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FOIA MARKER

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Record Group/Collection: George H.W. Bush Presidential Records
Collection/Office of Origin: Chief of Staff, White House Office of
Series: Sununu, John, Files
Subseries: White House Offices Files

OA/ID Number: 29184
Folder ID Number: 29184-005

Folder Title:
Science and Technology (Bromley) (1991) [5]

Stack:	Row:	Section:	Shelf:	Position:
G	15	25	6	1

*discussed w/ POTUS &
Scowcroft*

THE WHITE HOUSE

WASHINGTON

March 12, 1991

THE CHIEF of STAFF
has seen

MEMORANDUM FOR GOVERNOR SUNUNU

FROM: D. ALLAN BROMLEY *Alan*
SUBJECT: THE PRESIDENT'S OTTAWA TRIP

In Ottawa the Prime Minister may raise the question of the Canadian KAON project--a \$750 million accelerator-based project in British Columbia--with the President or failing that, the President may wish to raise the matter with the Prime Minister.

Currently the Canadians are at the point of decision on this project, one that would give them world leadership on the high intensity frontier of modern fundamental particle physics. The Province of British Columbia has committed to payment of one-third of the project cost and one-third is anticipated from foreign sources. We in the U.S., for example, have committed, through DOE, to a roughly \$100 million (Canadian) contribution to the project if it moves forward in timely fashion and major contributions are anticipated from the Japanese, Italian, Germans, and others.

At the invitation of John Fraser, the Speaker of the Canadian House of Commons, I visited Ottawa last November for discussions with the Deputy Prime Minister, the Minister of Finance, Justice, Planning, and several others concerning this project and Canadian science generally. I strongly supported moving forward with KAON as a unique opportunity for Canada to build on its existing excellence--both in facilities and people--in this field and in so doing take world leadership in it. I believe that all these Cabinet members, as well as the Prime Minister, are leaning toward federal support but William Winegard, the Minister of Science and Technology, remains opposed because he feels that smaller projects are more deserving of support in a very tight financial situation. Per capita, the Canadian deficit is larger than ours.

From our parochial U.S. viewpoint, KAON, at \$100 million (Canadian) is a tremendous bargain and extremely cost effective. It would replace a project long touted at the Los Alamos National Laboratory costing us at least \$750 million (US) which we have placed on indefinite hold pending the Canadian decision on KAON. The U.S. community, reflected in the Nuclear Science Advisory Committee (NSAC)--reporting jointly to NSF and DOE--gave U.S. participation in KAON enthusiastic support and high priority; these recommendations have been accepted by DOE.

I am convinced that moving forward with the project would be in our best interest and certainly in Canada's best interest.

A demonstration of interest on the part of the President in his discussions with the Prime Minister could, I believe, tip the scales in the right direction. If you agree, perhaps you would mention this to the President.

I will be happy to provide any further information that might be useful to you or to the President.

Withdrawal/Redaction Sheet

(George Bush Library)

Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
02. Memo	From D. Allan Bromley to POTUS Re: Proposed Awardees for the National Medal of Science, 1991 (7 pp.)	2/25/91	(b)(6)	

Collection:

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Office: Chief of Staff to the President, Office of the
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Subseries: White House Offices File
WHORM Cat.:
File Location: Science & Technology
 (Bromley) (1991) [5]

Date Closed:	12/29/2004	OA/ID Number:	29184-005
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P-2/P-5 Review Case #:		Disposition Date:	
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RESTRICTION CODES

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Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
03. Memo	From D. Allan Bromley to John Sununu Re: Change of Chairmanship of IPCC/RSWG Working Group (1 pp.)	3/4/91	P2 , P3	

Collection:

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WHORM Cat.:
File Location: Science & Technology
 (Bromley) (1991) [5]

Open on Expiration of PRA
 (Document Follows)
 By JP (NLGB) on 10/28/05

Date Closed:	12/29/2004	OA/ID Number:	29184-005
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THE WHITE HOUSE
WASHINGTON

March 4, 1991

MEMORANDUM FOR GOVERNOR SUNUNU

FROM: D. ALLAN BROMLEY

SUBJECT: Change of Chairmanship of IPCC/RSWG Working Group

As you know, Dr. Frederick Bernthal has chaired the Response Strategies Working Group (RSWG) of the U.N./WMO sponsored Intergovernmental Panel on Climate Change (IPCC) since its first meeting in January of 1989. Dr. Bernthal has left the Department of State to become Deputy Director of the National Science Foundation and is unable to continue as the chair of the RSWG.

The next Plenary meeting of the IPCC will take place March 13-15, 1991. It is important for the U.S. to be represented in the Chair at that meeting. The DPC Global Change Strategy Task Force has therefore proposed that Dr. Bernthal be replaced as the chair of RSWG by Bob Reinstein, the Chief Negotiator for the U.S. on the Framework Convention on Climate Change. He is also the Deputy Assistant Secretary of State for Environment, Health and Natural Resources. As you are aware, Mr. Reinstein was chosen for the position of chief negotiator due to his knowledge of the critical issues involved in climate change and his previous participation in the work of the IPCC.

Unless you have any objections to this course of action, we will proceed with Mr. Reinstein as the Chair of RSWG.

The charge to RSWG by the IPCC was to lay out as fully and fairly as possible a set of response policy options and the factual basis for those options. The RSWG has met several times since 1989 and recently produced a book, Climate Change - The IPCC Response Strategies, which gives a summary of its work (attached).

*Reinstein, in my
view did an excellent
job at the Climate
meeting. DAB.*

file
SK per JHS
3/12/91
AHC
I called Ken Yale - done
AHC

THE WHITE HOUSE

3-5-91

Dear Mr. Richardson -

Governor Sununu shared with me
your letter regarding Tufts "technology
dinner." I will follow up with
Dr. Allan Bromley on your behalf.
Please keep in touch.

Sincerely,

Andy Card

Andrew Card
THE WHITE HOUSE
WASHINGTON

THE CHIEF of STAFF
has seen

D. Kenneth Richardson
President & CEO
Hughes
P.O. Box 45066
Los Angeles, CA 90045-0066

bcc: Governor Sununu ✓

THE WHITE HOUSE
WASHINGTON

DATE: 3-5-91

TO: Dr. Allan Bromley

FROM: ANDY CARD *Andy*

I understand you have been invited by Tufts University to participate in a "technology dinner" in New York on May 4. Please give every consideration to attending.

D. Kenneth Richardson,
President & CEO of Hughes,
has contacted us regarding
your participation.

THE WHITE HOUSE
WASHINGTON

DATE: March 4, 1991

TO: ANDY CARD

FROM: GOVERNOR JOHN H. SUNUNU

Please discuss this with Dr. Bromley.

I think it would be a good event for
him to attend.

*I sent a note
to Dr. Bromley?
HOLD this
for my f.i.b.
JHS is likely not to
participate.*

217029

HUGHES

Subsidiary of GM Hughes Electronics

D. KENNETH RICHARDSON President and Chief Operating Officer

27 February 1991

THE CHIEF of STAFF
has seen

The Honorable John Sununu
Chief of Staff
The White House
Washington, D.C. 20013

Dear Mr. Sununu:

Fred Nelson suggests that the best way to invite Allan Bromley to address the "technology dinner" Fred discussed with you is to forward the invitation to you. This I am pleased to do.

Fred said that he had described the event to you in some detail. My wife Connie and I are delighted that, as of this date, you are free on May 4 and will attend.

We hope that you would join Dr. Bromley in speaking to the guests. We intend the evening to focus on engineering, technology, and their relationship to national competitiveness and security. Your expertise and viewpoints would contribute invaluable to the evening.

The dinner will be a good opportunity for important discourse on issues which concern the future well-being of the United States. And the evening will celebrate Tufts' and the Engineering College's impressive, growing commitment to research and education in Technology.

We will phone your office in the next few days to confirm.

Thank you for your interest and your help.

Sincerely yours,



D. Kenneth Richardson

/ch

Enc.

p.s. Connie and I very much enjoyed meeting Harry at the grand opening of Tufts' new Science and Technology Center. (and I met you at the reopening of the refurbished Berg Laboratory)

HUGHES

Subsidiary of GM Hughes Electronics

D. KENNETH RICHARDSON President and Chief Operating Officer

27 February 1991

Dr. D. Allan Bromley
Assistant to the President
for Science and Technology
Old Executive Office Building
Room 358
Washington, D.C. 20500

Dear Dr. Bromley:

I am pleased to invite you to address a significant science and technology event which my wife and I, as alumni of Tufts University, will host on behalf of the University in May.

On the evening of May 4, Tufts will hold a "technology dinner" in New York for selected alumni, parents, and friends of Tufts' technology-related programs. We intend that this dinner be dedicated to issues of education, research, and policy which face emerging technologies in America and the support which educational initiatives, public and private, can lend to our technological competitiveness and national security.

The audience will be members of the Tufts university community whose interests in this subject are predicated on their investments in and ownership of technology driven companies, their management of the same, and their entrepreneurial activities. Representatives of the banking and investment communities will also attend.

I know that the audience will be very interested and acutely receptive to your address. We would be delighted and honored by your involvement and I urge you to accept our invitation. Should this date not be available on your calendar, we do have some flexibility for scheduling.

A representative of the university's office of special events will phone your office in a few days to confirm.

Sincerely yours,



D. Kenneth Richardson

/ch

cc: Mr. John Sununu

Withdrawal/Redaction Sheet

(George Bush Library)

Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
04a. Memo	From D. Allan Bromley to John Sununu Re: Suggested Letter for President to Heads of Delegation February 4 Negotiating Session (1 pp.)	1/29/91	B5	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff to the President, Office of the
Series: Sununu, John, Files
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WHORM Cat.:
File Location: Science & Technology
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 By JP (NLGB) on 10/28/05

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Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
04b. Letter	Draft Letter for President to Heads of Delegation February 4 Negotiating Session (2 pp.)	1/29/91	P- 5	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff to the President, Office of the
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 By gf (NLGB) on 10/28/05

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THE WHITE HOUSE
WASHINGTON

January 29, 1991



MEMORANDUM FOR GOVERNOR SUNUNU

FROM: D. ALLAN BROMLEY *Adm.*
SUBJECT: SUGGESTED LETTER FOR PRESIDENT TO
HEADS OF DELEGATION
FEBRUARY 4, NEGOTIATING SESSION

In our discussion group we have concluded that the difficulties associated with a video message from the President to this group are such that we would recommend against it. We have also agreed that it might be more appropriate were the President to address a letter to the Heads of Delegations rather than the Heads of State. Only 2 ministers, at present count, will be present--Goldemberg from Brazil and someone from a small African nation.

sent to staffing
I enclose herewith a draft of a possible letter from the President to the Heads of Delegations.

//
I have talked with Dick Truly and Lennard Fisk at NASA and they are entirely agreeable to having Bob Watson act as our monitor on the Framework negotiations. Now all I need is approval of a mechanism that can bring him to OSTP through June 30, 1992 while remaining on NASA staff and payroll. I need your help!

Hope your flu is improving!

Enclosure

THE WHITE HOUSE
DRAFT
WASHINGTON

January 29, 1991

Dear Delegates:

It is with great pleasure that I welcome you to the United States as we gather to begin negotiations on a landmark international agreement on climate change. This agreement will serve as a framework for our future cooperative efforts in our collective role as responsible stewards of this planet.

As we are so painfully reminded by the events of the past weeks, the future of our Earth's integrity, indeed, the future of our planet, requires true partnerships among nations in order to achieve peace, economic growth, and environmental protection for all. Accordingly, we look forward to working with you, recognizing that, together, we face a difficult task of shaping a new international legal regime. I assure you that we are prepared to work openly, diligently and respectfully toward achieving the goal of completing a climate change convention in time for its signature at the United Nations Conference on Environment and Development to be convened in June 1992.

The IPCC has defined our common agenda: accelerating scientific and economic research to help reduce remaining uncertainties; taking action now that responds to our present state of knowledge; and negotiating multilateral agreements that are fair, comprehensive and enforceable. As I said last April at the White House Conference on Science and Economics of Global change, to exercise effective global stewardship, we must advance our knowledge of natural and human systems, and we must create solutions that join economic growth with sound management of our environment.

Through our U.S. Global Change Research Program, we are working aggressively with other nations to improve our understanding of the global ecosystem and the relationship of our economic activities to the natural environment.

In addition, a number of nations are implementing policies to reduce greenhouse gas emissions. I am pleased to provide to you at this conference a copy of the U.S. action plan for climate change - America's Climate Change Strategy. This comprehensive strategy for action is built upon a series of actions which will have broad-ranging benefits - from curbing air pollution, to conserving energy, to restoring forest lands - and which will help curb net greenhouse gas emissions.

DRAFT

I am also pleased to report that the actions which are currently included in America's Climate Change Strategy will result in U.S. greenhouse gas emissions in the year 2000 being equal to or below the 1987 level.

We in the U.S. take the challenge of global stewardship very seriously and feel that these negotiations offer the opportunity for launching a new era of cooperation toward that end. The outcome of our talks will be profoundly important to the state of nature and the fate of humanity. Working together, I am sure that we will be successful.

Withdrawal/Redaction Sheet

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05a. Note	From D. Allan Bromley to John Sununu Re: William Wells Trip Report (1 pp.)	1/8/91	P-5	

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THE WHITE HOUSE

Dear John:

THE CHIEF of STAFF
has seen

January 8, 1990

I thought you might be interested in this
trepreneur from a former member of my staff.
I recruited him from his post-grad at
George Washington U for six months to set
up my office. A retired Air Force Colonel,
he served on the House Science and Tech

Committee for several years and then
at the AAAS headquarters where I got
to know him in 1980-1982.

Because the President's interest in
young Chinese scientists is so great.

Our umbrella S&T agreement with
the Chinese expires in June 1991 and I
very much hope that we can see our
way to renewing it. We both have
much to gain.

Allan

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

December 26, 1990

MEMORANDUM FOR D. ALLAN BROMLEY

FROM: WILLIAM G. WELLS, JR. *WGW*

SUBJECT: Observations Based on my Recent Visit to the PRC

Overview

To remind, Allan, during this past October in Beijing at the invitation of China's State Commission on Science and Technology, I participated in a one-week "foreign-experts" review and critique of that nation's annual series of Science and Technology Policy White Papers. After the conference, I spent another two weeks visiting a number of companies, domestic Chinese as well as foreign joint ventures, various Chinese organizations, and Chinese individuals whom I was able to contact through private sources.

In total, I talked with dozens of individuals and visited over a dozen companies and organizations in the Beijing, Shanghai and Hangchow areas. Some visits were as short as an hour; others were as long as a full day, e.g. Shanghai Volkswagen, Shanghai Bell and the Legend Computer Group in Beijing.

Major Personal Conclusion

I left for China already a strong supporter of President Bush's policies toward China. I understand them as including the continuation of most-favored nation trading status, maintaining the student exchange program, as well as the gradual easing of economic, financial and other restrictions.

I returned with a different bent of mind: not in many years have I come to believe so strongly and passionately in a set of political policies. The President is absolutely correct; his current policies and their extension offer the best possible hope for the development of human rights, democracy, and political and economic reform in that vast, ancient and tragic land.

