coworkers believe their magnolia tree lived along a lake shore during the Miocene Epoch between 17 million and 20 million years ago. At this time, the Himalayas were being formed and apes had not yet evolved.

The remains of the magnolia leaf, along with bits and pieces of other flowers, stems, insects and fish, were preserved in an ideal but unusual environment. Geologists believe the magnolia fell into a deep lake and sunk to the bottom, a cold and toxic place deprived of oxygen and hostile to the bacteria that otherwise would have consumed all organic matter. The leaf then was covered and compressed by layers of clay. Unlike most fossil remains, in which minerals invade living tissue, the magnolia leaf remained moist and mostly intact.

"The leaf was beautifully preserved," said Charles Smiley of the University of Idaho, who has worked at the site since its discovery a decade ago and who contributed to the current research.

To extract and read the genetic information, Clegg and his colleagues used a technique called the polymerase chain reaction, also known as PCR. PCR allows a scientist to rapidly make billions of copies of a gene—the quantity needed to analyze it—from a tiny sample of DNA.

"What is of major importance is that this will stimulate people to reexamine some of their sites and their fossils and to see if their materials were preserved in a similar manner. If they were, they could employ the same techniques we used. It could be very powerful," Smiley said.

i.e., April

NCI Academy of Sciences

This article is a good example of how science can look to the past.

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9:00 - Section mtgs.

11:30 - Class mtgs

12:30 - Luncheon on lawn

2:30 - POTUS

3:30 - Symposium

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Advanced Computing for Science

High-speed computation is dramatically changing the way science is done. Traditionally investigators have developed idealized models from which predictions can be made that are tested by observation or experiment. In complicated systems it is hard to find simplifications without taking the risk of throwing out the baby with the bath-water, because some of the most important phenomena can emerge from the unforeseen combination or amplification of small effects.

Computers are enabling investigators to cope successfully with such phenomena, which range from the diffusion of charge carriers in a semi-conductor to collisions between galaxies containing millions of stars. By using models of such systems it is increasingly possible to work out the consequences of simple theories in complex situations. In addition, with sufficient computation it is possible to determine the consequences of a theory without invoking questionable approximations or simplifications. An accurate computational model allows for measurements to be made in much the same way as they are in laboratories. But a computational model is better in that infeasible experiments can be done and parameters inaccessible to experiment or observation can be measured. For example, because Newton's law of gravity is well understood and accurate computational models of the solar system exist, it can be determined how the orbit of the earth would differ if Mars did not exist.

Theorists have often been forced to oversimplify so that approximate consequences can be computed and compared with the real world. One result of the increase in computational power available to scientists is a shift in the balance away from such reductionist methods to "analysis by synthesis.' The synthetic approach is called for when the fundamental processes of the interactions among the parts of a system are known, but the detailed configuration of the system is not. One can attempt to determine the unknown configuration by synthesis: one can survey the possible configurations and work out the consequences of each. By carefully matching the observable details of the experimental situation with these consequences, one can choose the configuration that best accounts for the observations.

A famous example of the synthetic approach from the 19th century is the attempt that was made to understand the observed but unexplained perturbations in the orbit of Uranus. Investigators added a hypothetical planet to the solar system and varied the parameters of its orbit until a satisfactory reconstruction of the perturbation was found. The work led directly to the

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discovery of Neptune, found near the predicted position. In the past the synthetic approach was limited to comparatively simple situations. The availability of high-speed computation has allowed synthetic methods to take their place firmly next to the traditional methods of reductionist analysis.

Analysis by synthesis has recently shed new light in an old field of astrophysics, gravitational dynamics, for here the increased speed of computers has enabled investigators to tackle problems that have long eluded other approaches.

On a grand scale the universe is populated by swarms of galaxies, some floating in relative isolation, others clumped in clusters and in clusters of clusters. Each galaxy consists of huge numbers of stars and vast amounts of gas and dust. The distances between the stars in a galaxy are sufficiently large compared with the diameters of the stars for collisions between stars to be extremely rare, even though the relative velocities of stars are typically tens or hundreds of kilometers per second. On a larger scale, collisions between galaxies are more frequent because the distances between galaxies are only 10 or 100 times larger than their diameters. On even larger scales, clusters of galaxies are separated from one another by distances comparable to their own diameters; interactions between clusters of galaxies take place over periods comparable to the present age of the universe and therefore cannot be studied as isolated events.

Collisions between galaxies make for some of the most spectacular traffic accidents in the universe. The view of the sky revealed by telescopes provides ample evidence for such violent encounters. There are paired galaxies that are close to each other in the sky and appear to be connected by bridges. Whereas most galaxies have either an approximately symmetrical spiral design or a simple spherical or elliptical shape, the galaxies that appear to be involved in collisions are often deformed or irregular. In the 1950's it was suggested that the deformations in these interacting galaxies are caused by the gravitational forces galaxies exert on each other. In the 1960's more exotic suggestions, involving magnetic fields and explosions, became popular. The motivation for rejecting the simpler gravitational explanation was that it was hard to see how purely gravitational interactions could result in sharp features such as the complex and detailed shapes of the tails and bridges emanating from, and sometimes connecting, pairs of interacting galaxies.

In the early 1970's Alar Toomre of the Massachusetts Institute of Technology and Juri Toomre, then at New York University, carried out the first systematic computer modeling of galaxy encounters. Their results were surprising: using only gravitational forces, they managed to reproduce the shapes observed in a number of systems of interacting galaxies. The Toomres approximated the gravitational field of a galaxy by the field of a point mass in the galactic center. They modeled the disks of the galaxies, which include many tens of billions of stars, with a mere few hundred particles that moved in the field of the model galaxies without contributing to that field. Even with these crude approximations, the investigators found that encounters of two model galaxies can produce a dazzling variety of splatter patterns that often include sheets and ribbons. When viewed edge on, the sheets and ribbons provide an explanation of some of the thin and sharp features that had driven other astronomers to invoke complicated magnetic-confinement processes.

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The work of the Toomre brothers provides a clear example of how new information is obtained from synthesis. The sequence of computer "snapshots' on these two pages, for instance, shows that the streamer apparently connecting the "whirlpool nebula' (also known as galaxy NGC 5194, or M51) with galaxy NGC 5195 is not really a bridge at all. The connection is simply an illusion, a consequence of the positions of the galaxies as they are seen in the sky.

Many problems in physics are still too complex to be tackled by direct synthesis of an all-encompassing model. Instead a two-pronged approach that starts with simulations of microscopic parts of a large system may be possible. Synthetic methods can often provide quantitative insights into the statistical behavior of very small subcomponents of a macroscopic system. A higher-level model that combines these statistical rules as building blocks can then be used to predict the behavior of the system as a whole.

An example of a problem that currently exceeds today's computational limits is the detailed modeling of the evolution of a star cluster consisting of a million stars--the size of some of the globular clusters orbiting our galaxy. It has proved possible to gain understanding of the clusters by exploiting a microscopic approach in which interactions between a single star and a double star (a pair of stars bound together tightly) are studied.

The gravitational interaction between two stars or planets is easy to calculate using pencil and paper. The equations of motion become intractable, however, for interactions among three bodies. What happens, for instance, when a single star collides with a double star? As long as the single star is far from the double one, the two stars making up the double star revolve around each other in an unperturbed elliptical orbit. If the third star passes by at a modest distance, the internal orbit of the double star will be perturbed. If the single star penetrates the double-star system, the encounter may be much more complicated.

The ultimate outcome of such an encounter can be classified into three qualitatively distinct types. The encounter may yield three isolated, unbound stars. In that case, in analogy to atomic physics, we say the double star is ionized. Alternatively, the encounter may yield a double star and a single star. If the resulting double star is made up of the intruder and one of the members of the original double star, we say we have an exchange reaction. If the members of the resulting double star are the members of the original double star, we classify the event as a flyby. Sometimes, during a near head-on encounter, the double star will temporarily capture the single star. The resulting three-body system can remain bound for a long time--unstable relationships lasting for hundreds or even thousands of orbital periods are not rare--but ultimately the system will decay again into a single star and a double star.

The type of outcome is quite sensitive to the initial conditions. A slight change in encounter velocity or orientation angles is enough to alter the complicated three-body dance drastically. An analytic description of this behavior is out of the question.

The number of parameters needed to describe the initial conditions for such scattering experiments is nine, a number that is far too large to allow a systematic survey of all possible combinations. The way the outcome of the experiments depends on the precise values of the parameters is extremely

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complex. Even if seven of the parameters are held fixed and only two are varied, a complicated picture emerges [see bottom of illustration on next page].

One way to gain quantitative insight into three-body scattering processes is to simulate a large number of individual scattering experiments and analyze the results statistically. Values for most parameters are chosen at random, subject to constraints that make sure the experiments lie in domains of interest to the astrophysical application at hand. When enough experiments are done, the uncertainties that are introduced by this "Monte Carlo' method of sampling the initial conditions become small enough so that interesting conclusions about the average outcome of three-body scattering experiments can be drawn.

Why are astronomers interested in this kind of collision? The answer lies in the role of double stars in generating "heat.' In a collision between a double star and a single star, the double star can shrink, transferring energy to the single star and thereby heating the pool of stars around them. This process is analogous to nuclear fusion, wherein atomic nuclei collide and fuse into heavier nuclei, releasing energy. Nuclear fusion is the same phenomenon that makes the stars, including the sun, shine.

Similarly, orbital shrinkage of double stars induced by encounters can heat the core of dense star clusters. This heat can balance the losses at the surface of star clusters, where stars boil off continuously. In constructing detailed models of globular clusters the statistical behavior of encounters between single stars and double stars must be known. Just as nuclear reaction rates are an essential ingredient in calculations of the structure and evolution of individual stars, so gravitational stellar reaction rates are essential in calculations of the structure and evolution of star clusters.

The problem of determining the gravitational reaction rates is similar to the one a nuclear physicist faces when asked to determine a nuclear reaction rate. A beam of high-speed nuclei of one type can be aimed at a target plate containing nuclei of another type. By counting the number of interactions, measuring their properties and analyzing the data statistically, the physicist can describe the average behavior during the encounter of two nuclei.

Gravitational reaction rates can be measured in a similar way, using a computational laboratory. One of us (Hut) has participated in a project to investigate the dynamics of star clusters by employing a statistical characterization of three-body scattering. Part of the project required doing millions of Monte Carlo three-body scattering experiments in which two of the parameters were held fixed and seven were varied in a complete statistical survey.

The three-body scattering experiment was quite feasible with available computer resources; it took less than a year of computer time on a Digital Equipment Corporation VAX 11/780. A similar scattering experiment with galaxies is much more difficult. Just as particle physicists throw atoms and subatomic particles together and examine the shrapnel produced in order to learn about the particles' internal structure, so galactic traffic accidents could provide important clues about what kind of matter permeates the universe and how it is distributed. It is embarrassing that although a great deal has been learned about the universe in the past few decades, it is still not known what most of the universe is made of. Stars, gas and dust--everything visible either with the unaided eye or with radio, infrared, X-ray and gamma-ray telescopes--make up

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only a small fraction of the total matter in the universe. The nature of the invisible matter remains one of the central unsolved problems of astrophysics.

There is good dynamical evidence that most galaxies incorporate large amounts of unseen material. In a typical disk galaxy the stars revolve around a common center. According to Newton's law of gravity, the orbital speed of a star in the disk should fall off rapidly with increasing distance from the center--if the only matter between the star and the center is the visible matter. Actually extensive measurements show that the rotational speed does not fall off with increasing distance; rather, it remains roughly constant for a considerable distance. The constant rotational speed implies that most of the mass is not visible and that this invisible matter is distributed in a large volume around the visible shapes.

Galactic collisions afford opportunities to study the distribution of dark matter. The splatter patterns produced sample the gravitational field of the invisible material. In effect, star-based paint is used to trace out what otherwise would have remained invisible. The problem of interpreting these tracings can be attacked with massive computer simulations. What is unknown here is the distribution and amount of mass in any particular galaxy. Given sufficient computer power and software support, one could simulate many collisions having different parameters and mass distributions. One could then look for splatter patterns that most closely resemble the actual patterns observed. The unknown masses and their distributions could be deduced if the models are sufficiently sensitive.

A typical galaxy has roughly 100 billion stars, each of which interacts with all the others through the gravitational force. Computing the interactions among so many particles is outside the range of any computer currently envisioned. On the other hand, the behavior of such a system can be approximated by a system that has far fewer particles if every million or so particles in the actual galaxy is represented by a single particle in the model.

What is the minimum number of particles in a scattering experiment of two spiral galaxies necessary to make the model accurate enough to allow detailed quantitative comparison with the real world? A real galaxy can be thought of as consisting of a centrally concentrated bulge of stars, which may be flattened somewhat by rotation, a disk of stars and gas in predominantly circular orbits and a more extended, roughly spherical halo of dark matter whose existence is inferred on dynamical grounds. These components exist in stable, stationary equilibrium in their mutual gravitational field. Since spiral galaxies have a disk diameter that is nearly 100 times larger than the thickness of the disk, at least a few hundred thousand particles must be sprinkled in to represent the disk; any smaller number would not allow the finite thickness of the disk to be resolved. A comparable number of particles in each of the components of both colliding galaxies requires that a realistic scattering experiment involve somewhat less than a million particles.

Integrating the equations of motion for a system consisting of between half a million and a million interacting particles presents a formidable task, requiring the best in numerical algorithms and the most powerful computers. But these are only part of the problem: there is also an enormous range of parameters that describe the possible initial conditions for a run of such a system. To set up an experiment one must choose distributions for each component and assemble the model galaxies. Values for all the initial

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parameters of the collision must also be chosen.

The most challenging aspect of the numerical simulation is the analysis of the results. Part of the analysis must be concurrent with the running of each galaxy encounter to determine whether it has run far enough to be terminated. Analysis is also needed to ascertain which initial conditions should be considered next to obtain the most interesting results. Finally, analysis must be done to abstract the qualitative structure and model parameters needed to characterize the results of the ensemble of experiments.

When has a galaxy scattering experiment been run long enough to be terminated? Suppose one were to look at a motion picture of the scattering process. Galaxies approach each other, crash with a great splattering of stars and either merge into one galaxy that soon settles down or separate and go their way with some damage to each of them. After some time one can determine whether the central regions of the galaxies merge or separate. At this point one just waits until measurements can be made of how much and what kind of damage was done.

The recognition of the termination and the classification of the outcome of a galaxy-collision experiment are a qualitative pattern-recognition task that is hard to automate but not impossible. The initial system consists of two hulks, each one gravitationally bound to a small, dense core. As the collision proceeds, the cores either separate altogether on unbound orbits or eventually merge. If they merge, there may be several passes of decaying, elongated orbits before they become tightly bound. In the process some of the particles from each bulk will become unbound; some will form bound or unbound transient shells, streamers and tails.

The required recognition is quite coarse. One must be able to follow a central core that is moving in a smooth way. It is not hard, computationally, to find the position of a central core in a motion-picture frame. It is not hard to predict the path from the positions of the cores in preceding frames. By following the cores in this way one can see whether they are becoming bound or whether they will separate.

We are currently embarking on a long-term project to model galaxy collisions. Several years may pass before we have definite results, because of the amount of computation required. Parallel processors could help in our simulations [see "Advanced Computer Architectures,' by Geoffrey C. Fox and Paul Messina, page 66, and "Programming for Advanced Computing,' by David Gelernter, page 90].

The scientific computation needed to extend the frontiers of knowledge often requires substantial resources. The reason is partly that the models are computationally complex and partly that numerous experiments are necessary in order to characterize a class of phenomena. Scientists have traditionally obtained these resources either by acquiring large-scale computers or by renting time on them. Both routes are expensive. Large-scale computers not only carry a large price tag but also entail a huge administrative burden. Furthermore, because large computers are often not well organized for a particular problem, the construction of appropriate software can be a long and complex task. Of course, much of the problem is determining exactly what algorithms are needed to investigate the phenomena, but the architecture of the computer can either help or hinder this development. Software for three-dimensional hydrodynamics that runs well on a conventional computer takes years to write.

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A significant part of the size, expense and difficulty of programming a large computer comes from the machine's generality. It is designed to perform well on a large variety of problems. In contrast, a specialized computer can be simple and physically small. Indeed, such hardware can be easier to design and build than software. One would expect to find scientists and computer designers cooperating in the development of computers tailored to specific applications in scientific computing. For instance, a machine designed to solve particular partial differential equations of mathematical physics could be built in about the same time, and at the same expense, as it would take to prepare programs for this application to run well on a supercomputer. Moreover, the specialized computer can become an ordinary experimental instrument belonging to the research group that made it, thereby avoiding the administrative burden and the scheduling problems associated with expensive, shared resources.

The cooperative design of specialized computers will not simply result in a few new machines for solving a few problems. Such projects will fundamentally change the culture of scientific computation. Traditionally, although scientists have been involved intimately in the design of their instruments, computers have been treated differently. Scientists are primarily users of computation; their needs are filled by a few remote vendors, most of whom are concerned primarily with the business market. Scientists must be enlisted in the design of their computing instruments. In fact, designing a computer is to a large extent a software-engineering problem, and the key to making the design of special-purpose computers an ordinary part of scientific-instrument building is simply to bring into the culture the attitude that such activity is feasible.

The kind of attitude change we foresee is precisely analogous to the change in attitude that took place a few years ago regarding the design of very-large-scale integrated (VLSI) circuits, in which tens of thousands of components are imprinted on a single semiconducting chip. In 1980 Carver A. Mead of the California Institute of Technology and Lynn A. Conway, then at the Xerox Palo Alto Research Center, codified a set of design rules for VLSI. By doing so they removed much of the mystery from VLSI design and made it possible for computer architects to design their own special-purpose chips. The MOSIS manufacturing service, which grew out of the work of Mead and Conway, separates the design of a circuit from its manufacture. It is now possible to design a circuit and ship the specification to a central service for manufacturing. The service has recently been expanded to include the specification of layouts for printed-circuit cards, making it possible for most of a computer's components to be manufactured at a distance.

An example of a special-purpose scientific computer that was created by such a technique is the Digital Orrery, which was built by one of us (Sussman) and a group of collaborators. The Digital Orrery was designed for investigating the long-term stability of the solar system. The computer is optimized for high-precision numerical integrations of the equations of motion describing small numbers of gravitationally interacting bodies. The actual design and construction of the Digital Orrery was carried out in one year by six people (three theoretical physicists, two computer scientists and a technican). The device consists of about one cubic foot of electronic equipment and dissipates the power of a 150-watt light bulb. For the specific problem it was designed to solve, the computer is 60 times faster than a VAX 11/780 with floating-point accelerator. The machine is currently serving in a study of orbits in the asteroid belt, aimed at understanding how empty spaces called Kirkwood gaps were formed. The Digital Orrery is also being employed to investigate the long-term

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stability of the orbit of Pluto. It has been used to determine what the orbits of the outer planets must have been for the past 100 million years and what they are expected to be for the next 100 million.

Before the Digital Orrery was built, high-precision integrations over simulated periods of millions of years were prohibitively expensive. As a result there were only a few small experiments making use of carefully scheduled resources. In spite of the obvious advantages of a special-purpose machine, the notion that one could be designed and built was simply not part of the cultural outlook of the astrophysics community. In fact, a preliminary proposal for constructing the Digital Orrery submitted to the astronomical instruments division of the National Science Foundation was rejected on the grounds that the project would be infeasible. Such an attitude is striking in view of the immensely complex engineering projects that have been accomplished by this same community when building telescopes. Building computers is just not that difficult.