In sharp contrast, the policies advocated by the President's critics -- such as suspending Most Favored Nation (MFN) trading status and disrupting the student exchange program -- would have nothing short of disastrous outcomes. The Markey-Pelosi brand of thinking, if enacted in national policy, would undermine and seriously damage the social and political forces in China that favor long-term economic and political reform. These very same forces are the ones favorably inclined to the West and particularly to the United States.

Allan, these words are far from being a traditional formal report. Rather, they reflect my highly personal observations and conclusions. This is not to disregard good, substantial analysis; yet, the older I get, the more I am inclined to trust my feelings and instincts on deep matters.

From a U.S. national interest -- as I see it -- we are "losing our asses" economically and in terms of potential future influences in China. All of Jim Lilley's experience and skill cannot offset the overwhelming presence and involvement by the Japanese, the Europeans, and, yes, even the Koreans and Australians. One German diplomat put it succinctly: "Given almost any alternative, the Chinese would prefer to work with you Americans, and you're throwing it away!"

Having now absorbed those intensive weeks and a myriad of experiences in China, I not only strongly believe the President is on the right track but also that the U.S. must move more forcefully in a number of ways toward building more positive relationships with China. At bottom, this will be in our long-term national interest for us as well as for the Chinese -- but especially for us.

Now, I'd like to tick off some specific points.

Conference and Related Events Protocol

The invited group of foreign experts was composed of representatives from Australia, the EC, Germany, India, Japan, the U.S.S.R. and the United States. On every occasion where there was a protocol choice, I was given deference: chairing the first day of the conference; placement at the head of the conference table next to the senior presiding Chinese official (Zhang Dengyi); and, at the concluding banquet, being seated at the head table next to Wu Wufeng, Secretary-General of the State Science and Technology Commission.

When I asked for several special briefings on matters of more than usual interest -- such as the special 862 High Technology Program -- my requests were promptly granted in the form of private audiences without the presence of the other foreign participants.

Finally, there was a small USSR-oriented component within the Chinese members of the conference who spoke Russian. They spent much time with the USSR representative (S. Kudria) -- clearly an old-line centralist. The core of this group, including Kudria, were placed half-way down the conference table on the right and were minimally involved in running the conference.

While I do not wish to place too much weight on the above noted events, I think it unlikely that there was much coincidence in the way they were handled.

Personal Conversations with Various Chinese

In my numerous private conversations with individuals and small groups, there was a common theme: a plea that the United States not take further steps in breaking with the Chinese; instead, there was the urgently expressed hope that we would resume directions closer to those of pre-June 1989, despite the tragic deaths and crackdown in Tiananmen Square.

Among these discussion groups were several arranged by a person who was a Visiting Scholar in my Program at the George Washington University during 1987. She and I have maintained contact in her capacity with the Chinese Academy of Sciences and in her work on industrial innovation. She and a number of her colleagues fervently stated that the more outspoken dissident students in the U.S. and Europe did not speak for the great majority of those in the intellectual communities of science and technology in China.

An essential point made by the majority of individuals who met with me was this: yes, reform is essential, but that reality calls for it to be gradually introduced over time. After well more than one hundred years of chaos -- including the recent and searing experience of the Cultural Revolution -- most Chinese yearn for stability -- and since 1978, they have had hope that relative stability and gradual change and reform were possible in achieving better lives. They repeated a theme I heard while I was in China during October 1988: many of the students wanted to go too fast too soon.

Indeed, there is no small bitterness among some who believe a minority of students in the U.S. are making life more difficult and vulnerable for many individuals in China. They cite with special bitterness the Chinese-student supported efforts of Markey, Pelosi and others to damage or take away MFN and student exchanges.

I was in a meeting with one group on an evening when word came over CNN about a House vote to remove MFN in China. The reaction was near hysterical! How could the U.S. possibly take such a terrible step? They said this would be seen as an "anti-China act" and thereby used by hardline, anti-reform elements in the leadership to undermine the more vulnerable pro-reform, pro-USA members of the political and intellectual elites.

In short, such U.S. actions would hurt -- and perhaps even destroy -- many of the changes and the very people we want to support in the long-run.

Often in these discussions, and in a meeting I had with Jim Lilley while I was in Beijing, the concept of "Guanxi" was raised. I'm sure the President is fully familiar with it from his own days in Beijing. A central operative axiom of developing and maintaining political and business relations with the Chinese is the concept of building "Guanxi".

"Guanxi" -- the relationship between two persons or two countries -- involves the long-term cultivation of trust, friendship, and mutual obligation. To break off such Guanxi with the Chinese people, after it has been cultivated over the past twenty years, would be seen -- even by many of our friends -- as an act of betrayal. Guanxi cannot be easily turned off and turned back on, and once it is broken, it is nearly impossible to repair. The Soviets found this out the hard way; the Japanese understand the concept fully and are acting accordingly, as I will describe more completely.

While some of the President's critics may think otherwise as they push for their ill-founded and simple-minded ideas of applying external pressures, Guanxi would be gone for a long time to come if they were successful. The U.S. would be out of the "China game" as an effective player.

A Reading of the Chinese Psyche

For China, domestic politics and international relations often operate in ways very different from those of other countries. It is incorrect to assume mechanically that historical examples of applying external pressure to bring about domestic political change in other nations are relevant in trying to affect change in China. Quite to the contrary, experience vividly shows that, in dealing with China, confrontational posturing and threats leads to Chinese intransigence and undercuts those forces in the Chinese leadership who favor accommodation.

China has entered a politically sensitive period of leadership transition, in light of the advanced ages of Deng Xiaoping, Chen Yun, and Yang Shangkun. Based on his service in China in 1974-1975, President Bush acquired better than most a deep understanding of the highly peculiar nature of Chinese politics during a succession crisis. In those years prior to the deaths of Chairman Mao Zedong and Premier Zhou Enlai in 1976, the struggle for power led to the politicization of virtually every issue and non-issue in Chinese life in ways that may seem totally arcane to most Americans and particularly to those politicians who understand little, if anything, about China.

Similarly, today, any move seen as negative or "anti-Chinese" could be presented and used as a pretext to attack the currently more vulnerable, pro-reform, pro-USA members of the political elite. An American curtailment of economic and cultural relations with China, even if intended as a short-term measure, could do serious damage to our long-term relationship with the Chinese people. Just as the abrupt Soviet economic withdrawal from China in 1959 left deep feelings of bitterness that influence Chinese attitudes toward the Soviet Union even today.

The MFN Question

Some of the President's critics have questioned why the United States should have continued MFN with China after the Tiananmen massacre and yet deny it to the USSR in light of Gorbachev's reforms. The Soviet MFN question is outside my

remarks on China, but I would only point out that ending MFN for China would mean breaking up an on-going established relationship, while the Soviet question involves whether or not we should begin a new level of relationships.

The President's critics miss the obvious -- these are totally different kinds of policy questions which call for totally different types of understanding and analysis. The Chinese and Soviet circumstances are not even slightly similar and we have far more to lose in the context of a negative decision on China's MFN status.

The Student Exchange Issue

I believe that President Bush's handling of the Chinese student question also has reflected his keen understanding of Chinese political culture. As compared to Americans, Chinese tend to place a greater premium on "form" rather than on "content." If the congressional bill to allow students to stay in the United States had not been vetoed, the Chinese leadership would have seen it as a direct affront and violation of the basic bilateral agreement. They would have used the bill as pretext to curtail the flow of more students and their spouses and dependents to the United States.

By vetoing the bill, the President prevented the Chinese side from abrogating the bilateral agreement. He thereby assured that the Chinese government would permit students to continue to come to the United States in large numbers and that the spouses and dependents of those students already in the United States would be allowed to join them. Then, by issuing the executive order, he protected the interests of the Chinese students already in the United States who may have been prominent in dissent activities.

I have no doubt whatsoever that the congressional bill would have largely disrupted the continued flow of students, spouses, and dependents to a far greater degree than the subsequent Chinese measures to limit somewhat the outflow of recent graduates and officially-sponsored students.

Observations on Company Visits

The largest and most successful automobile joint venture in China is Shanghai Volkswagen. This facility equals anything I have seen in the U.S. or Europe in terms of modernization, quality of output, training of employees and efficiency of production. About 40 percent of the parts are imported from Germany, creating significant export earnings and jobs in Germany. On the other hand, sufficiently high engine quality in combination with competitive costs has made possible the export of a significant number of engines to Germany. This has become an important and durable cooperative business venture between the Chinese and the Germans for which we have no successful counterpart.

The most prominent and highly successful telephone exchange manufacturing company is Shanghai Bell -- a joint venture with Alcatel, the Belgian equivalent of AT&T. The original technology for the medium-sized digital switching systems was American, but

it is the Belgians who are in China as 50-50 partners. These exchanges are being installed in dozens of small and medium-sized towns and cities using fiber optic technologies. About 50 percent of the parts are imported from Europe, and the U.S. is out "in the cold" in this important area of telephone switching systems. While it is true that AT&T is exporting some large 5ESS switching systems to China, the Chinese are far more interested in arrangements such as Shanghai Bell.

In my examination of production lines and test equipment at domestic Chinese firms (computers, satellite disks, foundries, cables, etc.), I found American equipment primarily of the early to mid-1980s vintage. The most recent, newly arrived items were -- with few exceptions -- German, Japanese, Swiss or other European.

I spent half a day with a Canadian joint venture involving the coal mining industry. The Canadians are staking out a major claim in the area of sophisticated computerized control systems for mining operations. A Canadian executive shook his head in wonder at the way the U.S. is leaving the economic field to the Japanese, Europeans, Australians and even to "us friendly Canadians!"

In my half-day visit to the Pudong Development Center in Shanghai which is an ambitious initiative to transform the economic face of Shanghai over the next twenty to thirty years, the overwhelming influence I encountered was Japanese and European. This is a large-scale development that will be tied in with the rest of Shanghai via a new subway system currently under construction of which the United States has not a piece. It may turn out that Pudong is overly ambitious as some in the United States think, but it would be a mistake to stand aside totally while the Japanese and Europeans and others participate in what the Chinese consider a centerpiece of their economic development.

Who Did I see in China?

One way to measure the level of economic and other cooperative activities taking place in China is to take a look at who is there.

The Japanese are there by the thousands and thousands -- tourists and business people. In each of the hotels where I stayed, the Japanese were by far the largest number of guests. By train, I travelled "soft seat-first class" and "hard seat." On one train with four first class cars, I was the only American; there were perhaps a dozen Europeans and Australians; and except for about 10-15 affluent Chinese, all there rest were Japanese. There are no Japanese in "hard-seat" cars.

On my China Eastern flight out of Shanghai to Tokyo, the majority of the passengers were Japanese. I upgraded to first class at my own expense; except for one other American, and three Chinese officials, all the rest in first class were Japanese businessmen. The week that I left China in early November, Lufthansa announced in a major advertising campaign that it was returning to China; to the best of my knowledge, United Airlines has only one flight a week into Beijing and erratic service to Shanghai.

While not as prominent as the Japanese, the Europeans are also present by the thousands. While I was there, major attention was devoted in the media to the European Community's vote to lift economic sanctions on China.

A big visual contrast for me between 1988 and 1990 was the sharp decline from the earlier thousands of American tourists to a virtual handful in 1990.

A new insight for me was the rapidly developing degree of Australian involvement in China. In fact, one of the largest joint ventures in the planning stages but near implementation is Australian. The more I learned about Australian initiatives, the more I came to the realization that Australia is becoming less Western-oriented and more Asia-oriented, and specifically China-oriented. This may not be news to others but it was for me.

Attitudes of Individual Chinese about Americans

Based on my experience and talking with other Americans, feelings on the part of many individual Chinese remain warm toward Americans. This is an enormous resource for the United States which should not be allowed to slip away. Nor should we take actions that would permit authoritarian "hard-liners" to erect barriers between us and the Chinese people.

Allan, I do not wish to dwell on "photos on my trip" but several photographs capture an essential component of the Chinese feelings about us. The enclosed photograph of me, a young Chinese girl (Ma Reng, age 5 when I met her in 1988) and her parents makes a point better than I could describe in many words. Ma Reng and her parents stopped me on the Bund in Shanghai to ask if Ma Reng could speak English with me. The pride on the parents' faces is obvious as their daughter conversed with me in quite fluent English.

I remained in contact from 1988 and met again with Ma Reng and her parents this past October. I had dinner with them in their tiny one-room apartment in a Shanghai working-class neighborhood. The mother is a cotton mill worker; the father a translator; and Ma Reng attends English classes three evenings a week after her regular school.

The parent's deepest fear is that Chinese-U.S. relations might become worse. Their strongest hope is that one day Ma Reng might be able to study in the United States. A hope, of course, shared by thousands upon thousands of Chinese.

Many people argue that the United States government should punish the hardline Chinese leadership by suspending MFN status as noted earlier, and assert that those who disagree with their proposals are insensitive to the cause of human rights and democracy in China. They claim that, while the Bush Administration is pursuing a policy based on misguided geopolitical concerns and cynical business interests, their call for cutting back economic and exchange relations with China is the humane and compassionate way of helping the Chinese people.

In fact, the truly tragic irony of the situation, is that such critics of the President and the Administration's policies are themselves advocating policies that would cause great political and economic harm to the very people and social forces they claim they are trying to help.

Allan, it is people like Ma Reng and her parents, like my friends in the Academy of Sciences and their colleagues, and like thousands and thousands of other reform-minded, pro-Western people who would be most hurt if the Markeys and Pelosis of this country are successful in overturning the President's policies.

A Final Major Conclusion

When Jim Lilley was here recently making the rounds we talked briefly -- and I wish to make it clear that I am not putting words in his mouth but rather my own -- about launching initiatives to counteract the Markeys and Pelosis.

There are several dozen astute businessmen who have visited China and understand the situation. There are labor leaders who could well understand the job creation factors arising from enterprises such as Shanghai Volkswagen and Shanghai Bell. There are scientists who understand the great value of maintaining contact with their Chinese colleagues.

There are many in this country who understand the enormous value for the United States to play an extraordinarily important role in educating the next generation of Chinese leadership. One need only look at the educational backgrounds of the current members of the Party's Politburo -- essentially they were educated in the U.S.S.R. or in China.

However, harnessing these multiple interests will not occur automatically. I believe it is timely to begin the planning of a forceful set of activities to offset the President's critics to show how wrong they really are and how disastrous their policies would be for our vital national interests. The locus of such a set of initiatives should be outside the government but would have to have at least the President's informal support.

Finally, I think it is highly important to conclude the current negotiations on the U.S.-China Science and Technology Agreement. Too much is being made over the intellectual property right impasse. Again, the Japanese and the Europeans seem to place relatively little weight on this issue in their economic dealings with the Chinese. They think we are making too big a deal of this considering how far the Chinese have come in the past five years on these matters.

In my view, the S&T Agreement should be disconnected from the trade negotiations; too much is at stake to allow a narrow point of view on trade affect negatively a wide range of potential scientific and technical cooperation and deep U.S. influence on Chinese science and technology in the years to come.