Improving the effectiveness of scientific computation requires going beyond incremental improvements in hardware and algorithms. The efficiency of the experimenter must be improved by providing him or her with the computational equivalent of a toolbox. The toolbox will be equipped with tools for building as well as manipulating computational models that enable investigators to specify and control computational experiments in terms of the underlying qualitative phenomena. The tools must do more than set up data for a numerical computation, run it and analyze the results; they must also understand how the computational models work and how they relate to the other descriptions of the phenomena being studied.

We envision systems that combine powerful numerical methods with sophisticated symbolic manipulation of both algebraic and algorithmic descriptions. An advanced environment will provide symbolic mathematical support for the automatic preparation, execution and analysis of the results of numerical experiments. Symbolic methods can be used to help manipulate the dynamical equations into a suitable form for simulation and to construct high-quality simulation programs, optimized for the particular situation from more general algorithmic descriptions. A scientist should be able to discuss a galaxy model with a computer in much the same way as one might describe it to a human assistant. We believe such computer systems are within reach even though none has yet been built.

New tools have often changed civilization in ways not envisioned by the inventors; automatic computation has already outgrown purely numerical calculation. Symbolic and qualitative computations are becoming an integral part of the scientific environment. Computers will soon provide the scientist with an effective laboratory assistant rather than a number-crunching slave.

Photo: SEQUENCE OF COMPUTER IMAGES simulates a collision between tw o spiral galaxies; the image at the bottom right resembles a pair of galaxies known as t he antenna galaxies (also called galaxies NGC 4038 and NGC 4039) in the constellation Cor vus. The yellow dots represent the central bulges of the galaxies and the blu e

dots the surrounding disks of stars. The red dots represent the dark halo of matter in th e galaxies; the halo cannot be seen but is manifested by its gravitational effects. The simulation, covering about half a billion years, is

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by Joshua Barnes at the Institute for Advanced Study.

Photo: COLLISION BETWEEN GALAXIES was simulated in a classic experi ment carried out on a computer in the early 1970's by Alar Toomre of the Massachusetts Institute of Technology and Juri Toomre, then at New York University. The simulation stages the encounter of the "whirlpool nebula' (also known as galaxy NGC 5194, or M51) and galaxy NGC 5195 (left). The Toomres chose a number of initial conditions after a careful analysis of the availabl e observational data. For each set of initial conditions they developed a sequence of "snapshots.' One of the sequences yielded a snapshot (right) that closely resembles the observed configuration of the galaxies. The two rows present two different viewing angles of the same event; 100 million years have elapsed between successive frames. The Toomre experiment shows that the streamer apparently connecting M51 and NGC 5195 is actually an illusion--a projection effect. At this time NGC 5195 is well behind M51 and the collision is a matter of history.

Photo: ENCOUNTER between a single star and a double star (a pair o f tightly bound stars) is complex, as the computer-generated simulatio n at the top left shows. Attempts at calculating such three-body scattering events using only pen and paper would be futile. Fortunately the essence of the process can be distilled by overlookin g the details and classifying only the eventual outcome, just as the scattering of particles in subatomic physics is studied. In this case there are three possible outcomes (top right). In a flyby the double star remains intact even though its orbital paramete rs may be affected. In an exchange the intruder replaces one of the original members of the double star. In an ionization event all stars become unbound. The number of parameters needed to describe the initial conditions for such scattering experim ents is nine--far too many to allow a systematic survey of all possible combinations. In the graph at the bottom, which summarizes the outcome of more than 1,000 different scattering experiments, seven of the parameters are held constant and only two are varied: the impact parameter (the point of closest approach of the single star to the double star) and the orbital phase (the relative positions of the members of the double star).

Photo: EXISTENCE OF DARK MATTER, or invisible material in the unive rse, is inferred from dynamical arguments. In a typical spiral galaxy, such as the "sombre ro galaxy,' or M104, the stars revolve around a central bulge (top). The bulge is s urrounded by a disk (bottom) and an invisible halo. According to Newton's law of gravity , if the only matter between a star in the disk and the center is what is visible, the rot ational velocity of the star should fall off rapidly with increasing distance from the bulge (black curve at bottom). Actually extensive measurements show that the rotational velocity doe s not fall off; rather, it remains constant for a great distance (colored curve) . The constant velocity implies that invisible matter is found in a large volume around the v isible shapes.

Photo: DISTRIBUTION OF DARK MATTER within galaxies could be deduce d

by extensive computer simulations of galactic collisions. Streamers of stars woul d sample the gravitational field of the unseen matter and trace out what would have remained inv isible.

Photo: DIGITAL ORRERY is a special computer for carrying out high-s peed, high-precision simulations of planetary orbits. The device consists of about

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a cubi c foot of electronic equipment and dissipates the power of a 150-watt light bulb. For th e

problems it was designed to solve, the computer does approximately 10 million floatin g-point operations per second, which is 60 times faster than a VAX 11/780. The speciali zed parallel architecture of the orrery, which is well matched to orbital-mechanic s problems, is the key to obtaining such high performance. The orrery has been used to determine what the orbits of the five outer planets in the solar system must have be en for the past 100 million years and what they are expected to be for the next 100 milli on; the period is 40 times longer than any previous precision integration of the motion s of the planets.

Photo: INCLINATION OF PLUTO'S ORBIT over a period of 214 million ye ars has been determined with the Digital Orrery (top). The inclination of a planetary orbit is the angle between the plane described by its orbit and the ecliptic, which is the plan e

of the earth's orbit (bottom). In the graph a 34-million-year modulation of a basi c

3.8-million-year oscillation can be discerned; there is even some evidence for a cycle of 137 mill ion years.

Photo: HYPOTHETICAL DIALOGUE between a computer and an astrophysici st illustrates how interactive systems in the future could help to construct, simula te and analyze models. The authors envision a system that can carry on a conversati on similar to the one shown here, although probably in a more formal language. The mos t important feature of this hypothetical dialogue is the conceptual level of the interact ion with the computer: the program understands a considerable amount about ga laxy modeling.

GRAPHIC: Photograph; Chart; Caption: Encounter between single and double stars is complex, as shown by simulation; Distribution of dark matter within galaxies could be deduced by simulations; Inclination of Pluto's orbit has been determined with the Digital Orrery

SUBJECT: Computers, scientific applications; Programming (electronic computers), scientific applications

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Date: April 17, 1990
Contact: Susan Turner-Lewis, (202) 334-2138

FOR IMMEDIATE RELEASE

...e manufacturing forum is modeled in part on the Academies' successful experience with the Government-University-Industry Research Roundtable, created in 1984, which brings together leaders from government, universities, and industry for dialogue on themes of common concern.

The forum is supported by funds from the Academy-Industry Program of the NAS and NAE, from the NAE Fund, and from the NSF.

A list of members follows.

# # #

stl: f,g,h,k,l

NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING
2101 Constitution Avenue, Washington, D.C. 20418

THE MANUFACTURING FORUM

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THE MANUFACTURING FORUM

National Academy of Engineering National Academy of Sciences
2101 Constitution Avenue, N.W. Washington, DC 20418 Telephone: 202/334-1579

April 1990

FACT SHEET

Why was the Manufacturing Forum established?

American manufacturing industries, and those who depend on them, face numerous challenges at home and abroad. While some measures of manufacturing performance suggest that the last few years have been good ones, other indicators paint a different picture, or suggest that the future does not look

[illegible] as bright. Opinion leaders hold surprisingly diverse views about trends in, and prospects for, U.S. manufacturing performance. The Forum will contribute to this important national debate by convening knowledgeable leaders to discuss the status of, and trends in, manufacturing. An important role of the Forum will be to address what might be done by industry, government, and universities to improve U.S. manufacturing performance.

Why did the National Academy of Engineering and National Academy of Sciences organize the Manufacturing Forum?

In organizing the Manufacturing Forum, the Academies acted in response to a request from the Director of the White House Office of Science and Technology Policy and from the Director of the National Science Foundation. At their request, the Academies sponsored a workshop involving a number of experts in manufacturing and related subjects that recommended the establishment of a Manufacturing Forum. The design of the Forum is based on the report of the workshop.[1]

The Academies and the National Research Council contribute scientific and technical advice and analysis to government pursuant to a congressional charter. The Academies also work closely with the private sector on issues and technologies affecting manufacturing and other fields. Based on their close relationships with the many communities involved in the manufacturing debate, the Academies are uniquely positioned to organize and host the Forum.

What is intended to be conveyed by the use of the word "Forum"?

The Manufacturing Forum is intended to serve as an opportunity for discussion, reflection, learning, and sharing; it reflects the classical concept of a forum as a place for deliberation.

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[1] The Challenge to Manufacturing: A Proposal for a National Forum, National Academy of Engineering and National Academy of Sciences, 1988.

Who are the members of the Forum, and how were they selected?

Members were selected by the presidents of the two Academies and by the Forum chairman. The members are senior executive officers of organizations responsible for manufacturing, senior government officials, or leaders in academic endeavors addressing manufacturing issues. Members were selected from diverse industries and regions, and a wide range of government responsibilities is represented.

Does the Manufacturing Forum include any members from foreign organizations?

All the members are or have recently been employed in American companies or institutions. Of course, a number of the members are executives of corporations, universities, or labor organizations that have substantial overseas, as well as domestic, operations.

Who pays for the Forum?

Approximately two-thirds of the Forum's operations are paid for by the Academies' own funds, and one-third by grants from the National Science Foundation.

Who can attend Forum meetings?