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06. Note	From D. Allan Bromley to John Sununu Re: William Wells Trip Report (1 pp.)	1/8/91	P5	

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Record Group: Bush Presidential Records
Office: Chief of Staff to the President, Office of the
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Subseries: White House Offices File
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File Location: Science & Technology
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THE WHITE HOUSE
THE CHIEF of STAFF
has seen

January 8 '90

Dear John:

The attached letter from Paul Doty of Howard is self-explanatory. I have confirmed his statements in the intelligence community and have obtained the enclosed preliminary comments from relevant experts.

It may well be that you already know all about this but the potential damage is so enormous that I pass it on anyway.

If you need further input just let me know at 7116.

Alan

5

HARVARD UNIVERSITY
CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS

*Professor Paul Doty
Director Emeritus
(617) 495-1401*

*John F. Kennedy School of Government
79 J.F.K. Street
Cambridge, Massachusetts 02138*

December 28, 1990

Dr. Allan D. Bromley
Special Assistant to the President for Science and Technology
Old Executive Office Building
Washington, DC

Dear Allan:

I had dinner the other night with Dr. Abdullah Toukan, a science and military adviser to the King of Jordan and an MIT Ph. D. whom I have known for some time. One thing he told me seemed sufficiently important that I thought I should pass it on.

His claim is that the valves on all the oil wells in Kuwait have been mined with remotely controlled explosives and that their being set off would produce an unimaginable catastrophe. This is because 80% of the wells connect to oil reserves under pressure and need no pumping. Hence when the exit pipes are opened the oil will flow. Their calculations are that it would produce a total flow of ten million barrels per day (five times normal production) for a very long time. Even without fires this would inundate much of Kuwait and the Gulf where it would be a complete ecological disaster from which they see no possible recovery. (The Vallez dump was only one shot of a quarter of a million barrels.) But of more immediate concern would be the burning of this oil from fires set by the explosives or by intent. They believe this could turn into a fire that would be orders of magnitude greater than any previously known and their calculations show that both the carbon dioxide and the carbon monoxide levels would exceed lethal limits over tens of square kilometers with the risk that it might drift over Desert Shield forces as well as be fatal to many in Kuwait. Moreover, the heat would be such that there would be no possibility of getting close enough to the sources (there are about a thousand wells in Kuwait) to extinguish the fire.

This all sounds pretty fanciful but it is hard to rule it out without some serious examination. Toukan did visit in Washington and I presume he has informed others of these views. And perhaps it has been studied and taken into account. But I thought I should make sure it was known in the inner circles.

On quite another matter I was surprised at the current news reports that immunization against anthrax was due to begin soon for our troops. When we discussed this a month ago in a DSB/DPS CW Policy Panel it was widely agreed that much more testing was needed to insure safety, that the protection provided was not great and required frequent booster shots, and that the production of the amounts needed would take a very long time. Unless we were badly informed such a program would seem to be quite premature.

Sincerely,

Paul

Home phone: 617 864 6679

cc: Brent Scowcroft
Gordon Oheler

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OCEAN ASSESSMENTS DIVISION
Hazardous Material Response Branch
7600 Sand Point Way N.E. - Bldg C15700
Seattle, Washington 98115

Date: January 7, 1990

To: Nancy Maynard

From: John Robinson *John Robinson*

Subject: Potential problems from massive oil spills in the Middle East

The following are a few short papers on some of the problems associated with massive oil spills in the Middle East that we discussed tonight. The intention of these papers was to try to quickly put something together on the big picture and not try to do an "opus magna" this evening. We have a pretty good library, as well as considerable experience in the area, and can supply references and further detail later if you wish. Each section includes the name and home phone number of the author so you can contact them tomorrow am if you have questions -- don't worry about the time, they are all accustomed to strange hours.

We've also enclosed a list of people you may wish to contact in the area for further information.

By the way, both Jerry Galt and Bill Lehr have considerable experience with respect to spills in this region of the world. Bill was an associate professor and research engineer for the University of Petroleum and Minerals in Dhahran, Saudi Arabia from 1980 to 1986, working specifically on oil spill problems. Jerry has done a lot of work with Kuwait on spill modeling and assisted them a few years ago in getting their computer modeling program going.



Oil Well Blowouts

(Bill Lehr 206-486-3649)

Oil wells in the Arabian Gulf region tend to be gas driven; that is dissolved gases in the oil bearing strata provide the pressure to bring the oil to the surface. In the past, gas was flared off but it is now separated in gas/oil separation plants (GOSP's) and used either locally or turned into LNG for export. Unfortunately, some reservoirs in the region contain hydrogen sulfide gas (sour gas reservoirs) which can be released in the event of a well blowout. One example of such an event occurred in the Hasbah oilfield some 140 kilometers off the Northeastern Saudi coastline. On October 2, 1980, The Ron Tapmeyer exploratory well blew, releasing H_2S in toxic quantities. Several workers died when they dived into the water and were overcome by the gas which is more dense than air and therefore formed a blanket on the water surface. Because the winds were calm, operations to shut-in the well were impeded and were finally completed eight days after the incident.

Wells in the region have devices to prevent blowouts and accidents are most likely to occur, as in the example above, when new drilling is being done. However, sabotage could possibly overcome these protective devices. One major area of concern must be Dhahran, Saudi Arabia, which is located over a sour gas reservoir. Dhahran contains, among other things, the Saudi ARAMCO oil company headquarters, a major airbase, and the US consulate.

Hydrogen sulfide has an IDLH (concentration which is immediately dangerous to life and health) of 300 parts per million. The danger zone from a blowout would depend on the amount released and existing environmental conditions. Hydrogen sulfide wells that have blown out in other fields around the world have created toxic threat zones in the ten mile range and the products released could be smelled out to distances of one hundred miles, which to an uninformed public poses the threat of a hysterical response.

Desalinization Plants

Bill Lehr (206) 486-3649

Much of the drinking water for the region is provided by desalinated water. Kuwait, for example, gets over three-fourths of its water supply from this source. These same plants also supply the majority of the power needs and in Kuwait during the Nowruz spill it was estimated that a summer interruption of power for air-conditioning would lead to a large number of fatalities.

The desalination plants use a reverse osmosis process which can be contaminated by dissolved hydrocarbons. Relatively small amounts of oil can affect operations. During the Nowruz oil spill, the Aziziyah desalination plant in Saudi Arabia was temporarily closed because of oil-fouled sediments near its intake.

Due to the shallow conditions offshore, the desalination intakes in Kuwait and the United Arab Emirates are close to the surface and are more at risk to oil spills than those on the Saudi coast. The major desalination plants for Kuwait are Doha, Al Shuwaik, and Al Shuaiba. The first two are in Kuwait harbor and would be at risk from a localized spill in the area. Al Shuaiba is on the the Southern Kuwait coastline and is more exposed, although the large spill at Nowruz never reached it. The desalination plant south of Jubail provides water supplies to Riyadh. It is protected to a certain extent from oil coming from the north by Abu Ali island although the offshore Berri oil fields are nearby and could potentially pose a threat.

General Background on Environmental Effects

(Jerry Galt 206-363-0190)

One quick way to put the effects of a massive oil spill in the Arabian Gulf into perspective is to consider what we know about a very large one that has already taken place. During the Iran/Iraq war the Nowruz oil field in the NE corner of the Arabian Gulf was bombed with the result that seven or more wells were ruptured and set on fire. The resulting release of oil and combustion by-products was massive and continued for several years while the fires burned themselves out and the well silted in. The actual size of the release is unknown, but likely to have been in excess of 100 million gallons.

During the Nowruz spill, smoke from the burning wells was visible in satellite imagery extending to the SE down the center of the Gulf for a distance of over 250 km. The floating oil trended down the Gulf and after several months extended some hundreds of miles in streaks and widely separated patches. A general indication of the distribution is seen figure 1, attached.

Over a several month period, oil was removed from the surface through two major processes:

- High outside temperatures resulted in a good deal of evaporation
- Intermittent sand storm activity caused a rain out of sand particles onto the floating slicks and increased their density to the point that individual tar balls sank. Once on the bottom, the tar balls were incorporated into the very active depositional cycle that is seen in the entire Arabian Gulf (Note: deposition rates are too high for the formation of coral in the northern Arabian Gulf, in contrast to the Red Sea).

Currents in the Arabian Gulf are predominantly tidal with an average velocity of less than one knot but coastal restrictions can cause swift flow in some locations. Evaporation rates are high and there is little fresh water inflow causing highly saline conditions. Because the water is so shallow, the Gulf is flushed quite rapidly for a body with its surface area. The estimated flushing time through the Straits of Hormuz is between two and six years. This contrasts with the Red Sea which has flushing times in the hundreds of years. This means that the residence time for pollutants in the Gulf is relatively short. Transport processes are dominated by the mean residual current patterns and the winds. These vary throughout the year, but some basic features are persistent:

- The residual current patterns in the northern Gulf show a SE or down coast current from Kuwait to Saudi Arabia. (Figure 2-attachment)

- During January, statistical winds show a good deal of variability but the dominant and most probable winds are from the NW. (Figure 3-attachment)

Both of these factors suggest that a major spill in Kuwait waters or along the northern coast of Saudi Arabia will spread along the shoreline and move SE along the coast. Oil spreading in scattered patches over hundreds of miles is likely with slicks persisting for several months. Computer simulations by a research institute in Saudi Arabia show that the southern Iranian coastline is also a high risk area.

In the event of a major spill, the most vulnerable aspects of the coastal areas are closely associated with human use of the area. In particular, oil could seriously impact desalinization/electric plants and commercial fisheries programs. With the exception of Kuwait harbor, the further south the oil extends the more sensitive the shoreline and indigenous fisheries become. A major spill initiated at Jubail or Ras Tanura would present a more serious problem with the Gulf of Bahrain acting as a collection area.

The most serious environmental harm would occur where oil may be transported into shallow, sheltered bays, or if there was large-scale stranding of oil on sandy beaches along important shrimping and fishing regions. Oiled sediments in these areas could be eroded from the shoreline and deposited onto the shallow subtidal regions where shrimp and fish feed and are caught.

The coastal environment of Kuwait includes sensitive tidal flats. The tidal flats along the northern boundary of Kuwait are among the most extensive found anywhere in the Gulf.

The most sensitive environments in the Gulf are along the southwestern shoreline from Ras Tanura to Abu Dhgabi. These areas are extremely shallow, have extensive sabkhas, (supratidal flats flooded aperiodically by wind tides), and coral reefs. Most of the remaining mangrove swamps in the Gulf are located near the UAE, and are not likely to be impacted.

Nonetheless, the environmental effects of a major spill are not likely to be profound, as evidenced by the lack of serious effects resulting from the Nowruz spill. First, the area has been subject to more or less continuous small spills so that background levels of hydrocarbons are high. In 1983, estimates of oil spillage due to normal operations was fourteen million gallons. Secondly the area

is not particularly rich in supporting a large nearshore ecosystem (although small areas of salt marsh and mangrove swamp do exist). Third, the area rapidly flushes itself as discussed earlier.

figure 1

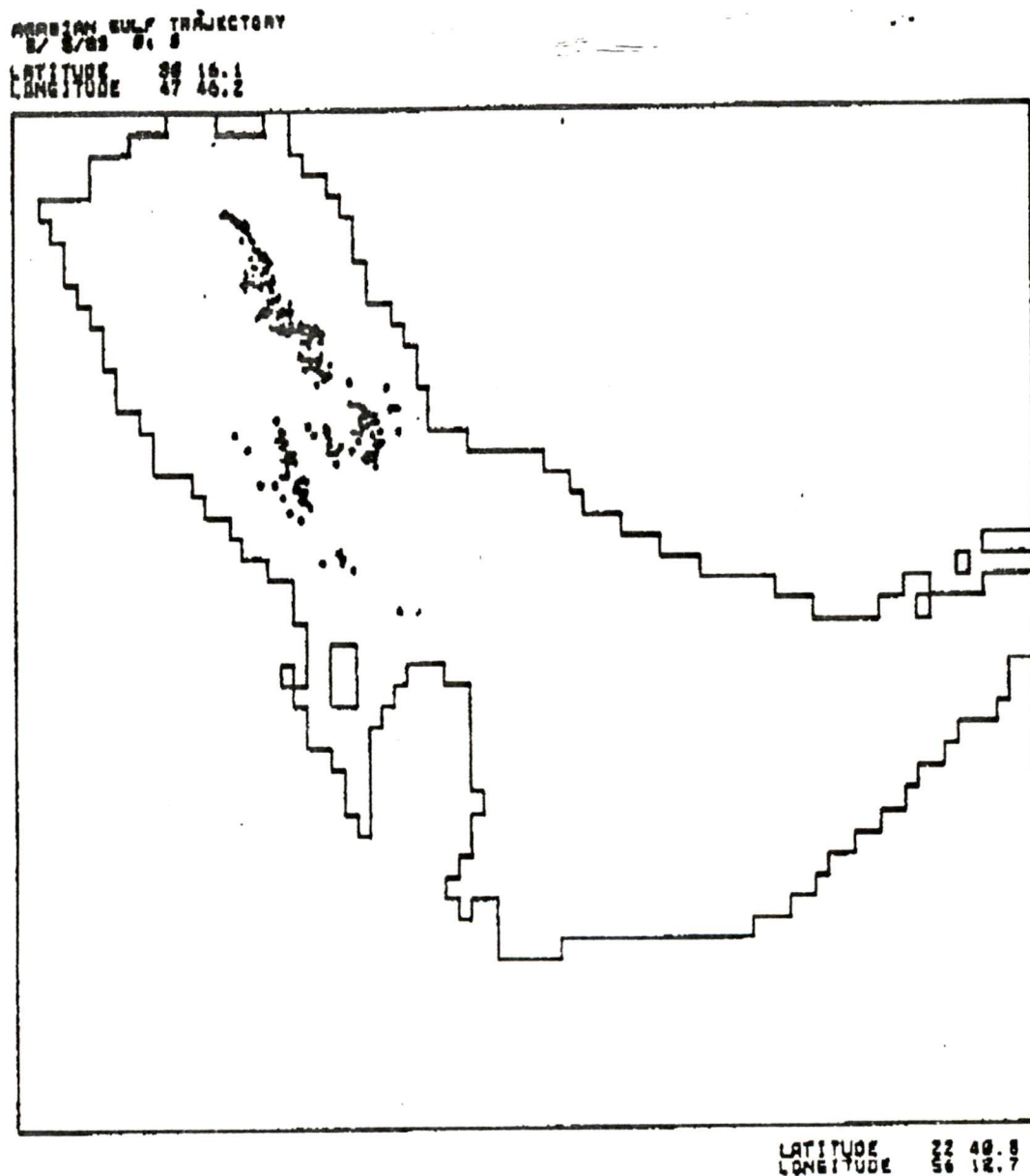


Figure 11. Spill distribution map of trajectory estimate for May 5, 1983.