The executive sessions of the Forum will be closed to the public and the press. Public sessions will be open to the community at large.

[illegible] will be open to the community at large.

Where and how often will the Forum meet?

The executive sessions of the Forum will occur about three times a year at the Academy headquarters in Washington, D.C. In addition, the Forum may sponsor occasional public meetings on topics of broad interest in Washington or at Academy facilities at the Beckman Center in Irvine, California.

Will the Forum publish studies or reports?

The Forum will use existing studies as background for much of its work. It may occasionally conduct or commission papers on specific subjects, or ask experts to prepare background studies as a basis for Forum briefings. The Forum will occasionally consider studies and recommendations by the many organizations that are actively examining issues in manufacturing.

Will the Forum make recommendations for action or take a stand on public policy issues affecting manufacturing?

The Forum will not make formal recommendations for action by the federal government or by the private sector. Instead, it will identify issues affecting manufacturing and be a place in which alternative courses of action and their consequences for manufacturing performance can be discussed and debated. If, as a result of these discussions, members wish to take action, the Forum will have performed an important catalytic action.

fact that several senior officials of the administration are serving as Forum members will enhance the coordination of its work with their needs.

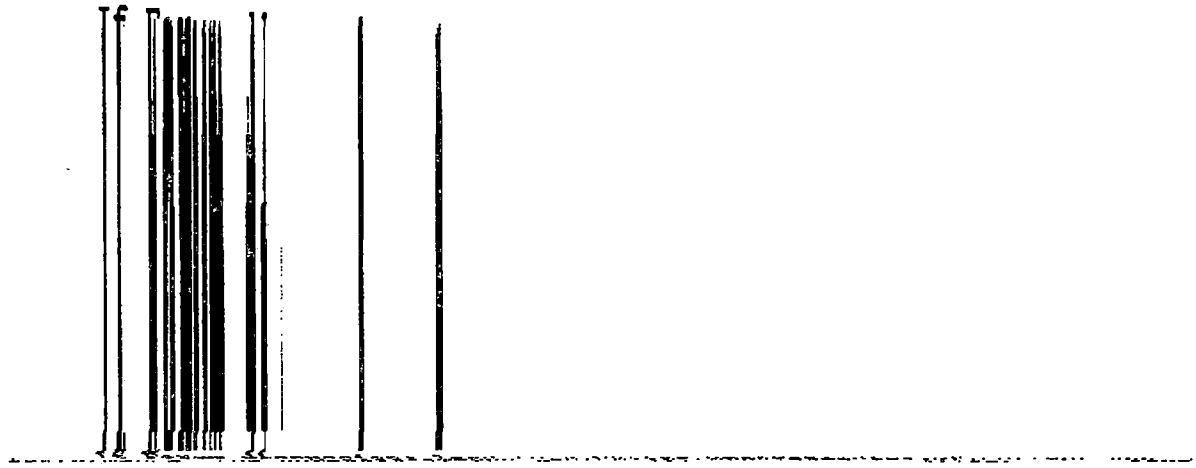
What is the relationship of the Manufacturing Forum to the Manufacturing Studies Board of the National Research Council?

The Manufacturing Studies Board carries out technical analyses and studies related to manufacturing and makes recommendations in response to requests for advice on specific topics by federal agencies. Findings and recommendations of the Manufacturing Studies Board may be considered by the Forum in its deliberations.

How long is the Forum expected to continue?

The Forum represents an initial two-year commitment by its sponsors and members. Presuming that U.S. manufacturing will continue to face unmet challenges, funding will be sought to continue the Manufacturing Forum for as long as it is needed and productive.

How will the success of the Forum be judged?



Technology. He has served as chairman of the Business Roundtable and of the Business Council.

The forum was created by the Academies in response to a request from the White House Office of Science and Technology Policy and the National Science Foundation (NSF). "The time is ripe for senior public and private leaders to come together to talk about what needs to be done to regain our leadership in manufacturing performance," said Assistant to the President for Science and Technology D. Allan Bromley. Bromley and NSF Director Erich Bloch are forum members.

"The Manufacturing Forum will identify issues and stimulate discussions among individuals who are in positions to provide leadership on important issues outside of the Forum process," said Christopher T. Hill, newly appointed forum director.

The forum is expected to discuss a broad range of topics, such as trends in manufacturing performance, technology development and utilization, incentives and disincentives for investment, improvements in management practices, trends in the labor force, and educational requirements for manufacturing excellence, Hill said.

The Manufacturing Forum is modeled in part on the Academies'

How broadly does the Forum define "manufacturing"?

The Forum is designed to take an expansive view of manufacturing and of issues in manufacturing. Thus, it is concerned not only with the industries that convert raw materials and energy into producer and consumer goods, but also with the service and other industries that either provide manufacturing with inputs or are dependent on close linkages with manufacturing for their own health and survival. Similarly, the Forum is concerned not only with the technology and the private-sector management of manufacturing but also with public policy issues affecting manufacturing in such areas as trade, capital cost and availability, productivity, taxation, competition policy, standards, quality management, corporate strategy, labor-management relations, and the education and training of the future work force at all levels from operator to advanced researcher. The Forum is concerned with manufacturing of the full range of advanced and traditional products for both consumer and industrial markets, as well as those that are needed for national defense.

How will the Forum relate to other organizations that address issues in manufacturing, competitiveness, or similar topics, inside government and out?

The Forum, its chairman, members, and staff have close relationships with numerous other bodies concerned with manufacturing. Such groups as the Vice-President's Council on Competitiveness, the National Association of Manufacturers, the National Center for Manufacturing Sciences, the Council on Competitiveness, the Defense Science Board, and the Manufacturing Studies Board of the National Research Council have been consulted in the initial design of the Forum and in the definition of the issues to be considered. The fact that several senior officials of the [illegible]

NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING
INSTITUTE OF MEDICINE

[illegible]

Mack Lange

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NATIONAL SCIENCE FOUNDATION
WASHINGTON, DC 20550

Office of Legislative & Public Affairs
Room 527

FACSIMILE COVER SHEET

PLEASE DELIVER THE FOLLOWING PAGES TO:

NAME: David Demarest

LOCATION: White House Communications

PHONE: 456-7620

FROM:

NAME: Al Shaw

LOCATION: NSF - Office of Legislative & Public Affairs

DATE TRANSMITTED: 4/16/90 TIME: 3:50 pm

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REMARKS:

Memorandum

4-16-90 Al Shinn, for

From: Alan Levitt, Public Affairs, NSF

To: David Demarest, White House Communications Director

Subject: Material for President's speech to NAE

You probably have the following material covered, but these are the points that are important to NSF.

If you need to follow up, your speechwriter can call Al Shinn, 357-7196.

Material for President's Speech to National Academy

The dramatic changes in the past year in the Soviet Union and Eastern Europe tell us that the world is changing. For the past forty years the most critical responsibility of government was to provide for the common defense.

Today, however, national security means more than military preparedness. Today, economic strength -- in the sense of our ability to compete on world markets -- is an integral part of national security. And that means a strong science and technology, for we cannot have economic strength without technological strength.

How should we do this?

O Because the new knowledge generated by basic research is so important, the doubling of the National Science Foundation budget must be put back on track.

O Because our most important economic resource is the talent of our people, we must fix our educational system. We need emphasis on technical subjects, but also on the knowledge of foreign language and cultures that we need to compete in foreign markets.

O Because only broad support can create the new knowledge and new technologies that we need, investment in university basic research by government and industry must increase. The emphasis should remain on individual investigator awards, but other forms of support, especially Science and Technology Centers, are also important.

By Bob Laird, USA TODAY

on, 6A

'Strange things' await Hubble

By Paul Hoversten
USA TODAY

Astronomy takes a colossal step back in time — possibly to the birth of the universe — with the launch of the Hubble space telescope next week.

The $1.5 billion telescope — seven years late and $1 billion over budget — will be deployed from the shuttle Discovery; takeoff is set for Tuesday.

Astronomers are overjoyed:

▶ "Strange new things are going to be discovered," says Edward Weiler.

▶ "We're not sure what we'll see, but it will be very good," says University of Michigan's John Clarke.

▶ "We might turn on the telescope and see a black hole consuming neighbor stars for lunch or a galaxy for dinner," says Andrew Fraknoi.

The telescope is 500 million times more sensitive than the human eye and will allow astronomers to study objects 14 billion light-years away.

Hubble also may "do in a theory or two" about the universe, says Caltech astronomer James Westphal.

Some astronomers say NASA could have launched a cheaper telescope years ago on an unmanned rocket.

But NASA argues astronauts can repair Hubble during its 15-year lifetime.

USAT, 4-6-90, P. 1A

Photocopy-Preservation

Stargazers jockey for peek at space

By Paul Hoversten and Todd Halvorson
USA TODAY

Hundreds of astronomers from around the world — including a handful of amateurs — are lined up to use the Hubble space telescope as their eyes on the universe.

Thousands more may get their chance during Hubble's expected 15-year lifetime.

"Hubble is a boost for astronomy across the board," says Ray Villard, of the Space Telescope Science Institute at Johns Hopkins University, which screens requests to use the Hubble telescope.

The telescope is such a precious tool for astronomers that five times as many proposals — with nine times the viewing hours — have come in as could be accommodated in the first few years of operation.

Hubble has only about 30 minutes each 90-minute orbit to actually focus on stars. The rest of the time it is either blocked by Earth or maneuvering to point at a target.

Hubble is expected to relay its first view about two weeks after launch. Then, engineers will spend about seven months verifying that systems work.

After that, project scientists will split the first year of Hubble's use with astronomers who sent proposals to the institute.

Six committees of astronomers — 62 scientists in all — trimmed outside requests from 556 to 162. About 20 percent of those accepted are from member nations of the European Space Agency, NASA's partner.