Figure 2

ARABIAN GULF
COMBINATION OF CURRENT COMPONENTS
NORTHWEST WIND TEST CASE
LATITUDE 22 48.8
LONGITUDE 56 12.7

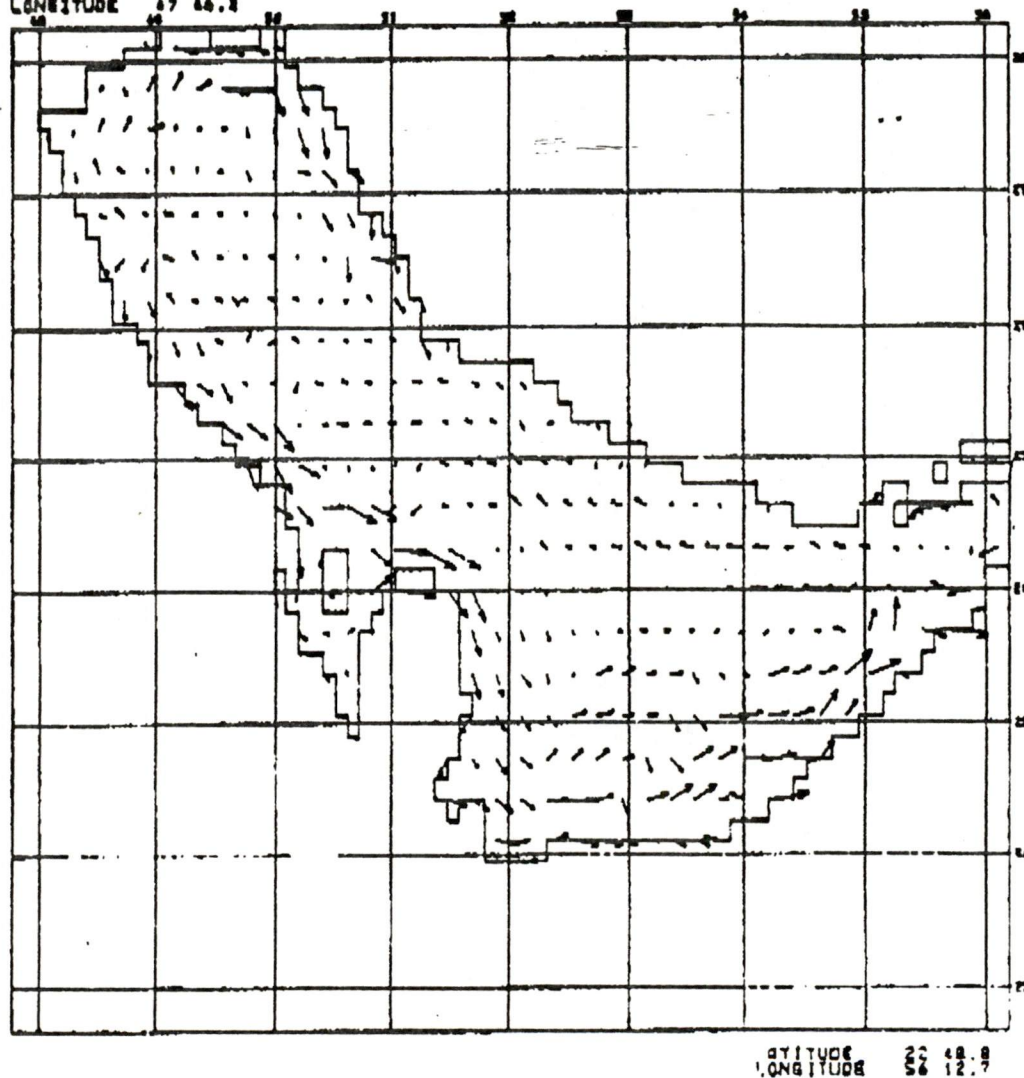
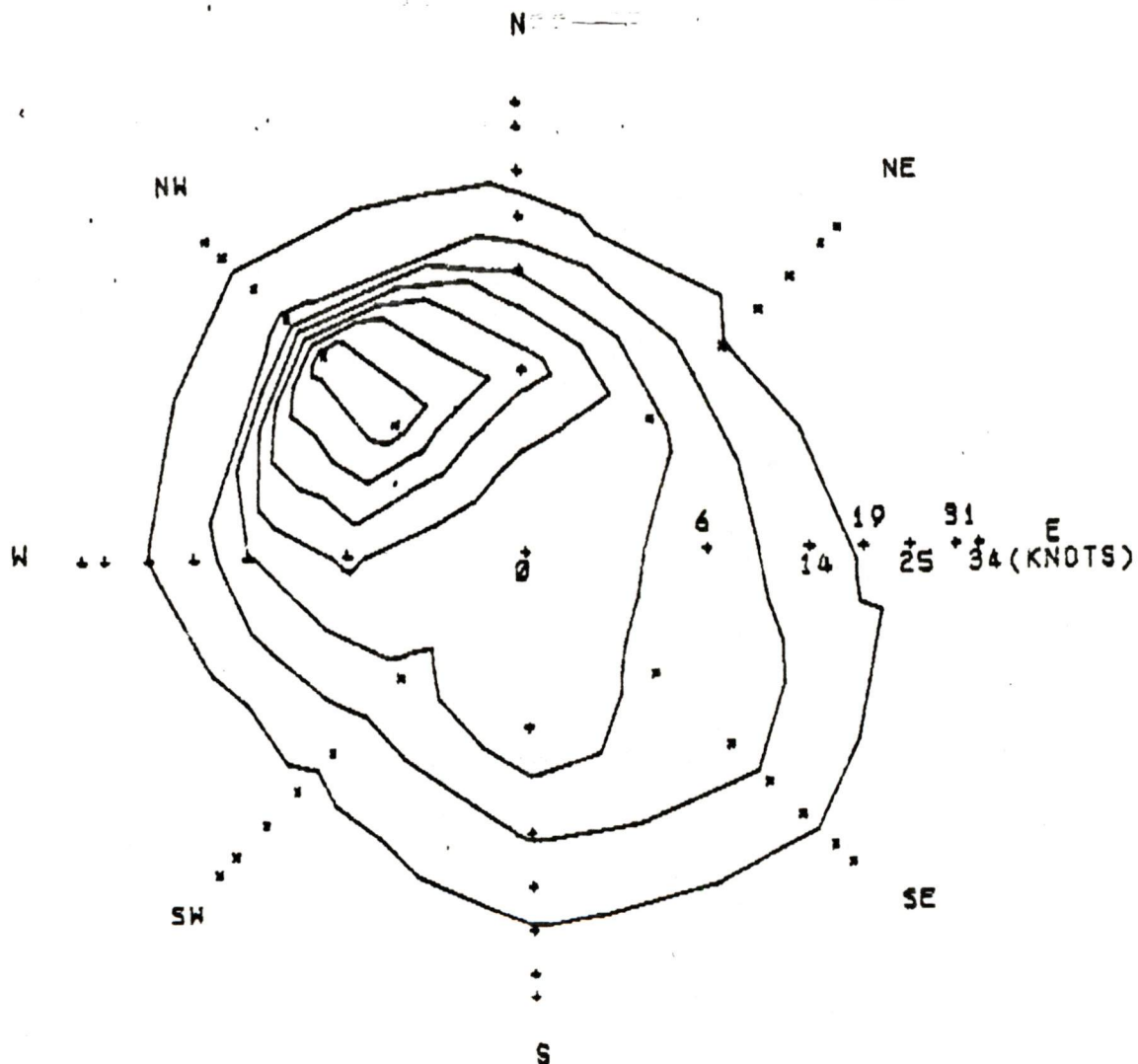


Figure 7. Linear sum of current components (Figures 2, 5, and 6) scaled to be consistent with observational data.

Figure 3



STATISTICAL WIND FOR JANUARY AT 29 04 N 48 10 E
CONTOUR LEVELS 0.5%, 2.5%, 4.5%, ETC.

Combustion By-Products

Sharon Christopherson (206-778-6949)

The combustion by-products of burning crude oil are similar in nature to what is found in the exhaust of a poorly functioning truck or automobile. Laboratory and small scale burning studies done over the last 15 years have attempted to characterize combustion by-products associated with a select number of crude oils. However, very little information specific to middle east crudes has been reported.

Approximately 10% of oil burned is converted to smoke in the combustion process. Smoke aerosol produced by combustion is composed of a graphitic (so-called elemental carbon) fraction and an organic carbon fraction. The elemental carbon fraction, or soot, makes up 80%-90% of the smoke and poses minimal threat to human health or the environment. Soot, or the elemental carbon fraction of the smoke, would be expected to have minimal impact on either the environment or human health.

From a toxicological point of view, the polynuclear aromatic hydrocarbons, or PAHs, are most commonly studied. These compounds, especially the higher molecular weight 4-6 ring PAHs, have been associated with cancer production in laboratory animal studies. Chemical analysis has shown that while the total PAH content of the original oil and oil smoke are nearly equal, the distribution of specific PAH compounds differs. Smoke has been found to have a higher percentage of the 4-6 ring PAHs compared to the original crude oil. Specific data on acute toxicity resulting from inhalation of PAH's is not readily available.

The primary gaseous combustion by-products of crude oil combustion (excluding water vapor) are carbon dioxide (95%) and carbon monoxide (4 %). Nitrogen oxides (NO, NOx) are also present at very low levels (.015% and .04%). Typical concentrations found of these gaseous products, at the source, are 4700 ppm CO₂, 180 ppm CO, 0.7 ppm NO, and 2.0 ppm NOx.

Carbon monoxide:	Concentration Immediately Dangerous to Life and Health (IDLH) 1500 ppm
Carbon dioxide:	IDLH 50,000 ppm
Nitrogen monoxide:	IDLH 100 ppm

Dilution effects: Even under stable meteorological conditions, dilutions of 1,000x could be expected one km downwind from the source and up to 10,000x two km downwind.

The burn residue remaining on the the water following combustion equals from 5% to 30% of the original mass of oil burned, and is essentially inert with all the soluble fractions burned off. Ingestion of residue by birds or fish could possibly result in a very minimal impact, depending on the quantity of residue produced.

INFORMATION RESOURCES FOR THE REGION

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THE WHITE HOUSE
WASHINGTON

January 9, 1991

THE CHIEF of STAFF
has seen

MEMORANDUM FOR GOVERNOR SUNUNU

FROM: D. ALLAN BROMLEY



SUBJECT: Critical Technologies Institute

Here is some additional information on the Critical Technologies Institute that we talked about briefly the other day.

The National Defense Authorization Act for Fiscal Year 1991, Sec. 822, Part C, TITLE VIII, called for the establishment of a Critical Technologies Institute under the sponsorship of OSTP. The format chosen by the Congress was as a Federally Funded Research and Development Center (FFRDC).

In recent weeks we have been struggling with how best to respond to the legislative mandate that also appropriated five million dollars for FY 1991. We have held dozens of discussions with groups inside and outside of government, including OMB, the Defense Department, and a representative sampling of existing FFRDCs.

We are exploring various alternatives for complying with the legislation as well as taking into account a less than certain funding support outlook beyond FY 1991. In the final analysis, we are seeking to devise an arrangement that will provide the most utility in the form of solid analysis to the President, OSTP and the rest of the Executive Office of the President.

I would be interested in any further thoughts you might have and I will keep you posted on our progress.

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THE WHITE HOUSE

WASHINGTON

January 7, 1991

THE CHIEF of STAFF
has seen

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MEMORANDUM FOR THE PRESIDENT

FROM: D. ALLAN BROMLEY

SUBJECT: MEETINGS WITH SCIENCE, TECHNOLOGY, AND
ENVIRONMENTAL OFFICIALS ON LATIN AMERICAN
TRIP

During your recent trip to Latin America, I had the opportunity to discuss science, technology, and environmental issues with senior officials in each of the countries visited. The meetings resulted in a good exchange of views on the regional global change institute proposed during the April 1990 White House Conference on the Science and Economics of Global Change, enhanced science and technology cooperation, and technology transfer. Outlined below are highlights of my discussions.

BRAZIL: President Collor indicated the importance he places on science and technology in Brazil's economic development. His Secretary for Science and Technology, Dr. Jose Goldemberg, reinforced this when I met privately with him. We agreed on the need to renew our bilateral science and technology agreement when it expires in May 1991 and noted that both sides would have to show flexibility on the issue of intellectual property rights (IPR) in the agreement. We agreed to hold a Joint Commission Meeting in Washington in the spring to discuss new areas for cooperation and to negotiate renewal of the agreement.

Dr. Goldemberg expressed great interest in hosting the regional global change institute. He stated that Brazil has the best scientific infrastructure in the region to support such an institute. I welcomed his support for the concept but emphasized that many other countries had similar interest in the institute. I mentioned the possibility of satellite institutions and told him that the United States would be willing to host a regional workshop in the late spring to discuss the scope, functions, agenda, management, and location of the institute. Dr. Goldemberg said that Brazil would support such a workshop.

With regard to technology transfer, I indicated that Brazil's implementation of full scope nuclear safeguards would be extremely helpful, as would a new IPR law. Dr. Goldemberg explained that the Brazil-Argentina agreement did not use the term "full scope safeguards" because of domestic sensitivities. However, he assured me that full scope safeguards would be implemented.

I also met with Minister for the Environment Lutzenberger who, earlier in your expanded bilateral with President Collor, had stated that 90 percent of the Amazon rain forest remained intact. I expressed some skepticism since other sources have quoted as much as 25 to 30 percent depletion. Lutzenberger stood by the Brazilian numbers and stated that Brazil is making new and serious efforts to maintain and restore the existing forests.

URUGUAY: At your request, I met privately with President Lacalle and his senior environmental official following the expanded bilateral meeting. President Lacalle raised five points which we discussed in detail: They were:

- o Lacalle's efforts to establish a "Common Market of Knowledge" in Punte del Este, attracting with diplomatic status and other inducements, some of the world's foremost academics for summers and on sabbaticals;
- o oceanography and Uruguay's desire to host the regional global change institute;
- o the environmental situation and deteriorating fishery yields in the south Atlantic for which the causes are unknown;
- o the state of education in the United States and Uruguay; and
- o U.S. positions for the February Framework Convention meeting.

ARGENTINA: In the expanded bilateral meeting, President Menem raised his interest in hosting the regional global change institute. I subsequently met with President Menem's Secretary for Science and Technology, Dr. Matera, and with Ambassador Zapata, Director General for International Cooperation, Ministry of Foreign Affairs to discuss the institute and other science and technology issues. The Argentines have put together a very comprehensive proposal for the institute, which they agreed to discuss more fully at a regional meeting to be hosted by the United States in the spring.

The United States and Argentina have a relatively inactive science and technology agreement. We agreed that the two sides should meet early next year to revitalize the agreement and to establish a "blue ribbon panel" to explore new areas of cooperation.

CHILE: I had hoped to sign a new science and technology agreement with the Chileans during our visit, but the agreement was not ready for signature due to last minute Chilean questions regarding intellectual property rights. I was assured by the Ministry of Foreign Affairs that the agreement would be ready for signature in early January. Chilean science and environment officials also expressed interest in hosting the regional global change institute.

VENEZUELA: Dr. Dulce Arnao de Uzcategui, the Venezuelan Minister for Science and Technology, and I had the great pleasure of signing a new science and technology agreement. The old agreement had expired in 1989, but was not renewed because of IPR concerns. The new agreement will serve to facilitate cooperation in a broad range of areas including environment, energy, health, and materials research. As with all other countries, Venezuela also made a bid to host the regional global change institute. I suggested that they begin to formulate their ideas more fully in preparation for a spring conference on the topic. The Vice Minister for the Environment agreed.

Should you wish any further details concerning any of these items, I would welcome the opportunity to provide them.