Average viewing time per proposal: 10 hours.

Not all who will use Hubble are professionals. Five USA amateurs were chosen to represent lay astronomers.

▶ Seattle homemaker Ana Larson wants to search for huge planets near newborn stars. She got the idea from her astronomy course at the University of Washington.

"What I hope to do is verify evolutionary theories on the formation of giant, gaseous planets by actually detecting one," she says.

▶ Raymond Sterner, a Woodbine, Md., computer scientist, hopes to study arcs in galaxy clusters he thinks were caused by colliding galaxies.

▶ High school science teacher James Secosky, of Shortsville, N.Y., will look for frost forming on Jupiter's moon Io as it dips into Jupiter's shadow.

▶ Engineer Peter Kandefer of New Hartford, Conn., will study a star in the Big Dipper that has a magnetic field 10 times that of the sun.

▶ And museum worker John Hewitt, of Berkeley, Calif., hopes to look at a nova — an exploding star.

Hubble won't make less powerful telescopes on Earth, still forced to peer through an obscuring atmosphere, obsolete.

"Just the opposite," says Villard. "We expect to increase demand for ground-based telescopes based on Hubble's discoveries. There are still some very clever things you can do from the ground."

Photocopy-Preservation

High hopes riding with astronauts

If ever a shuttle crew needed kid gloves, it would be Wednesday when they deploy the Hubble space telescope.

The hopes and dreams of thousands of astronomers rest with Discovery's five astronauts carefully placing the giant telescope in orbit on Day 2 of their five-day mission.

Veteran astronauts **Bruce McCandless**, 52, and **Kathryn Sullivan**, 38, have trained five years for an emergency spacewalk for Hubble.

They'll step outside Discovery if Hubble's solar panels or antennae don't deploy, or if the aperture door won't open.

"What we've tried to do is get complete coverage so that when some future crew ... goes up there, they will not find any (surprises)," says McCandless, a Navy captain from Boston who flew in 1984.

Sullivan, a geologist from Woodland Hills, Calif., who also flew in 1984, says "the only plausible case" for Discovery bringing Hubble home would be if a solar panel "deployed catastrophically or bent itself."

Astronaut **Steven Hawley**, 38, who will operate Discovery's 50-foot robot arm, is the only astronomer of the group.

"We all feel a little bit of disbelief that we're actually finally getting to do this," says Hawley, making his third flight.

Commander **Loren Shriver**, 45, an Air Force colonel, and co-pilot **Charles Bolden**, 43, a Marine colonel, will fly Discovery to a 360-mile high orbit — highest ever for a shuttle.

— Paul Hoversten



By Michael R. Brown, USA TODAY

CREW: In front, from left, Charles Bolden, Loren Shriver; in back, from left, Bruce McCandless, Steven Hawley, Kathryn Sullivan

4 'Great Observatories' will watch action-packed universe

Seeing isn't always believing — at least not to astronomers who chart the universe.

The Hubble space telescope, which can look at stars 14 billion light-years away, is the first of four "Great Observatories" that NASA will launch this decade.

But Hubble sees mostly visible light — like the human eye.

Companion spacecraft will be launched to study those invisible aspects of the universe like Gamma rays, X-rays and infrared light — leftovers from the "Big Bang" that scientists believe gave birth to the universe 15 billion years ago.

"The universe is a violent place," says NASA science chief Lennard Fisk. "One of the reasons life formed in our solar system is we live in a tranquil part of the universe. But you can look out and find galaxies that are exploding and ones that are colliding."

Most of what the $1.5 billion Hubble will see is serene. The violent stuff may turn up on three other observatories:

▶ **Gamma Ray Observatory**, set to launch Nov. 1 from shuttle Atlantis will study the early universe and emissions from "black holes" — collapsed stars with gravity fields so dense that light can't escape.

The $529 million spacecraft will operate up to 10 years.

▶ The $1.7 billion **Advanced X-Ray Astrophysics Facility**, set to launch from a shuttle in 1996, will measure the dark matter inside galaxies.

▶ **Space Infrared Telescope Facility**, planned for launch in 1999 into a 100,000-mile high orbit, will look at residual energy from stars and galaxies.

Smaller, companion spacecraft to the four observatories will record cosmic rays, ultraviolet light and radio waves — completing the electromagnetic spectrum of the universe.

Telescope will seek planets of other suns

By Paul Hoversten
USA TODAY

With the shuttle Discovery set to carry the Hubble space telescope aloft next week, scientists may be one step closer to answering the ultimate question: Are there planets beyond our solar system?

Scientists say an answer would be the crowning glory for the Hubble project.

The obstacle: a new planet would have to be as big and bright as Jupiter to even show up within a star system billions of light-years away.

Despite Hubble's superior power, its limitations all but rule out finding a smaller, dimmer planet like Earth in orbit around a star like our sun.

A planet large enough to be spotted by Hubble would be "a big spectacular," says Riccardo Giaconi, head of the Space Telescope Science Institute, Johns Hopkins University.

The telescope — if pointing at us from another galaxy — probably could not pick out our planet Earth.

The problem is like trying to find a gnat around a streetlight from afar; the brightness of the light obscures the bug.

"We are going to demand that the Hubble look into regions of total darkness, to look where nobody has ever looked," says scientist Eric Chaisson of the Space Telescope Science Institute.

Whether life could exist there would be another matter. Hubble would not be able to zero in close enough to tell.

"If you ask two scientists, 'How many planets are there in our galaxy with life on them?' you may get answers ranging from none to lots. And they're about equally accurate," says William Jeffreys, a University of Texas astronomer.

Proof that other planets are out there, though, should force us to rethink our place in the universe, scientists say.

Says NASA science chief Lennard Fisk: "Nature is much more imaginative and clever than we are, and is bound to amaze us."

Are humans ready philosophically for such finds?

"Think of what poor Copernicus' generation had to put up with," says Fisk. "They thought they were the center of the universe and discovered instead that they were going around the sun.

"Even in (astronomer Edwin) Hubble's time, the concept that there was more than just our galaxy was not known. The difference today with breakthroughs in astronomy is that these kinds of discoveries become instantly known."

The telescope could well rewrite the textbooks in more disciplines than astronomy.

"Many people believe that we're primed now for physics to revise itself," says NASA astrophysics chief Charles Pellerin. "The history of science has always been that when you make new measurements you look closely at nature and you understand nature in a different way."

▶ Countdown begins, 1A



American Institute of Physics
HUBBLE: Proved the universe is expanding

Hubble findings gave evidence for 'Big Bang'

U.S. astronomer Edwin Hubble, for whom the telescope is named, is regarded by many scientists as the most important stargazer since Galileo.

"Hubble is principally remembered for proving the expansion of the universe," says NASA scientist Lennard Fisk.

That discovery, which Hubble nailed down in the 1920s at Mount Wilson Observatory in Pasadena, Calif., was the cornerstone for the "Big Bang" theory that the universe began 15 billion years ago in a cataclysmic explosion.

Born in Marshfield, Mo., Hubble was handsome, athletic and almost became a professional boxer.

His sister, Betty Hubble, 85, recalls his ambition: "Edwin knew exactly what he wanted. That was his main thing in life."

Biographies based on Hubble's own stories say he practiced law in Kentucky, grew bored with it and enrolled in the University of Chicago to study astronomy.

But researchers can find no record of a Kentucky law practice, and say he taught physics, Spanish and coached the basketball team at New Albany, Ind., High School. He died in 1953 at age 63.

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Probing the UNIVERSE

The $1.5 billion Hubble space telescope, set to launch Tuesday aboard the space shuttle Discovery, will spend 15 years examining the universe in finer detail than can any ground observatory. Hubble — a joint project between NASA and the European Space Agency — is the most expensive science satellite built. The 12 1/2-ton telescope, the size of a railroad tank car, is expected to revolutionize astronomy by spanning vast distances. Astronomers hope it can answer fundamental questions about the size, age and formation of distant stars and galaxies. In orbit high above Earth, the telescope will be free from the atmospheric distortions that ground-based observers encounter. Hubble's 8-foot diameter primary mirror is the world's most finely-polished, allowing it to see faint light from some of the oldest stars — farther and in greater clarity than ever before.

2 Satellite beams image to tracking station

3 White Sands, N.M., relays image to commercial satellite

4 Commercial satellite

5 Space Telescope Science Institute in Baltimore analyzes data

1 Antenna transmits to NASA tracking data relay satellite

Earth

Orbital tuneup

The shuttle will visit Hubble every 3 to 5 years for maintenance. Instruments can be upgraded and batteries replaced. Two spacewalking astronauts could spend up to six hours each on repairs, if needed.

Scientific instruments

14 ft. diameter

Wide field planetary camera

Fine guidance sensor

Pointing sensor

Primary mirror

Computer

38.7 ft.

Solar panel

Twin solar panels power Hubble's five science instruments, each the size of a refrigerator. They each operate on just 110-150 watts, the power of a common household light bulb.

What a view!

Here's a simulated view of a cluster of galaxies at a distance of 1.5 billion light-years as seen from an Earth telescope. The view of the same galaxy cluster as seen with the Hubble telescope reveals numerous galaxies as a much clearer image.

View from earth telescope

Hubble's view

What unaided eye can see: 600,000 light-years

What telescopes can see now: 2 billion light-years

Secondary mirror

The observable universe

The volume of universe that can be observed with the telescope is 350 times greater than that of Earth-based telescopes. It can see objects with 10 times the clarity of ground-based telescopes.

42.7 ft.

Light shield

Solar panel

Aperture door

What Hubble will see: 14 billion light-years

Star or planet

EARTH

3 Telescope is pointed at star cluster; solar panels and antennas deploy; aperture door opens

2 Shuttle's robot arm lifts telescope into space on second day of mission

Discovery flies 160 to 360 miles above Earth; opens cargo bay

1609: Italian astronomer Galileo Galilei points telescope at moon, planets

1700s: Seven of nine planets discovered (Neptune found in 1846, Pluto 1930)

1918: 100-inch Hooker telescope begins operations in Pasadena, Calif.

1920s: Edwin Hubble proves universe is expanding; German astronomer Hermann Oberth proposes telescope in orbit

1958: U.S. space program is established

1977: Construction begins on Hubble

1600 1700 1800 1900 2000

Source: NASA; USA TODAY reporter Paul Hoverston
Graphic by Bob Laird, USA TODAY

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Spacecraft Sees Few Traces of a Tumultuous Creation

By WARREN E. LEARY
Special to The New York Times

WASHINGTON, Jan. 13 — First glimpses of the heavens by a new spacecraft looking for evidence of the beginning of existence have revealed an almost too perfect universe, scientists said today.

Preliminary sweeps of the skies by the unmanned craft, the Cosmic Background Explorer, reveal evidence of an early universe devoid of disturbances and irregularities that could explain the origin of the galaxy clusters, expansive voids and other large structures common to space, researchers said.

In presentations at the annual meeting of the American Astronomical Society, scientists said the COBE spacecraft, launched almost two months ago to look for evidence of the Big Bang, is working better than expected.

And early data appear to confirm the predictions of this leading theory of the origin of the universe, they said. The theory holds that all existence sprang from the explosion of a fist-sized ball of unknown, primordial material 15 billion years ago.

Smoother, More Uniform

But evidence so far shows an expanding universe much smoother and more uniform than most scientists had expected.

Many cosmologists, scientists who study the origin of the universe, had expected the spacecraft by now to have seen evidence of disturbances that occurred several hundred million years after the Big Bang that could have disrupted the smooth flow of the charged gases from the cataclysm. These disturbances or irregularities, in theory, would have caused some of the expanding plasma to condense and become the "seeds" for massive structures like the giant gas clouds, great strings of galaxies and huge empty areas now seen dotting the universe.

The craft, however, so far has not detected any such disturbances.

"We can see no deviation from a simple Big Bang theory," Dr. John Mather, the chief project scientist for COBE, said at a news briefing. "But it's hard to understand that with all the large features we see in the universe, we have no evidence of their origin."

Dr. Mather, of the National Aeronautics and Space Administration's Goddard Space Flight Center in Greenbelt, Md., where the COBE satellite was designed and built, said that in several months, the spacecraft should gather much more detailed data. At that point, he said, evidence of origins of current structures should be apparent, if it exists at all.

'It's Going to Be Small'

"We're getting pretty good evidence that there's nothing there, but it could be hiding in the background," Dr. Mather continued. "Whatever it is, it's going to be small."

Dr. George Smoot of the University of California at Berkeley, who also is working on the $400 million project, said scientists were still looking for a missing link between a smooth early universe and the many structures that began appearing relatively soon afterward. If later data from COBE find no such link, it may be necessary to re-examine some elements of the Big Bang theory, he said.

"Using the forces we know now, you can't make the universe we now know," Dr. Smoot said.

COBE, which contains the most sensitive detectors ever flown on a space mission, is looking for "fossil" radiation generated from within minutes of creation until the time the first stars and galaxies formed.

The solar-powered spacecraft, orbiting 560 miles above the Earth, is to twice map the entire sky in the next year. NASA plans to operate the 16-foot-tall, 28-foot-span craft for two years.

The craft contains three principal surveying instruments, including a device to distinguish faint microwave radiation from early times from that produced by the solar system and the Milky Way galaxy in which it resides. The other two examine different wavelengths of infrared light. To boost their sensitivity, the infrared instruments are cooled with liquid helium to within 2 degrees Celsius of absolute zero.

The Big Bang theory holds that after the initial explosion of the superhot ball that began it all, a process began that led to the creation of atoms within 500,000 years and the early formation of stars and galaxies 200 million years later.

After about 300,000 years from the event, the opaque plasma from the primary explosion turned into more transparent gas, a process that released microwave radiation scientists hope COBE will detect.

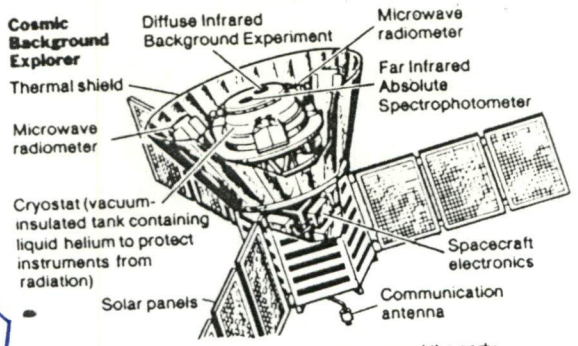
Bright and Dark Spots

Scientists are hoping to find bright spots and dark spots in relics of this radiation that could be evidence of disturbances in the smooth gas that later would be building blocks in the formation of other bodies, structures that make the universe complex and bumpy rather than smooth and uniform.

Dr. Michael G. Hauser, also of the Goddard center, said early COBE data look good for fulfulling another part of the satellite's mission, completely a multi-frequency infrared map of the nearby galactic sky. Background infrared radiation from the beginning of the universe is so faint that it is difficult to distinguish it from more intense radiation of the Earth's immediate neighborhood.

"We are off to a good search and now have by far the best data on the foreground radiation clutter of our own solar system and galaxy," Dr. Hauser said. Within three years, he said, project engineers should complete sky maps that allow astronomers to filter out nearby radiation from their readings so that the faint signals of fossil cosmic background radiation come through.

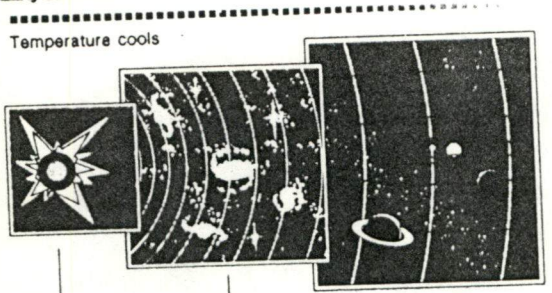
A Snapshot of the Early Universe



New understanding of the origin of the universe and the early formation of matter is expected from studying measurements of radiation in space recorded by the Cosmic Background Explorer. Remnants of the Big Bang, the explosive origin of the Universe, exists in background microwave radiation. Measurements of infrared radiation are expected to provide new insights into how matter first evolved. Changes in density offer indications that clumping of matter occurred soon after the Big Bang, advancing the formation of large-scale structures like galaxies.

Early Universe

Temperature cools



Big Bang — As temperature cools, matter and energy separate; galaxies and stars begin to form.

Early Matter

Present-day — Present-day universe: remnants of primeval radiation still detectable.

Sources: Scientific American, The International Encyclopedia of Astronomy

The New York Times/Jan. 14, 1990

In Space News Conference, Astronauts Hail Their Good Catch

By JOHN NOBLE WILFORD
Special to The New York Times

CAPE CANAVERAL, Fla., Jan. 13 — With their major objectives accomplished, the astronauts of the space shuttle Columbia settled down today to work on engineering and medical experiments for the rest of the mission, which is to end next Friday morning.

In a news conference this morning, the astronauts used phrases like "breathtaking" and "pretty neat" to describe the view from 200 miles above earth and the experience of living and working in weightlessness. They spent much of the day using a special large-format camera to take television pictures of the world below them. "We're all very happy and relieved that we've finally gotten it," Dr. Bonnie J. Dunbar said, referring to the 11-ton science satellite that the astronauts retrieved Friday.

Tests of Satellite Data Due

Capt. Daniel C. Brandenstein of the Navy, the mission commander, said that having the bus-size satellite stowed in the cargo bay should create "no problems at all" in landing at Edwards Air Force Base, Calif. Shuttles usually return with a virtually empty cargo bay.

The recovered satellite, the Long Duration Exposure Facility, holds dozens of tests on the performance of metals, plastics and other materials in space. Analysis of how well the materials survived almost six years in orbit should influence the design of future space vehicles. Examination of the satellite's condition is to begin shortly after the Columbia is returned to the Kennedy Space Center here.

> Tests on everything including the shuttle and its crew.

Flight controllers said the craft continued to operate without serious malfunctions. A television survey of its exterior showed one heat-shielding tile missing; it was lost in the launching last Tuesday. Engineers said it posed no extra risk.

Al Pennington, the chief flight director at Mission Control in Houston, praised the piloting skills of Captain Brandenstein and Lieut. Comdr. James D. Wetherbee of the Navy, saying that their maneuvering of the shuttle in the rendezvous with the satellite was "even better than we supposed."

Mr. Pennington said the pilots carried out a surprisingly fuel-efficient rendezvous, using much less steering propellant than had been budgeted. This left them with more than ample fuel reserves for the planned 10-day flight.

Tests on Fliers Themselves

Among the crew's activities for rest of the mission will be continuing 11 medical tests to understand the changes that the human body undergoes in the microgravity environment of orbit. One of the astronauts, G. David Low, is collecting data daily on each crew member.

The objectives will be to document decreases in heart size, changes in heart rates and changes in inner eye pressures and in the retina. Other tests should determine whether immune systems are altered in space flight. The astronauts are also taking prescription drugs to treat the motion sickness that has afflicted more than half of all American and Soviet space travelers.

Marsha S. Ivins has been operating experiments in the growth of crystals and the behavior of fluids in the microgravity being used in crystal-growth studies.

Mr. Pennington said this particular experiment was "temporarily suspended" until the astronauts, advised by scientists from the ground, could determine the nature of the malfunction and whether it posed any hazard.