THE WHITE HOUSE
WASHINGTON
December 21, 1990

THE CHIEF of STAFF
has seen
90 DEC 24 PM 2:16

MEMORANDUM FOR THE PRESIDENT

FROM: D. ALLAN BROMLEY 

SUBJECT: Sea Level Rise

The NSC advised us that a sea-level rise issue was raised on your meeting with Pacific Island heads of state last month. Attached is a copy of the NASA report that was discussed in that meeting. Following is a summary of recently published scientific information on sea level rise as well as some facts on U.S. research activity related to this issue.

There are six direct and indirect causes of changes in sea level.

Sea level at any particular place in the ocean varies over time. The direct causes of these variations include vertical land motion and change in the volume of sea water. Indirect causes of changing sea level include: changes in climate, plate tectonics (such as continental drift and similar land mass shifts), ice and snow, and ocean circulation. Climate-related factors that are thought to contribute to sea-level rise include: expansion of the oceans due to temperature increases, and melting of glaciers, small ice caps, and large ice sheets (eg the Antarctic). Sea level rise also varies between different regions of the world. There are areas where sea level rise may be considerably greater than the global average and areas which are less.

Recent scientific evidence predicts some sea-level rise in the next 100 years.

National Academy of Sciences, National Research Council, Sea-Level Change, 1990

"...On the basis of estimates of global warming of the atmosphere and ocean... One hundred years from now it is likely that sea level will be 0.5 to 1 metre higher than it is at present...."

Intergovernmental Panel on Climate Change WMO/UNEP, Climate Change the IPCC Scientific Assessment, 1990

"For the IPCC business-as-usual scenario at year 2030, global, mean sea level is 8-29 cm higher than today, with a best estimate of 18 cm. At the year 2070, the rise is 21-71 cm, with a best estimate of 44 cm... Nonetheless, the implied rate of rise for the best-estimate projection corresponding to the IPCC business-as-usual scenario is about 3-6 times faster than over the last 100 years."

Some Pacific Island nations are concerned about sea-level rise.

Some Pacific Island Nations feel particularly vulnerable to the potential for sea-level rise, especially those who live on small islands with less than three metres total elevation. This concern was raised in your meeting with the heads of state and was reiterated in a speech by the Prime Minister of Tuvalu at the Second World Climate Conference two weeks ago. (Tab A)

The U.S. has a solid history of quality research programs on sea level.

Understanding and monitoring sea level is a high priority for the Administration's Global Change Research Program (USGCRP). Some of the activities of the USGCRP include: deployment of stations to measure sea level, global ice sheet observations to monitor changes by remote sensing, regional glacier monitoring, studies of atmospheric and oceanic circulation to estimate temperature change, and studying the geologic record to reconstruct the causes and histories of past changes.

The U.S. has fully participated in the international process which has been examining sea level change. The U.S. has endorsed the United Nations sponsored Intergovernmental Panel on Climate Change (IPCC) as an appropriate mechanism to consider the scientific aspects of climate change. The IPCC has three standing working groups: one on the science of global climate change, another on the impact of such change, and a third on possible responses to changes. The U.S. chairs this third group, called the Response Strategies Working Group. Through these and other programs the U.S. is continuing to work with the international community to provide sound science with which decisions can be made.

The NASA paper on monitoring global change is limited in scope.

Attached is a copy of the article to which you referred during your visit with the Pacific Island heads of state (Tab B). It discusses a recent development by U.S. government scientists, a new technique (passive microwave radiometry from satellites) which provides accurate estimates of global atmospheric temperatures.

Previously, it was believed to be impossible to maintain the calibration of satellite instruments over an extended period of time. Studies have shown otherwise, opening up the entire planet to precise temperature and other measurements, rather than just part of its land area.

The paper did conclude that there was no detectable climate change based on the last ten years of data from this new technique. However, climatologists believe that 30 to 500 years of data is required to predict any trends in climate change. While their ten-year temperature record is too short for use in any analysis of climate change, this new technique will allow relatively precise determinations of the locations and magnitudes of temperature change events in the future.

enclosures

CHECK AGAINST DELIVERY

**Address
by the
Prime Minister of Tuvalu
Rt Hon. Bikenibeu Paeniu
to the
Second World Climate Conference**

**Geneva
6, November 1990**

I am most honoured and privileged to be amongst the main key speakers this morning.

I congratulate the World Meteorological Organisation (WMO) and the United Nations Environmental Programme (UNEP) and all those who have worked hard to ensure the holding of this most important Conference.

I must say it is quite a daunting experience to address a collection, or should I say a cluster of most eminent scientists, experts, researchers, diplomats and policy makers today on the subject of climate.

When I was asked to take part in this Conference, I was comforted by the very fact that I could speak with my heart on the matter. I can assure each and everyone of you that I speak to you today from real experience because I live on one of the most smallest island groups in the Pacific. We are therefore, along with others, extremely vulnerable to environmental hazards and the dangers of the Greenhouse Effect and sea level rise. These are problems which we have done the least to create but now threaten the very heart of our existence.

We in the Pacific, the Carribean and elsewhere had done the least to create these hazards but now stand the most to lose.

My colleagues who have eloquently spoken before me are prominent leaders from some of the leading nations of our world. From the onset, I want to express my gratitude for their important remarks and their concern for climate change. Despite the smallness of my country, and of others, we are all here gathered to address a paramount global challenge. Climate change will affect all of us.

However, because of our vulnerability and high susceptibility to climate changes, we would be affected proportionally more than many of the countries represented here today.

I am very confident that not only do I speak for my country, but also I speak for my neighbouring countries in the Pacific and as well as others, especially those from the Southern Hemisphere.

I sincerely hope I will be able to share with you this morning a somewhat different but interesting perspective on the problem of climatic change.

Why Tuvalu is particularly susceptible to Climatic Changes

As some of you may not know, my country has a total land area of only 24.4 square kilometres - only a speck on the maps of the world. This 24.4 square kilometres is further divided among nine islands, ranging in size from Vaitupu which is 4.9 sq.km to Niulakita of only 0.4 sq.km. All our nine islands are low lying coral atolls dispersed over an area of 1.2 million square kilometres of the South Pacific Ocean, none rising more than 2 metres above sea level.

In sharing a number of thoughts with you today, I want to tell you the reality of life in Tuvalu in terms of the impact on our lives of the global climatic changes so far. My country is amongst the most vulnerable to climate and sea level rise in the world. The survival of Tuvalu and the survival of other neighbouring countries in the South Pacific - Kiribati, Tokelau, Tonga, Marshall Islands and so forth - hang in the balance. This eminent gathering therefore could make the difference between Tuvalu's imminent demise and its continued existence.

The scientists have confirmed that global warming is now a certainty. The findings of the international scientific community finalised in Sweden this year, have now been confirmed by the experts gathered here last week. We have learned of the best Scientific and Technical estimates assuming "business as usual" for greenhouse gas emissions which are:

An average rate of increase of global mean temperature during the next century of about 0.3 de C per decade (uncertainty range of 0.2 to 0.5 deg C).

An average rate of global mean sea level rise of about 6 cm per decade (uncertainty range of 3-10 cm per decade).

Now it is up to the decision makers of the world, particularly those of the leading industrialised nations, to respond with decisiveness and conviction. We know from all the scientific evidence collected to date that the fragile and delicate atmospheric balance on which life and our existence depends has been upset. The threat to the atmosphere comes predominantly from the breath of industrialised civilisation.

We in the island nations cannot afford to wait for more studies and research. We would like to have firm and pragmatic solutions to curb the negative impact of climatic changes on our lives.

We live on these small fragile islands and we know that the problems are now and not tomorrow. The time to act is now or never.

Tuvalu needs help to face up to this challenge. In particular, we in the Pacific and others in the Southern

As we in the Pacific Island region enter the 1990's, we increasingly face a range of environmental problems far more extensive and more serious than ever before. Problems of ozone depletion, climate change, sea level rise, hazardous waste dumping, driftnet fishing - to name some which fall into this category. These impinge severely on the development process itself of our countries in the Pacific and the overall impact has been, and will continue to be, unfavourable.

Already we in Tuvalu have been experiencing the adverse effects of global warming and the greenhouse effects. I am happy to share with you some of the most salient features.

a. Frequency of Tropical Cyclones

In 1940 there were 2 cyclones, but over the last fifty years the number has risen dramatically - a ten-fold rise to 8 in 1960, 18 in 1980 and 21 so far in 1990. These storms have seriously caused erosion to the already extremely limited amount of land we possess. This in turn bears an impact on population growth and pressure on other resources.

Cyclones have also devastated many of our crops and trees. The loss of trees can cause the interruption of the nutrient cycle above and below the soil. The soil loses fertility, plants and animals lose their habitats, and our food and water supplies and our healthy air is also seriously affected.

b. The Water Table

We have not yet installed measuring instruments to test the rise in sea level but we have noted increased salinity in ground water supplies, attesting to intrusion of sea water into the water table. This increased salinity impacts unfavourably on both the supply of drinking water as well as efforts to grow things, - agriculture being already difficult due to harsh soils.

c. Temperature Changes and Rainfall levels

Despite the rise in the number of cyclones, Tuvalu has been experiencing an increasing number of dry spells, with average annual rainfall declining from 420 millimetres per annum at December 1980 to 300 millimetres at December 1988 - a drop of 28.6% in the eight year period. Simultaneously, average daily temperatures have risen by 0.5 degree celsius over the last thirty years.

In light of all the above we entreat this Conference to propose measures which promote urgent and pragmatic actions, rather than having this gathering end up as

Action Being Taken by Tuvalu to Prevent/Mitigate Adverse Climatic Changes

a. Energy

Less than 50% of our total population of 8,309 people have access to electricity but 1.8% of household energy consumption is solar generated. We intend to increase this proportion to 3% by 1993. All electricity in the outer-islands is solar generated.

b. Agriculture

We have embarked on a modest re-afforestation programme whereby, between 1970 and 1987 some 115.3 hectares of land was replanted with coconut trees. Early in 1991 we intend to begin a new tree planting exercise, including coconuts, mangoes and citrus. As a further measure, farmers are actively encouraged to inter-crop coconuts with root crops. Again we consciously utilize natural manure instead of chemical fertilizers and promote biological pest control rather than dangerous pesticides in our agricultural practices.

Assistance Tuvalu Needs to Promote a Healthy Environment

We recognise that much more can and needs to be done. For instance we currently use borrow pits dug out by the U.S. Army during the Second World War to help in the construction of an airfield - to dump our garbage, because of limited land space.

We know there are more environmentally friendly methods of solid waste management, but due to financial and other constraints we cannot access them.

Already the EEC is providing funding in the areas of coastal reclamation and solar energy, while the Australian Government has promised to supply us with equipment to test the rise in sea level. But there has been a rather slow response from donors to our request for rehabilitation assistance for damage caused by the most recent Cyclone Ofa - which occurred in February of this year.

Therefore we urge the developed countries to come to our assistance in designing and implementing a comprehensive environmental strategy. We need assistance in the training of a number of national experts in environment and climatic changes as well as the strengthening of our national capabilities to monitor onsite climatic changes and sea level rise.

Regional and Global Perspective

On a regional perspective, the Pacific Island governments have demonstrated unity on environmental issues where we have perceived outside activities likely to cause damage to the environment and threaten our small islands and fragile ecosystems.

Our opposition to these abuses by others of our environment has led to our undertaking collaborative efforts in a number of areas.

In particular, I refer to the South Pacific Nuclear Free Zone Treaty, the Convention for the Protection of the Environment and Natural Resources of the South Pacific Region which recently came into force, our actions on Driftnet Fishing and our collaboration through the South Pacific Regional Environmental Programme.

We welcome and encourage the participation of other governments in these important areas where our small island countries have already joined together with some of our larger neighbours to protect our common heritage.

Some of our developed partners present here today may be asking themselves what they can do to help countries like Tuvalu withstand this problem. At a Summit between leaders of the South Pacific sovereign nations with President Bush, held at Hawaii on 27 October, the environment and climatic changes were amongst the contentious issues discussed. At one point, President Bush asked - "What can we, the United States do in order to help countries in the South Pacific?" I replied immediately - "Mr President, can I answer that question?" He looked at me and said - "Go ahead". Then I said - "Well, the United States could help countries like Tuvalu in building coastal protection schemes such as those the FEC are already providing us with though we would need more assistance in this area; we would need to build more water catchments. I went on saying: "I am pretty sure I shall be the only Head of a South Pacific Government that will be present at the forthcoming Second World Climatic Conference in Geneva early next month. At that Conference, Ministers will deliberate on Ministerial Declaration which will, inter alia, include provisions for developed countries to cut down their emission rates of greenhouse gases; for developed countries to provide the necessary resources to developing countries to help them establish the required measures and infrastructures which will lessen the impact of the Greenhouse effect." Then I said, "Mr President, I look forward to the support of the United States on this Ministerial Declaration".

On the same token, and in anticipation of a similar question from our developed partners present here today, I will add the following:

- Provide assistance at the regional level to help us strengthen the South Pacific Regional Environmental Programme
- Help us train our nationals in the areas of environment and climatic changes
- Help us to strengthen both at the national and regional levels our capabilities of monitoring and detecting cyclones and other natural disasters in order to allow us prepare in advance
- Help countries in the South Pacific establish a pragmatic and reliable Disaster Preparedness and Rehabilitation Programme.

Ministerial Declaration

I support the Draft Ministerial Declaration presented to us by our experts merely because I consider it a start of an imperative process towards a Framework Convention on Climate. I must admit however that I am not happy with the commitments made by a number of the industrialised countries which has resulted in a weak Declaration. It appears that science has been ignored by a number of decision makers. I would be content if such stance is done on goodwill. But if science is being deliberately ignored, then I will regard such an attitude as one of total selfishness, and inhuman.

The problem we are addressing right now is of a global nature. We need the cooperation and support of all nations in this world. We in Tuvalu, and this goes as well for our sister countries in the Pacific, the Indian Ocean and the Carribean, contribute little or nothing to the problem and yet we will be the first to suffer. Our survival is at stake.

I may come from a poor and small nation but the fact of life is that my country and its people in particular are a distinct race of our earth planet. Like yourselves, we are citizens of the world - our world. We have our own language and culture. We have a God given right to live on earth. We may be small but we have a spot there to maintain in our biosphere. We contribute to the diversity and balance of the earth's ecosystem. It will therefore be an injustice should we in Tuvalu and the island nations, be denied our right to live in our homeland.

The nations of the developed world carry an enormous burden of responsibility. The problem is clear and the options for action are clear. This Conference therefore presents a clear opportunity for effective and speedy action. These countries which have been contributing to the accumulation of greenhouse gases for so long continue to pollute our atmosphere. I say this with no sense of criticism for past actions - indeed the world has only in the past few years realised the problem. At times I feel that this is God's way

of telling us, human beings, to be more responsible in the maintenance of the earth's balanced ecosystem. After all the earth was not created by a human being. And if we do not respond positively to the challenge, then I feel the catastrophe will take place as predicted by science. Such is not at all fair to Tuvalu.

My bigger neighbours in the Pacific - Australia and New Zealand - have been quick to act with decisive national policies. However, the effects of their efforts will not be enough on the global scene. It is up to the large industrialised economies of the world to respond to the clear challenge. Let us all bind ourselves together and pragmatically solve the problem as responsible citizens - brothers and sisters - of the world. We will surely bring about peace and prosperity to all if we join together in addressing the problem.

TABLE 2

EMISSIONS REDUCTIONS EXPECTED IN THE YEAR 2000
DUE TO CURRENT ENVIRONMENTAL COMMITMENTS
AND OTHER INITIATIVES ASSUMED IN THE ANALYSIS

<u>CURRENT COMMITMENTS</u>	<u>MILLIONS OF TONNES REDUCED (Carbon Equivalents) 2000⁴</u>
o TREE INITIATIVE	~9
o DOE ENERGY EFFICIENCY INITIATIVES	28
o DOE APPLIANCE STANDARDS	4
o DOE RENEWABLE INITIATIVES	4
o CLEAN AIR ACT	17
o LANDFILL REGULATION	44
o CFC PHASEOUT & MONTREAL PROTOCOL	551

⁴ Assumes a 100 year time horizon in GWP calculations.

Precise Monitoring of Global Temperature Trends from Satellites

ROY W. SPENCER AND JOHN R. CHRISTY

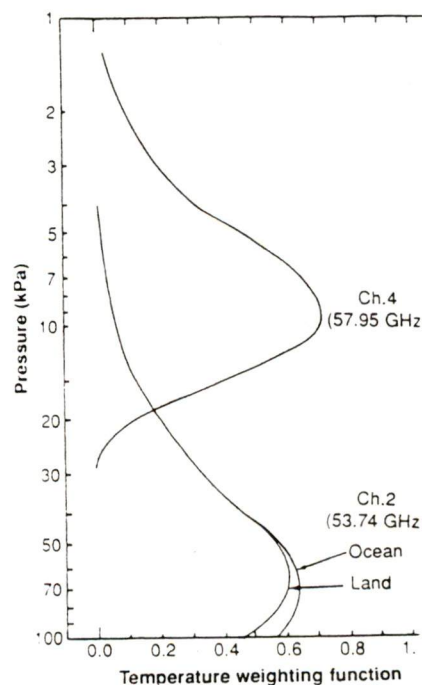
Passive microwave radiometry from satellites provides more precise atmospheric temperature information than that obtained from the relatively sparse distribution of thermometers over the earth's surface. Accurate global atmospheric temperature estimates are needed for detection of possible greenhouse warming, evaluation of computer models of climate change, and for understanding important factors in the climate system. Analysis of the first 10 years (1979 to 1988) of satellite measurements of lower atmospheric temperature changes reveals a monthly precision of 0.01°C , large temperature variability on time scales from weeks to several years, but no obvious trend for the 10-year period. The warmest years, in descending order, were 1987, 1988, 1983, and 1980. The years 1984, 1985, and 1986 were the coolest.

ACCURATE ESTIMATES OF GLOBAL ATMOSPHERIC TEMPERATURES are needed for evaluation of global climate models, detection of climate changes, and a better understanding of the climate system. Global temperatures have generally been estimated from surface temperature records, but there has been much debate regarding, for example, whether these data provide evidence of recent greenhouse warming (1). The primary source of uncertainty is the relatively sparse distribution of thermometers over the surface of the earth. Most of the earth is covered by oceans, and vast oceanic areas go unmeasured. Even over land, the coverage is greatest where the population is greatest; therefore, remote land areas also go unmeasured. An additional problem is that urban sites, which represent only a small part of the globe but where many long-term measurements have been made, have warmed because of heat from man-made structures, and thus these records are difficult to interpret (2, 3). Depending upon how the thermometer data are analyzed, various answers can be expected. In contrast to surface thermometers, sensors on satellite platforms can provide nearly complete earth coverage in as little as one day and can obtain measurements from various levels of the atmosphere. Calibration of satellite sensors is particularly difficult, however. For climate temperature monitoring a precision of 0.1°C is needed, a goal that has been perceived as difficult for any earth viewing radiometer. The difficulty arises from uncertainty about the long-term stability of satellite sensors. In this article, we show that accurate long-term global temperature measurements can be obtained from satellites

now operating and discuss data obtained from 1979 to 1988.

Methodology. In late 1978, a series of passive microwave radiometers was launched aboard the TIROS-N series of National Oceanic and Atmospheric Administration (NOAA) satellites. These radiometers, or microwave sounding units (MSUs), are Dicke-type radiometers designed to measure the thermal emission of radiation by atmospheric O_2 at four frequencies near 60 GHz (4). The atmospheric concentration of O_2 is constant in both space and time (5), and thus O_2 provides a stable temperature tracer. The strong interaction of radiation from 50 to 70 GHz with O_2 through rotational energy transitions causes absorption and emission. As the channel frequency of the MSU approaches the 60-GHz peak in the absorption complex, higher levels in the atmosphere will be measured (Fig. 1) (6). We have analyzed data from MSU channel 2 which measures the temperature of the middle troposphere at 53.74 GHz. At 57.95 GHz, MSU channel 4 can be used to monitor temperatures of the lower stratosphere. MSU channels 1 and 3 are more difficult to interpret for climate purposes because channel 1 is too sensitive to surface effects on the earth and cloud water, whereas channel 3 detects radiation from a strong temperature-transition region between the troposphere and stratosphere (the tropopause). The four channels have traditionally been used to obtain vertical profiles of temperature in remote regions of the earth where weather balloon data are not available. However, because the weighting

Fig. 1. Temperature weighting functions (unitless) for MSU channels 2 (mid-troposphere) and 4 (lower stratosphere). Also shown are the different channel 2 weighting functions for ocean and land surfaces, which arise because the less emissive ocean reflects more of the downwelling atmospheric radiation back upward. Sensitivity to the surface radiation itself cannot be implied from the magnitudes at the intersection of the curves with the surface. [Adapted from (6)]



R. W. Spencer is at Marshall Space Flight Center Huntsville, Code ES43, Huntsville, AL 35812. J. R. Christy is at Johnson Research Center, University of Alabama, Huntsville, AL 35899.

functions for each channel are vertically broad (Fig. 1), retrieval of adequate data on the vertical temperature structure of the atmosphere that are needed for computer modeling of the weather has been difficult. The temperature measurement within a constant-pressure depth, however, rather than at traditionally measured specific pressure levels, is completely adequate, even preferable in some respects, for climate monitoring.

The MSUs are externally calibrated, after each earth scan of the instrument, by measurement of the cosmic background radiation (for our purposes, constant at 2.7 K), and a warm target in the instrument that has its temperature monitored with redundant platinum resistance thermometers. This calibration design is considered to be the best available for microwave radiometers because any temperature changes in the instrument components are canceled out. The earth-viewing measurements are then calculated as a "brightness temperature" (T_b) by interpolation between these two reference extremes. The term "brightness temperature" acknowledges that the temperature measurement is actually based upon radiative brightness and is only equal to a thermometric temperature when the emitting body is completely "black" (nonreflective). This condition is nearly true of measurements of the atmosphere from MSU channel 2.

Satellite intercomparison. Because two MSUs have usually been simultaneously operating on separate satellites, a comparison between them shows how different sensors agree in their measurements and gives an estimate of errors. The NOAA-6 and NOAA-7 MSUs were simultaneously operating during a period of nearly 2 years (29 June 1981 to 16 April 1983). These satellites are in sun-synchronous, near-polar orbits, and have constant local crossing times of 7:30 a.m. and p.m. and 2:30 a.m. and p.m., respectively. The precession rates of their orbits are quite different so that in a single day there are many differences (but also many overlaps) in the areas of the globe sampled by the two satellites. The MSUs scan across the satellite subtrack, and thus paint out swaths of coverage about 2000 km wide beneath the satellites.

We averaged the channel 2 T_b data from the separate satellites at

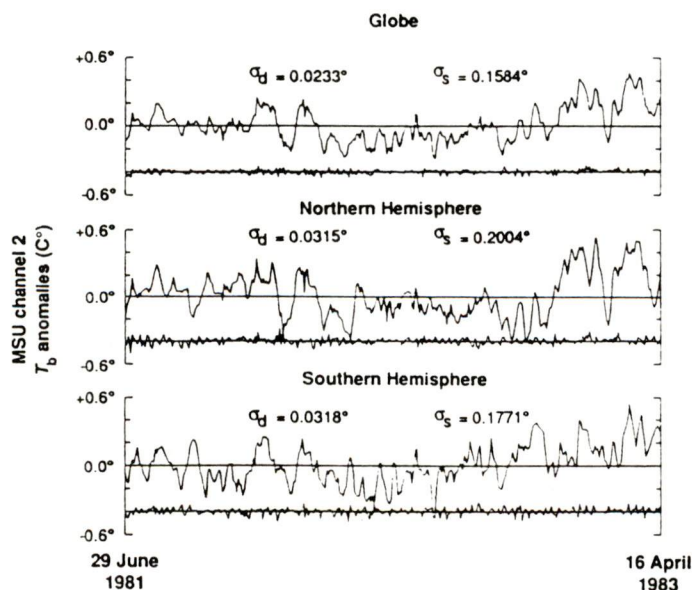


Fig. 2. Comparison between global MSU channel 2 T_b values from NOAA-6 and NOAA-7 during a nearly 2-year period (29 June 1981 to 16 April 1983) when both satellites had MSUs operating. Time series of global and hemispheric satellite averages (sum divided by 2) and differences (difference divided by 2) are shown by the large-variation and small-variation curves, respectively. The difference time series are offset -0.4°C for legibility. The SD of the two-satellite sums (σ_s) and differences (σ_d) are also listed.

2-day intervals over both the Northern and Southern hemispheres in 2.5° -latitude bands with cosine-latitude weighting to account for the decrease in surface area of these bands toward the poles. We reduced contamination of the measurements by large thunderstorm complexes, which cause infrequent depressions in T_b over small areas (6, 7), by excluding any scan lines that had individual footprint measurements that deviated by more than 1.5°C from their average relationship to both neighboring footprint measurements. The resulting variations in the 2-day averages are dominated by the seasonal change of temperature (8), termed the annual cycle. This annual cycle is sinusoidal in shape, and a smoothed cycle was computed for each satellite individually. Then this cycle was subtracted from the original 2-day time series to arrive at the anomalies in temperature, that is, the temperature deviations from the average temperature for a particular time of year. A period of data considerably longer than 2 years is necessary for a more representative annual cycle (and thus, more representative anomalies), but the short-term data are utilized only for satellite intercomparison. Several revealing observations can be made from the data (Fig. 2):

1) The standard deviation (SD) of the sums of the data from the two satellites is much larger than the SD of their differences. This relation means that both satellites were measuring nearly the same temperature variations and implies that hemispheric temperature anomalies can be measured with relatively little error from a single satellite. The 2-day average difference between these satellites was about 0.05°C , and for monthly averages, the difference improved to about 0.011°C . Similar noise was found in monthly comparisons between data acquired from sensors on (i) TIROS-N and NOAA-6 (0.012°C), (ii) NOAA-7 and NOAA-9 (0.012°C), (iii) NOAA-9 and NOAA-10 (0.006°C), and (iv) NOAA-10 and NOAA-11 (0.008°C), although much shorter overlap periods were available. Thus, we estimate that the precision of monthly satellite measure-

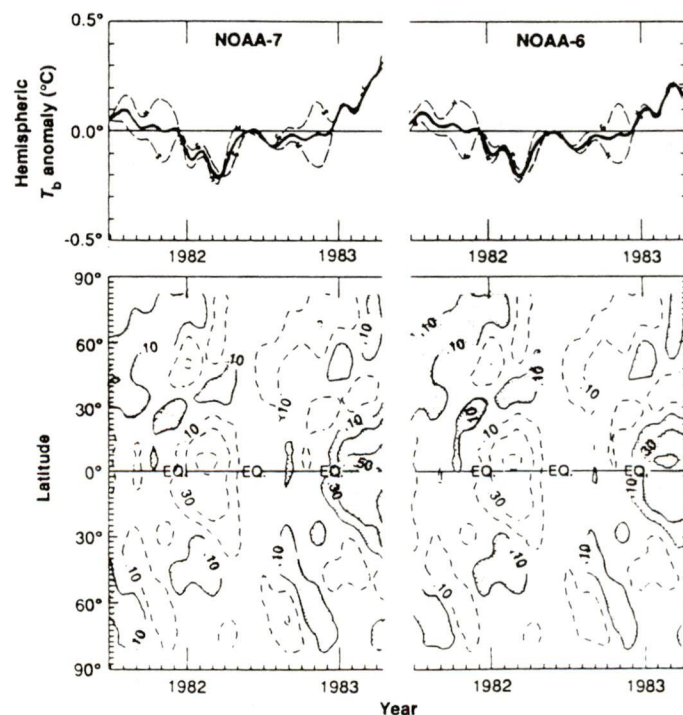


Fig. 3. Low-pass filtered hemispheric (top) and zonally averaged (bottom) MSU channel 2 T_b anomalies during the 2-year overlap period of NOAA-6 (right) and NOAA-7 (left); "N" and "S" labels represent Northern and Southern hemispheres, respectively, and the global time series is the heavy line. The time series do not agree near the beginning and end of the period because of the low-pass filter and the lack of data past the end of the period for NOAA-6 or before the beginning of the period for NOAA-7. Warm zonally averaged anomalies are stippled.

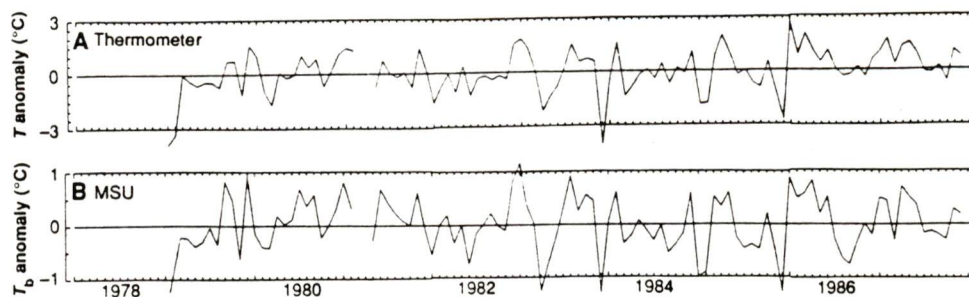
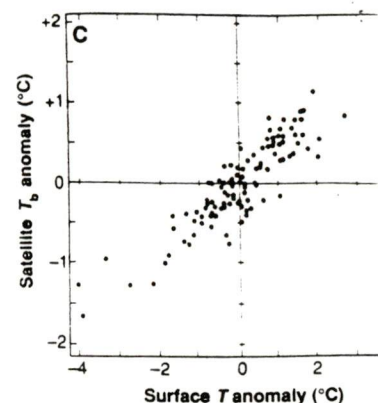


Fig. 4. Time series of monthly U.S. surface air temperature anomalies (A) and MSU channel 2 T_b anomalies (B) for the period 1979 to 1987. Their scatterplot (C) has a correlation coefficient (r) of 0.89, and an explained variance (r^2) of 79 percent. March and April 1981 satellite anomalies are not included because of a high percentage of missing data.



ments is about $\pm 0.01^\circ\text{C}$ for the globe.