Tests About Ground Sites

One experiment, conducted for the first time on this mission, is a test of a new technique for determining the precise latitude and longitude of known ground sites. The astronauts used a modified Hasselblad camera equipped with a wide-angle lens. They would take two photographs of the same target at 15-second intervals.

The data were then fed into a small computer to calculate the site's precise longitude and latitude. The experiment is expected to assist oceanographers to determine the location of objects observed from space, particularly transient features.

The planned long duration of the Columbia's flight itself is an experiment. Most shuttle missions run about five days. The Columbia has been supplied with additional fuel and oxygen for 10 days, or 12, if necessary, in a test associated with plans to modify shuttles for flights that last up to 30 days.

Mark:

Source these things: Yes, Ma'am!

1.) p.2...fourscore and ten or twenty billion years ago, it all began..... SEE (6)

2.) p.3...Today I call on all Federal labs, facilities... POLICY; SEE (2)

3.) p.4...industrial and business communities to create new alliances... POLICY; SEE (3)

4.) p.4 Today, I want to call on Congress: put our money where our future is...NSF budget. SEE (4)

5.) p.5...molecular biology and genome { WORD-OF-MOUTHED. N.I.H. PUBLIC AFFAIRS CAN HELP.

6.) p.5...we will not attempt to direct the course of science } POLICY

7.) p.6...we will not try to impose them on science

8.) p.6...low temperature super conductivity Jas Krow →

9.) p.7...half a billion times more sensitive than the human eye. SEE (5)

+ Call Jastrow

George Bednorz & Alex Müller

New Scientist
July 15 '89
p. 71 & 73

The Big Bang was proposed in the 1930's as a means of accounting for observations by Edwin Hubble in the previous decade that the universe is expanding, with galaxies hurtling out uniformly in all directions, as if from some explosive event. If gravity is the dominant force in shaping the cosmos and if the universe is homogeneous on the large scale, then Einstein's theory of relativity requires an expanding universe to have originated with an explosion.

(*!

...if the universe keeps expanding, it'll be difficult to comprehend the gravity of the situation.

for a single pt.

LEXIS® NEXIS® LEXIS® NEXIS®

I'm not sure we lay people will fully grasp

& the forces that rule the universe

Approaching the prof. of origins from many directions

off Hubble is the farthest-looking, particle accelerators are the time machines

SSC - this colossal collider

will be the largest (and most violent?) - re-creating that

unimaginably fireball of our origin in miniature, to re-create

particles that (many) may not have existed since the birth

a new language / new characters, bosons and

gravitons & charmed quarks - possibly even gravitons and preons

Hubble & SSC, to paraph Carl Sagan -- "billions & billions of dollars"

technologies from quantum physics

between 1910 + 1930 now account for more than

a fourth of U.S. GNP

to retain our scientific talent

past breakthroughs have created whole new industries

to make sure we're getting a big bang for our big bucks.

Shakespeare, William

The

HOME BOOK OF SHAKESPEARE QUOTATIONS

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ARRANGED AND EDITED BY

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CHARLES SCRIBNER'S SONS · *New York*

HAMLET c. 1601

; in the malice of mankind that he thus ad-
:s us.
'imon of Athens. Act iv, sc. 3, l. 456.
Bandit]

ne devil whisper curses in my ear,
d prompt me, that my tongue may utter
forth
e venomous malice of my swelling heart!
'itus Andronicus. Act v, sc. 3, l. 11. [Aaron]
lice forced with wit.—*Troilus and Cressida*,
, 1, 63.
hink there is not in the world either malice
matter to alter it.
The Winter's Tale. Act i, sc. 1, l. 36. [Ar-
:hidamus]

MAN

e also Character; Gods and Men; Master and Man; Wife: Man and Wife

I—Definitions

All the world 's a stage,
id all the men and women merely players:
ıey have their exits and their entrances;
id one man in his time plays many parts,
is acts being seven ages. At first the in-
fant,
ewling and puking in the nurse's arms.
id then the whining school-boy, with his
satchel
id shining morning face, creeping like
snail
nwillingly to school. And then the lover,
ghing like furnace, with a woeful ballad
ade to his mistress' eyebrow. Then the
soldier,
ull of strange oaths and bearded like the
pard,
alous in honour, sudden and quick in
quarrel,
eeking the bubble reputation
ven in the cannon's mouth. And then the
justice,
fair round belly with good capon lined,
/ith eyes severe and beard of formal cut,
ull of wise saws and modern instances:
nd so he plays his part. The sixth age
shifts
ıto the lean and slipper'd pantaloon,
/ith spectacles on nose and pouch on side,
lis youthful hose, well saved, a world too
wide
or his shrunk shank; and his big manly
voice,
'urning again toward childish treble, pipes
nd whistles in his sound. Last scene of all,
'hat ends this strange eventful history,
s second childishness and mere oblivion,
ans teeth, sans eyes, sans taste, sans every
thing.
As You Like It. Act ii, sc. 7, l. 139. [Jaques]
The only use of "mewling," "puking,"
"satchel," and "slipper'd." "Pantaloon" oc-
curs again in *The Taming of the Shrew*, ii,
1, 37. "Pard" (leopard) is repeated in *A*

Midsummer-Night's Dream, ii, 2, 31; *The Tempest*, iv, 1, 262; and *Troilus and Cressida*, iii, 2, 201. "Sans" is used eleven times.

1
What a piece of work is man! how noble in reason! how infinite in faculty! in form and moving how express and admirable! in action how like an angel! in apprehension how like a god! the beauty of the world! the paragon of animals! And yet, to me, what is this quintessence of dust? man delights not me; no, nor woman neither.
Hamlet. Act ii, sc. 2, l. 316. [Hamlet]
"Quintessence" is used a second time in *As You Like It*, iii, 2, 147: "The quintessence of every sprite."

What is a man,
If his chief good and market of his time
Be but to sleep and feed? a beast, no more.
Hamlet. Act iv, sc. 4, l. 33. [Hamlet]

2
'Homo' is a common name to all men.
I Henry IV. Act ii, sc. 1, l. 104. [Gadshill]
The only use of "homo."

3
This little kingdom, man.
II Henry IV, iv, 3, 118. See under SACK.
This foolish-compounded clay, man.
II Henry IV, i, 2, 9. See under INVENTION.
The only use of "foolish-compounded."
Men are but gilded loam or painted clay.
Richard II, i, 1, 179. See REPUTATION, 1266:12.
Men of mould.—*Henry V*, iii, 2, 23.

4
Will you tell me, Master Shallow, how to choose a man? Care I for the limb, the thewes, the stature, bulk, and big assemblance of a man! Give me the spirit, Master Shallow.
II Henry IV. Act iii, sc. 2, l. 275. [Falstaff]
"Thews," so spelled, is repeated in *Julius Cæsar*, i, 3, 81: "Thews and limbs"; and in *Hamlet*, i, 3, 12: "Thews and bulk."
O, give me the spare men, and spare me the great ones.
II Henry IV, iii, 2, 288. See under THINNESS.

5
So in the world; 'tis furnish'd well with men,
And men are flesh and blood, and apprehensive.
Julius Cæsar. Act iii, sc. 1, l. 66. [Cæsar]

6
Is man no more than this?
King Lear. Act iii, sc. 4, l. 107. [King Lear]
Unaccommodated man is no more but such a poor, bare, forked animal as thou art.
King Lear. Act iii, sc. 4, l. 112. [King Lear]
The only use of "unaccommodated."

7
The earth hath bubbles, as the water has,
And these are of them.
Macbeth. Act i, sc. 3, l. 79. [Banquo]
First Murderer: We are men, my liege.
Macbeth: Ay, in the catalogue ye go for men;
As hounds and greyhounds, mongrels, spaniels, curs,
Shoughs, water-rugs and demi-wolves are clept
All by the name of dogs.
Macbeth. Act iii, sc. 1, l. 91. The only use

of "shoughs," "water-rats," "demi-wolves," and "clept."

8
But man, proud man,
Drest in a little brief authority,
Most ignorant of what he 's most assured,
His glassy essence, like an angry ape,
Plays such fantastic tricks before high heaven
As make the angels weep.
Measure for Measure. Act ii, sc. 2, l. 117. [Isabella] "Glassy" is repeated in *I Henry VI*, v, 3, 62, and in *Hamlet*, iv, 7, 168, in both cases "glassy stream."
How some men creep in skittish fortune's hall,
Whiles others play the idiots in her eyes!
Troilus and Cressida. Act iii, sc. 3, l. 134. [Ulysses] "Skittish" is repeated in the Prologue, l. 20: "Skittish spirits"; and in *Twelfth Night*, ii, 4, 18: "Unstaid and skittish."

9
Man is but an ass. . . . Man is but a patched fool.
A Midsummer-Night's Dream, iv, 1, 212. See under DREAM for full quotation.
Man is a giddy thing.
Much Ado about Nothing. Act v, sc. 4, l. 110. [Benedick]
Therein do men from children nothing differ.
Much Ado about Nothing. Act v, sc. 1, l. 33. [Antonio]

10
'Tis not a year or two shows us a man:
They are all but stomachs, and we all but food;
They eat us hungerly, and when they are full,
They belch us.
Othello. Act iii, sc. 4, l. 103. [Emilia] "Hungerly" is repeated in *Taming of the Shrew*, iii, 2, 177, and in *Timon of Athens*, i, 1, 262.
We must think men are not gods.
Othello. Act iii, sc. 4, l. 148. [Desdemona]

11
In men, as in a rough-grown grove, remain
Cave-keeping evils that obscurely sleep.
Rape of Lucrece, l. 1249. The only use of "rough-grown" and "cave-keeping." "Cave-keeper" occurs in *Cymbeline*, iv, 2, 298. "Obscurely" is repeated in *Julius Cæsar*, i, 2, 323.