2) The sums of the two sets of data reveal that dramatic globally averaged warming and cooling events of greater than 0.5°C can occur in less than 2 weeks. The warmings, representing huge energy exchanges, are possibly associated with stormy periods when large amounts of latent heat were released in precipitation of moisture previously evaporated from the sun-warmed ocean. The coolings might be from formation of widespread low-level cloudiness, which reflects significant amounts of incoming solar radiation.

3) The long-term drift of one instrument relative to the other, seen in the difference time series in Fig. 2, is so small that it is virtually unmeasurable. Any trend is less than $\pm 0.01^\circ\text{C}$ for the 2-year period. This high degree of stability was unexpected. The four other satellite overlaps mentioned above also gave no indication of drift.

Further evidence that the measurements were repeatable is shown by low-pass filtered (9) time series of hemispheric (and global) temperature anomalies from NOAA-7 and NOAA-6 data and the zonally averaged distribution of those anomalies (Fig. 3). The zonal averages allow examination of which latitude bands of the earth were responsible for the warm or cool events seen in the hemispheric and global time series. The zonal average patterns are nearly identical between satellites. Such agreement improves our confidence that even regional areas can be studied to find the origins of the hemispheric anomalies.

Comparisons with United States and global thermometer measurements. Although the above results indicate that the sampling provided by a single satellite is geographically extensive and that the measurements are radiometrically stable enough to be useful for monitoring climate, it still must be demonstrated that MSU measurements are closely related to temperature. Earlier investiga-

tors have made point comparisons between weather balloon data and satellite measurements (10–12). The differences between individual radiosonde and satellite measurements are generally less than 1.0°C . These differences are usually attributed to (i) the isolated balloon sampling compared to the large area represented by a single satellite measurement (a circular footprint 110 km in diameter); (ii) errors in calibration of the balloon thermometer before its release (iii) the random noise of a single MSU measurement, about 0.3°C and (iv) time mismatches between the satellite and balloon observations. We compared the 1980 through 1988 MSU observations to T_b data obtained from radiosondes launched twice daily by 60 National Weather Service offices around the United States. The T_b data were calculated with the radiative transfer equation for MSU channel 2, and thus the radiosondes had to reach a fairly high pressure altitude, 2 kPa or less. Only MSU data within 200 km of the radiosonde location and within 3 hours of its release time were included. The comparisons revealed that there were biases of up to $\pm 1^\circ\text{C}$ between the two data sets; the biases are most easily related to the difference in time between the release time of the radiosonde (all simultaneous at 00 and 12 GMT) and the MSU observation times, which are sun synchronous. After correction for these biases on a station-by-station basis, we found no long-term trend in the 9 years of differences between MSU and radiosonde-calculated T_b values and a monthly SD of 0.068°C .

The MSU data also can be compared to records of temperature variability from near-surface thermometers. Even though they are different variables, their common variability helps to assess how well coupled the near-surface temperature variations are to the deep layer variations. Although the global distribution of thermometers is suspected by many researchers as being inadequate for accurate monitoring, the distribution over the United States is widely

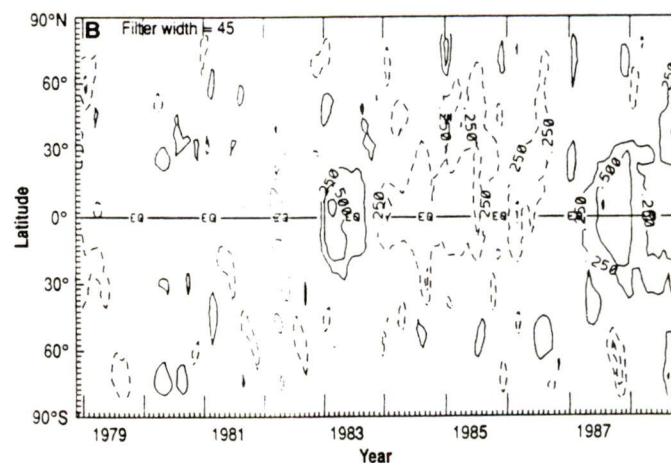
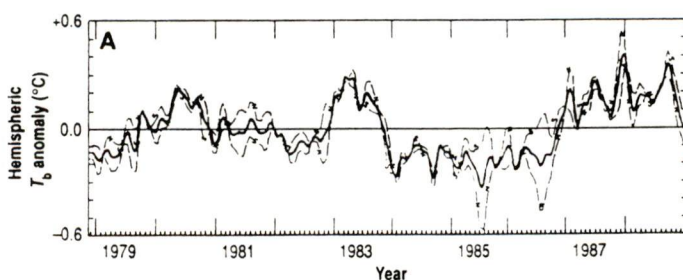


Fig. 5. Hemispheric anomalies (A) and zonally averaged anomalies (B) about the average annual cycle of MSU channel 2 T_b values for the 10-year period 1979 through 1988; "S" and "N" refer to Southern and Northern hemispheres, respectively; the global time series is in a heavy line. Zonal anomalies are contoured every 0.25° ; positive anomalies (warm) are solid and negative ones (cool) are dashed.

accepted as good enough for climate work. We compared monthly temperature anomalies from thermometers over the contiguous United States for the period 1979 through 1987 (13) to our monthly mid-tropospheric temperature anomalies from the satellites. The resulting anomaly time series (Fig. 4, A and B) are similar, as verified by a scatterplot (Fig. 4B) and a correlation coefficient of 0.89. This correlation agrees with those between radiosonde near-surface and upper air measurements, for which monthly temperature anomalies range from 0.8 for the eastern United States to greater than 0.9 for the western United States. The surface anomalies are typically two to three times as great as the MSU anomalies. This relation is probably a result of daytime solar heating and nighttime cooling of the surface, which largely control the deeper air mass temperatures over the United States on monthly and seasonal time scales.

Two major research groups have been responsible for hemispheric calculations of temperature anomalies from thermometer measurements, and we refer to them by their leading authors names: Jones (14, 15, 16) and Hansen (17). Their results have been sufficiently different to spark debate in the climate community and have led to conflicting reports in the popular press regarding global temperature trends. We have compared our satellite-measured hemispheric anomalies to the thermometer-based anomalies from these two groups (Table 1). Again, when the separate systems are viewed as a bivariate distribution in which we wish to determine the level of common variability, these comparisons reveal that the level of

agreement between the calculations by Jones and the satellite data is about 40% better than that between the calculations by Hansen and the satellite data. As might be expected for two land-dominated data sets, the Jones and Hansen data are much better correlated with each other, with an explained variance of 94%, than either is with the MSU data. The much lower explained variances for the hemispheres and globe (Table 1) compared to the United States are the result of both poor thermometer coverage over much of the earth and weak thermal coupling between the middle and lower troposphere over much of the oceans. This latter effect was deduced from radiosonde near-surface and deep layer temperature comparisons: When monthly surface temperature anomalies from radiosonde are compared to the corresponding radiosonde-calculated channel 2 anomalies for United States-controlled ocean stations, the explained variances drops to about 35% for the Caribbean, 0 to 20% for the tropical Pacific, and 25% for the tropical south Atlantic. Although there are few high-latitude ocean radiosonde stations, the data suggest that the thermal coupling increases poleward (for example, 52% in Iceland), probably because of the wider range of air mass temperatures encountered there. Thus we would **not expect as good agreement between MSU anomalies and tropical ocean surface air temperature anomalies as are obtained over land**, even if the oceanic thermometer coverage were adequate. This conclusion is substantiated by the somewhat poorer agreement between the satellite data and combined thermometer and sea surface temperature data from

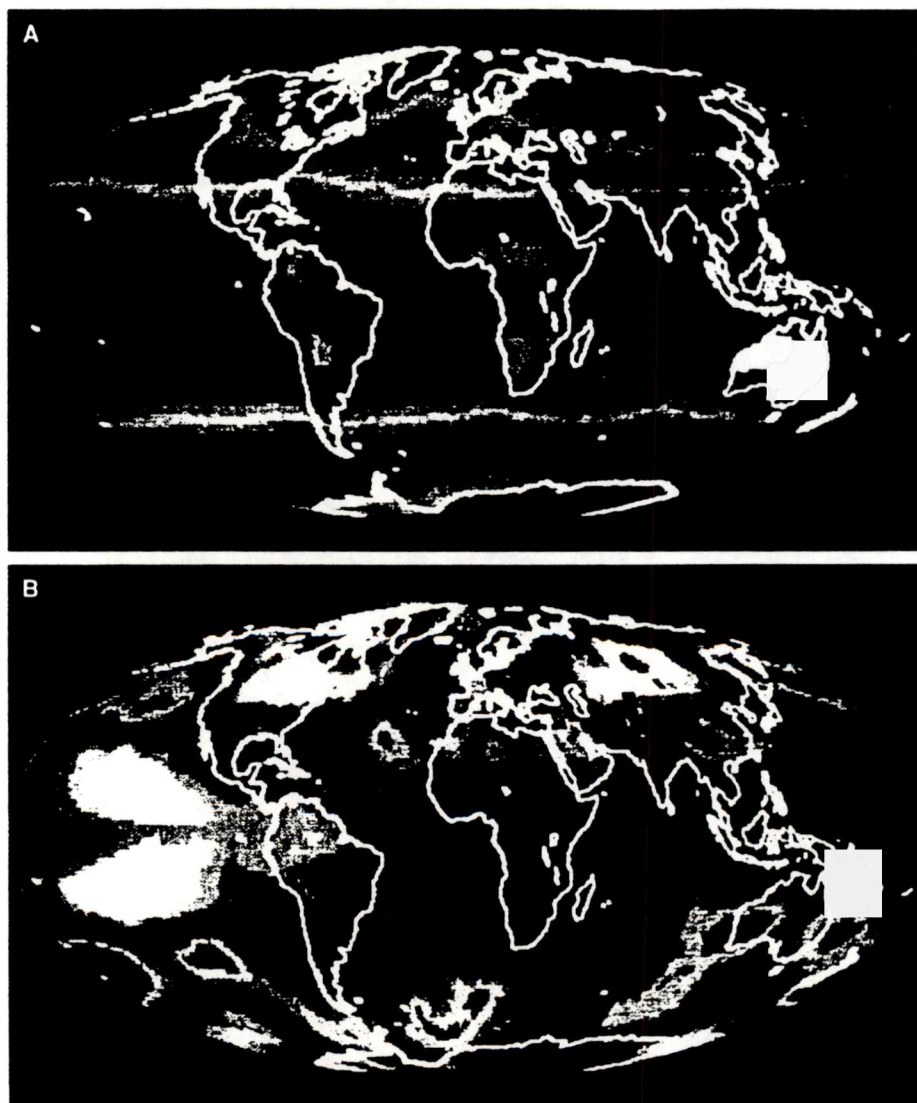


Fig. 6. Average MSU channel 2 T_b (A) during the 10-day period 26 January to 5 February and temperature anomalies (B) for the same 10-day period during the 1983 ENSO climate anomaly. Temperatures range in top image is gray, representing 235 K, to red, representing 260 K, in 1 K increments; temperature anomalies in bottom image change color every 0.25 K, the blue side of dark gray is colder, red side is warmer.

Table 1. Monthly and annual explained variances (in percent) between MSU and thermometer-measured temperature anomalies for United States (U.S.), Northern (NH) and Southern (SH) hemispheres, and the globe from 1979 to 1988. Thermometer-based calculations for the United States are from Karl (13); monthly and annual hemispheric and global thermometer anomalies are from Jones (14–16); annual anomalies are from Hansen and Lebedeff (17), and hemispheric and global anomalies, which also include sea surface temperatures, are from Farmer *et al.* (18).

Source	U.S.	NH	SH	Globe
<i>Monthly</i>				
Karl	77			
Jones		33	10	35
Farmer		26	11	28
<i>Annual</i>				
Karl	77			
Hansen		67	27	53
Jones		72	66	74
Farmer		77	24	69

Farmer *et al.* (18) (Table 1). The poor agreement raises the important issue of whether near-surface temperatures or deep layer temperatures should be monitored for detection of climate change. Because they are often different from one another over the tropical oceans, it would be best to monitor both in order to gain an understanding of how the entire troposphere behaves. Indeed, it might well be that the oceanic surface air layer is so strongly coupled to sea surface temperature variations that a deep layer mean would provide an earlier signal of possible greenhouse warming.

Global temperature anomalies 1979 to 1988. The first 10 years of satellite data reveal large fluctuations in the hemispheric and global temperatures (Fig. 5A). The Northern and Southern hemispheres trends follow each other for the slower, interannual trends, but often oppose each other on monthly to seasonal time scales. The warmest years, in decreasing order, were 1987, 1988, 1983, and 1980. There is no obvious long-term trend, and anomalies during the first 5 years nearly balance those during the last 5 years. The 1988 warm event was traced to the mid-latitudes, as was the 1980 warm anomaly. Both years included summer heat waves in the United States. The largest warm anomaly in the Northern Hemisphere for the 10-year record occurred in 1987 and 1988 (Fig. 5B). The 1987 and 1983 warm events were associated with El Niño/Southern Oscillation events [ENSOs (19)]. During the 1983 ENSO, transfer of heat from record-setting sea surface temperatures in the eastern Pacific to the atmosphere caused major changes in atmospheric flow that impacted weather conditions worldwide. Warming locally exceeded 2°C in two Pacific anticyclones (Fig. 6) that straddled an equatorial zone of intense convective activity caused by the warm water. This event caused globally averaged temperatures to rise more in several months than what is expected within several decades if enhanced greenhouse warming is occurring. Although the 1987 ENSO has been considered weaker than the 1983 ENSO, it was associated with higher temperatures that were more uniformly spread throughout the tropics. The mid-latitudes in both the Southern and Northern hemispheres in 1988 experienced warm conditions that appear to be coupled to the 1987 tropical warmth. The period 1984 to 1986 was dominated by cooler than normal tropical air. The 10-year time series exhibits bifurcation in that there are nine cool or warm years, and only one year (1981)

that could be considered "average." This pattern makes the definition of what is "normal" for global temperatures uncertain, for a shown above normal can mean either warm or cool conditions.

The future. Our data suggest that high-precision atmospheric temperature monitoring is possible from satellite microwave radiometers. Because of their demonstrated stability and the global coverage they provide, these radiometers should be made the standard for the monitoring of global atmospheric temperature anomalies since 1979. Their use will allow relatively precise monthly determinations of the locations and magnitudes of temperature change events. The resulting data should provide a greater focus of scientific debate on why temperature anomalies occur rather than whether they occur. The advanced microwave sounding unit (AMSU) will replace the MSU on NOAA satellites in the mid 1990s, and these units will allow extension of the time series into the next century. Various computerized climate models, which predict future changes through time-dependent equations representing physical processes, can now be evaluated with accurate global temperature measurements. These data should result in improved specification of processes in these models, which still require independent verification. These improvements should facilitate more informed policy decisions concerning the effects of anthropogenic greenhouse gas production.