There 's no trust,
No faith, no honesty in men; all perjured,
All forsworn, all naught, all dissemblers.
Romeo and Juliet. Act iii, sc. 2, l. 85. [Nurse] "Dissembler" is repeated in *Richard III*, i, 2, 185, and in *Much Ado about Nothing*, v, 1, 53.

12
Men as plants increase,
Cheered and check'd even by the self-same sky,
Vaunt in their youthful sap, at height decrease,
And wear their brave state out of memory.
Sonnets. No. xv.

13
I have, in this rough work, shaped out a man,
Whom this beneath world doth embrace and hug
With amplest entertainment.
Timon of Athens. Act i, sc. 1, l. 43 [Poet]

w/o stray
we are

Hubble

gazing back to the birth of time.

almost
to see to the ends of the univ
& the beginning of time

Hubble, the most sophisticated celestial object
as an offering
ever lifted to the heavens, offering understanding of
by man
and our place in it, a revol. that rivals Copernicus
- origin of univ. this pixel of a telescope jeweler's eye
[only a billion times more
sensitive than the human eye
TALK ABOUT THE VISION THING...
windows into worlds were never seen before [microscope].

about the size of a school bus. w/ power to look
back 15 billion years.

but done
matter so unimaginably compressed, about the size of your fist
so the theory goes, this cosmic baseball exploded in fiery dissemination
10 or 20
billion years ago.
objects
things have slowed down
since then

PACE OF GOD?
WON'T

Staffed Copy

(Lange/Cawley)
April 19, 1990
3:15 P.M.
[SCI.DOC]

PRESIDENTIAL ADDRESS: NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C.
MONDAY, APRIL 23, 1990
2:00 P.M.

Thank you, Frank [Press]. Distinguished members of the National Academy, Dr. Press, Dr. Bromley, ladies and gentlemen: It's an honor to be with you today. The advice and counsel of this Academy has been crucial to American Presidents for well over a century. I'm proud to be the latest to thank you.

We stand at a moment of wondrous prosperity. But our wealth goes far beyond the merely material. Ours is an **intellectual** prosperity, unprecedented in history. For that, and the health and security it affords this nation and the world, gratitude is owed to the men and women who have committed their minds and lives to science.

Those devoted to such work -- its patient searching, its passionate struggles -- have engaged themselves in mankind's exalted mission, and the mind's manifest destiny: the search for understanding.

President Abraham Lincoln established this great institution in the dark hours of our nation's greatest crisis -- which testifies to the enduring importance of scientific knowledge. And when this magnificent building was finally dedicated, Calvin Coolidge predicted "a new day in scientific research. A new sun is rising," he said.

He was right. The awesome scientific advances of this century, many of which you've brought about, bring us ever closer to understanding the universe, its origins, and our own. And science has told us a stranger and more wondrous story than myth might ever have written for us.

Fourscore and ten or twenty billion years ago, it all began. With a quantity of energy and mass unimaginably hot and dense, about the size of a baseball, containing everything that would become the universe, they say. And then, in one incomprehensibly powerful instant, energy and matter of every kind exploded in at least four dimensions. Or in a layman's terms, somebody hit that cosmic baseball right out of the park.

But while the pace of **universal** change may have begun with blinding speed and slowed down since, the pace of our **scientific** evolution has been accelerating rapidly. Growing in intensity throughout this century like a series of chain reactions in a critical mass of highly-trained American grey matter -- touching off revolutions in every direction.

Today, I want to outline the role this Administration is playing to fuel those revolutions. Because as the pace of science accelerates, I believe that **government must keep pace -- and <u>will</u> keep pace -- with science.**

First, we've moved to better integrate science and technology into the policy process. My assistant for Science and Technology, Dr. Allan Bromley, is an active member of the Economic Policy Council, and chairs a White House Working Group

that advises the Domestic Policy Council. And we're already working to better integrate our science and technology efforts across the spectrum -- to get the "biggest bang" out of those big bucks.

But beyond the Federal role, we're committed to greater cross-fertilization with talent from the private sector -- on issues ranging from pure research to manufacturing performance.

So this year we created a President's Council of Science and Technology Advisors -- experts whose guidance has already been invaluable. We'll also be looking for counsel from this Academy's new Manufacturing Forum, just established this month.

We're committed to advancing America's tradition of innovation -- so our '91 budget called for a substantial increase in civilian research and development, and a permanent extension of the research and experimentation tax credit. But along with the applied, market-driven knowledge so crucial to this country's competitive future, let me reaffirm two priorities.

First, **math and science education** -- where we're engaged in a broad effort of reform and restructuring in cooperation with the states that began with our first-ever Education Summit with the nation's governors last fall. Our goal is to make American students first in the world in science and math achievement by the end of this century.

Today, I call on <u>all</u> Federal laboratories, facilities, and agencies to open their doors to students and teachers -- and get involved with education at the local level. And I ask our

industrial and business communities to create new alliances for education, mobilizing more of this nation's great technical resources, for the sake of the future.

The second priority I'd reaffirm is **basic research** -- the historical wellspring of this nation's well-being. Science must be able to continue seeking answers to our most fundamental questions. But here, some vigilance is needed. Earlier this year, I proposed to double the National Science Foundation budget. **Today, I want to call on Congress: Put our money where our future is. Put the National Science Foundation budget back on track.**

Without strong science we are blind: unable to grasp the real parameters of the present, or real potential of the future. But with the past as prologue, we know that **the investments we make in science are some of mankind's most promising.**

Satellites already help us study the earth's natural systems and assess environmental threats. And combined with video cameras they've become a potent force for peace -- both a product of science and a source of conscience -- **bringing the actions of nations before the eyes of the world.**

Pictures from Poland, scenes on the Berlin Wall... the eye of technology has proved more powerful than chisels for breaking down barriers -- etching the idea of freedom on the psyche of humanity -- and setting off a wondrous, hopeful, **political** chain reaction, worldwide.

Molecular biology, already responsible for agricultural advances that help feed the world, is tackling the challenge and promise of mapping the genome [GEE-nome] -- breaking the code of human life that might allow us to isolate and conquer such diseases as A.I.D.S., and cancer.

And just this month -- while one group of scientists pulled strands of D.N.A. from a 17 million-year-old magnolia leaf buried at the bottom of an ancient lake in northern Utah -- another group in San Jose managed to see and manipulate single **atoms** under a new scanning microscope -- bringing us a step closer to the creation of man-made molecules, new generations of tailored materials with undreamed-of properties, and computers with inconceivable power.

[[Of course, I can't claim to comprehend all of this. Like many, I've gain my scientific understanding from those Gary Larson cartoons. Like the one where, after detailed calculations, Einstein discovers that Time is actually Money.]]

While this administration is convinced that science is a priority investment -- and we're **committed** to keeping pace with science, as partner and catalyst -- we will not attempt to <u>direct</u> the course of science, any more than we would dictate the work of art, music, or literature.

Now more than ever -- on issues ranging from climate change, to A.I.D.S. research, to genetic engineering, to food additives -- we rely on the objective perspective of science for guidance. And as the frontiers of knowledge are increasingly distant from

the understanding of the many, it is ever more important that we can turn to the few for straightforward advice.

The National Academy of Sciences is **renowned** for objectivity and immunity to partisan pressures. So it is essential that the members of this body -- the most distinguished scientists in America -- preserve the objectivity that has been the Academy's hallmark.

On this I know we agree -- because so many of our technical and scientific achievements have been the products of independent minds. And if the earth-moving events of 1989 reminded us of anything, it's that complex bureaucracies and centralized planning don't work well in the governance of societies. **We will not try to impose them on science.**

Just as entrepreneurs and small businesses fuel the growth of the American economy, the backbone of American science is its brilliant array of individual investigators, spread across the nation, well, like a thousand points of enlightenment.

Among so many, think of two physicists who worked in secret because their firm wouldn't approve it, and discovered low-temperature superconductivity. Or Chester Carlson, who invented the Xerox machine in a little room behind a beauty parlor. Or Barbara McClintock, working alone, who made monumental discoveries in genetics 40 years ago that the world began to understand only in the last decade.

One of the **best** things government can do to support the magnificent creativity and energy of the American technical

community is to locate individual scientists with talent, and through agencies like N.I.H., N.S.F., and others, furnish them with the equivalent of venture capital. But there are **also** scientific challenges that, because of their unprecedented scope, demand unusual support.

So we maintain a balanced commitment to projects like Space Station Freedom. And the new Supercollider -- so critical to retaining our scientific talent -- that will re-create the unimaginable fireball of our origins in miniature, allowing us to study matter that hasn't existed since the birth of the universe.

Leading-edge technologies often help us find what we aren't even looking for -- whether it's breaking the genetic code of life, or getting a new look at the most ancient forms of light.

Our space program is a leading example -- as is the Hubble telescope -- the most sophisticated celestial object mankind has ever tried to lift into the heavens, with the power to see to the ends of the universe, and back to the birth of time.
[[I understand it's half a billion times more sensitive than the human eye. Talk about the vision thing...]]

On the southwest grounds of this great Academy rests a bronze memorial to a scientist who helped redefine mankind's understanding of time and space, of matter and energy. Among the engravings on that memorial are words of wonder -- about the "joy and amazement" Einstein felt, "at the beauty and grandeur of this world, of which man can just form a faint notion." Your work,

the work of science, daily brings that beauty and grandeur into sharper focus.

Still, if Nature were a goddess, she would be a clever and imaginative one, with an endlessly amusing habit of resting just beyond anticipation... but not quite beyond the reach of imagination.

We count on you to ask the questions that confound us -- and to struggle, that solutions might not manage forever to evade us. Because for those whose hearts are as open as their minds, the answers will surely, ceaselessly, enlighten and amaze us.

Thank you. And God bless you.

# # #