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8. Other, smaller signals are also present in the measurements. These include a small surface temperature contribution (8 percent of the total over land, 4 percent over the ocean), wind-induced roughening of the ocean surface, cloud liquid water effects, water vapor variations, sea surface temperature changes, and soil moisture changes. The effects of variations in each of these parameters on the measured 7 values have been theoretically evaluated, and have been determined to be small for MSU channel 2 (0.01°C or less) on a hemispheric and global basis. Larger effects could conceivably occur over small regions. In contrast, MSU channel 4 is essentially unaffected by any of these changes. The radiative transfer theory involved in the analysis of these effects is covered in (6).
9. Low-pass filtering of the time series allows isolation of the more slowly varying temperature variations that are of interest to climatologists. Here, the filter retains 50 percent of the power of cycles having 90-day periods, progressively less power of periods shorter than 90 days, and more power of longer periods.
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20. R. Jenne and D. Joseph provided the MSU data used in this study; R. Ho provided data processing and programming support; N. Grody collaborated portions of this research and provided general advice; F. Wentz provided updated sea surface emissivity estimates; P. Olsen, F. Soltis, and P. Swanson assisted us obtaining technical data on the MSU; G. Wilson helped obtain the satellite datasets; discussions with J. Dodge and R. McNider led to the present research.

27 October 1989; accepted 23 February 1990

Withdrawal/Redaction Sheet

(George Bush Library)

Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
08a. Memo	From Andy Card to John Sununu Re: Memo from Bromley (1 pp.)	12/22/90	P-2 , P-5	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff to the President, Office of the
Series: Sununu, John, Files
Subseries: White House Offices File
WHORM Cat.:
File Location: Science & Technology
 (Bromley) (1991) [5]

Open on Expiration of PRA
 (Document Follows)
 By JP (NLGB) on 10/28/05

Date Closed:	12/29/2004	OA/ID Number:	29184-005
FOIA/SYS Case #:	1998-0004-F[2]	Appeal Case #:	
Re-review Case #:	2005-0426-S	Appeal Disposition:	
P-2/P-5 Review Case #:		Disposition Date:	
AR Case #:		MR Case #:	
AR Disposition:		MR Disposition:	
AR Disposition Date:		MR Disposition Date:	

RESTRICTION CODES

Presidential Records Act - [44 U.S.C. 2204(a)]

P-1 National Security Classified Information [(a)(1) of the PRA]
 P-2 Relating to the appointment to Federal office [(a)(2) of the PRA]
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THE WHITE HOUSE
WASHINGTON

Date: 12/22/90

THE CHIEF of STAFF
has seen

FOR: *Gov. Sumner*

FROM: ANDREW H. CARD, Jr. *Andy*

☐ Action

☒ Your Comment

☐ Let's Talk

☐ FYI

*Bromley wants to
have Buff Bohlen and
Bob Reinstein appointed consistent
with the State Department.*

Withdrawal/Redaction Sheet

(George Bush Library)

Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
08b. Memo	From D. Allan Bromley to John Sununu Re: Negotiator for Framework Global Climate Change Convention [FOIA RESTRICTIONS REDACTED] (2 pp.)	12/19/90	P5 , (b)(6)	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff to the President, Office of the
Series: Sununu, John, Files
Subseries: White House Offices File
WHORM Cat.:
File Location: Science & Technology
 (Bromley) (1991) [5]

Document Partially Declassified
(Copy of Document Follows)
 By JP (NLGB) on 10/28/05

Date Closed:	12/29/2004	OA/ID Number:	29184-005
FOIA/SYS Case #:	1998-0004-F[2]	Appeal Case #:	
Re-review Case #:	2005-0426-S	Appeal Disposition:	
P-2/P-5 Review Case #:		Disposition Date:	
AR Case #:		MR Case #:	
AR Disposition:		MR Disposition:	
AR Disposition Date:		MR Disposition Date:	

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THE WHITE HOUSE
WASHINGTON

AC - INFO

December 19, 1990

MEMORANDUM FOR JOHN H. SUNUNU

FROM:

D. ALLAN BROMLEY
EDE HOLIDAY

SUBJECT:

NEGOTIATOR FOR FRAMEWORK GLOBAL CLIMATE
CHANGE CONVENTION

At a meeting in your office in August to review the Fall agenda in the global climate change area, we discussed the issue of the appropriate level of negotiator for the framework convention deliberations that were then expected to begin early in 1991. Several options were presented, but it was decided to defer any final decision on the issue until closer to the actual negotiations.

With the negotiations set to begin on February 4 in nearby Chantilly, Virginia, a decision is now timely. State has recommended and is prepared to proceed with the designation of Curtis "Buff" Bohlen, Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs (OES), as chairman of the U.S. delegation. Bob Reinstein, the Deputy Assistant Secretary for OES, would be designated vice-chairman of the delegation and would shoulder the principal negotiating responsibilities. You will recall that Bohlen and Reinstein are the respective successors to Fred Bernthal and Bill Nitze. Bohlen has recently led delegations to the first preparatory meeting in Nairobi for the 1992 Brazil U.N. Conference on Environment and Development and to meetings in Chile on protection of Antarctica's environment. Reinstein did most of the negotiating that led up to the ministerial portion of the Second World Climate Conference (SWCC), when Dr. John Knauss from the National Oceanic and Atmospheric Administration stepped in, and generally has been given significant credit for the reasonable ministerial declaration that ultimately emerged. The recommendation of State for the designation of Bohlen and Reinstein has received Bob Zoellick's attention and approval.

Alternatives to the designation of Bohlen and Reinstein do exist:

(b)(6) A senior official from elsewhere within the federal government could be designated. This individual would conduct the negotiations with technical support from State and the other appropriate federal agencies. One possible candidate for this role would be [REDACTED] who has experience in global climate change issues from his role at the SWCC and at the Bergen Conference earlier this year and who performed quite capably in both of those fora.

Bohlen and another senior government official could be designated as the co-chairs of the delegation and share the negotiating responsibility. This would ensure that a State Department official is tasked with overseeing the technical aspects of preparations and the work that must be performed between negotiating sessions. The naming of a co-chair might give emphasis to other aspects of the issue, such as science or economics.

An individual from outside the government could be designated and given special ambassador or similar rank. This individual would be supported by State and the other agencies or a separate office and staff could be established (or some combination of the two pursued). No names immediately come to mind, and it may be difficult to recruit someone to assume this role so close to the framework convention meeting and to obtain the needed eighteen-month commitment (the time it is anticipated it would take before a framework convention is signed).

State notes that the designation of Bohlen and Reinstein is consistent with the traditional approach of the department to international environmental negotiations since they hold positions comparable to the designated representatives from other countries. State argues that the designation of a more senior government official or an individual from outside the government would only heighten expectations and add extra pressure on the U.S., raise the overall visibility of the negotiations and--especially if someone from the government were brought in--more closely tie the White House to the process.

State has not advised of any critical date by which the designation must be made and an announcement through cables made. We have requested that no action be taken pending review of the question by the White House.

Our recommendation would be to accept the State Department offer to designate Bohlen and Reinstein, as outlined above.

We also request that you focus on the possibility of designating a special ambassador for the 1992 U. N. Conference on Environment and Development in Brazil, at your earliest convenience.

We would appreciate your thoughts on how we should proceed.

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Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
09. Memo	From D. Allan Bromley to Richard Darman Re: Science Education and University Research Infrastructure (2 pp.)	12/21/90	P5	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff to the President, Office of the
Series: Sununu, John, Files
Subseries: White House Offices File
WHORM Cat.:
File Location: Science & Technology
 (Bromley) (1991) [5]

**Open on Expiration of PRA
 (Document Follows)**
 By JP (NLGB) on 10/28/05

Date Closed:	12/29/2004	OA/ID Number:	29184-005
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Re-review Case #:	2005-0426-S	Appeal Disposition:	
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EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

December 21, 1990

MEMORANDUM FOR RICHARD DARMAN

FROM: D. ALLAN BROMLEY 
SUBJECT: SCIENCE EDUCATION AND UNIVERSITY RESEARCH
INFRASTRUCTURE

Following up on our earlier discussions, I am pleased to attach a discussion draft of a possible Administration initiative on Science Education and University Research Infrastructure. The discussion draft is based on some analysis and suggestions requested by John Sununu.

The focus of this potential initiative is on renewing the university infrastructure in our country. The attached draft explores the relationship of this renewal effort to excellence in undergraduate mathematics and science education and to the university role in upgrading the quality of precollege teachers in these fields. Ties to economic growth are also noted.

This potential initiative provides a real opportunity to blunt effectively Congressional attempts to obtain more academic science pork. First, it provides an answer to those in Congress and the universities who say they earmark only because competitive programs are not available. Second, the initiative is structured to provide substantial merit-based resources to institutions in states that are not currently major recipients of Federal R&D funds. Third, the emphasis on universities' role in dealing with the crisis of poorly prepared mathematics and science teachers at the pre-college level will be attractive to many of those in Congress involved with earmarking.

Depending on which option is selected, the annual cost of such an initiative could be as much as \$800 million. These resources would have to come from existing resources, such as current Congressional earmarks for R&D and R&D facilities; rescheduling or rescaling one or more of the so-called "megaprojects" in the basic sciences; and shifting some of the science education base, following the extensive review of such programs now under way by Admiral Watkins' FCCSET Committee. The FY 1991 budget approved by Congress, for example, contains over \$275 million earmarked for facilities at academic institutions only - a real misuse of scarce resources. This figure of \$275 million is from an excellent analysis of FY 1991 Congressional earmarking for R&D items including these academic facilities. A copy of the analysis is attached along with a summary memorandum to John Sununu.

Richard Darman
December 21, 1990
Page two

Congress, of course, must agree to cease earmarking for R&D if we are to take credit for these savings. There may be several approaches to getting Congressional agreement, involving recisions and deferrals of earmarked projects as well as sections in authorizations or appropriations for NSF or other R&D agencies prohibiting support by those agencies of universities that receive pork. Such an agreement might well be attainable in the context of the proposed initiative, which would be a substantial carrot for most Congressional districts. You are clearly much more knowledgeable in these areas than am I.

I send you this outline as a follow-up to our discussion at your Director's Review; I understand that you are not sympathetic to the university position on the reasonable grounds that they got themselves into it -- but we as a nation do have a serious problem for the future. I would very much welcome any thoughts or suggestions these notes may trigger as to how best we should attack the problem.

With all best wishes for the holiday season and the new year.

DISCUSSION DRAFT

An Administration Initiative on

SCIENCE EDUCATION AND UNIVERSITY RESEARCH INFRASTRUCTURE

U.S. economic growth increasingly depends on the nation's technological resources. The human resources that support these technological resources must be nurtured at the graduate, undergraduate and precollege levels if we, as a nation, are to remain competitive with our major trading partners. A cornerstone of the efforts to nurture education and to improve economic growth is sustained academic excellence of our colleges and universities.

The Administration initiative outlined below serves to reexamine the relationships that have evolved between the Federal and State governments, the universities, and the private sector. It is aimed at:

- o preserving U.S. leadership in graduate science and engineering education and research,
- o upgrading undergraduate mathematics and science education, and
- o addressing some very high priorities in K-12 mathematics and science education.

It also reasserts Presidential leadership in these crucial areas at a time of growing, aggressive congressional attention. Depending on the options selected, the initiative can be budget neutral.

Technology and Economic Growth

Technological progress plays a central role in economic growth. This progress, in turn, depends on a supply of educated professionals in mathematics, science, and engineering and a scientifically and mathematically literate workforce. Two recent Bush Administration reports, the February 1990 Economic Report of the President and the September 1990 U.S. Technology Policy, emphasize these points. The February 1989 Administration document, Building a Better America, also focuses on the importance of these investments in America's future.

The attached page proofs of an article by University of Pennsylvania Professor Edwin Mansfield contain some of the first comprehensive evidence of the role of academic research in industrial innovation. Mansfield's findings suggest that about one-tenth of the new products and processes commercialized during 1975-85 in seven industries could not have been developed (without substantial delay) without recent academic research.

His estimate of the social rate of return from academic research during 1975-78 is 28 percent, based on crude but conservative calculations.

U.S. Science Education

In the United States, our graduate education system in mathematics, science, and engineering is, without doubt, the best in the world. It attracts the best students and researchers from all over the world. We must preserve this leadership.

The quality of our undergraduate education in these areas is much more variable than that found in most other countries. We have peaks of excellence and valleys of mediocrity, but on average we are competitive; however, we do need to improve weaker institutions.

Precollege education in the United States -- especially in mathematics and science -- is scandalous. International comparisons of educational achievement in these subjects place American students near or at the bottom compared to other industrialized nations. This situation must be improved.

The challenge to the nation and the Bush Administration is to fix that part of our educational system that is broken and preserve excellence where it exists.

Precollege education is predominantly a non-Federal government responsibility. The Administration has done an excellent job of developing broad policy and shaping a climate for reform of our K-12 system. The President and the Governors have enunciated National Education Goals, and White House leadership has taken us well along the path toward educational reform that will be necessary for their attainment.

We have also made significant progress in developing a coherent Federal approach to mathematics and science education. A committee of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), chaired by Admiral James Watkins, was asked to review all existing Federal agency-supported programs in the area of mathematics and science education, with the intent of providing greater coordination and efficiency among disparate Federal programs. In the process of doing this interagency cross-cutting evaluation, the Committee has taken the President's and Governors' goals and developed a National Education Priority Framework for the Federal government, with specific strategic objectives and implementation priorities. The highest priorities relate to teacher competence and to curriculum and organizational reforms. These priorities have provided a template for a 16-agency Federal program for FY 1992, to be submitted to Congress, at its request, with the FY 1992 budget.

Colleges and universities have a clear and apparent role in graduate and undergraduate education. They also influence K-12 education in crucial ways.

The question is how we should position Federal support of science in universities in order to best preserve our lead in graduate education, improve our undergraduate instruction, and assist in fixing our K-12 problems.

BACKGROUND

Since the end of the Second World War, the United States has perpetuated a myth that the Federal government supports research in universities but does not support science and engineering education at the graduate level. In reality, generations of graduate students in all fields have been supported as research assistants on Federal grants and contracts throughout their graduate education program. The present initiative would move us away from that myth ever so slightly. It also provides an opportunity to require that the universities plan, in return for the support provided by the initiative, steps they would take to bring university costs, and bureaucracies, under control so as to stabilize and perhaps even reduce tuition costs at the undergraduate and graduate levels.

During the post-Sputnik years, into the late 1960's, support for universities grew rapidly. U.S. universities developed patterns of facility construction and faculty expansion with large out-year mortgages for facility maintenance and faculty salaries. When these Federal crash programs terminated in the late 1960's, the universities responded by deferring maintenance, modernization, and investment in new capital instrumentation in order to protect their most valuable resource -- their faculties. This response effectively froze out many young scientists and engineers who wished to have academic careers.

The faculty situation is self-correcting, and faculty tenured in the 1960's are now retiring to make room for the young. The facilities (infrastructure) problem, however, has continued to grow. It is very real.

It might be argued that this unfortunate situation is a direct consequence of university mismanagement. We are, nevertheless, faced with the reality that unless this infrastructure problem is solved, we shall, in the future, be unable to look to these universities for both new knowledge and the trained scientists and engineers needed for our economic growth and national security and which we, unique among the developed nations, demand of our research universities.

In the absence of Federal initiatives to deal with the problem over the last two decades, universities have gone to the Congress one by one. Earmarking by Congress for research and facilities has greatly increased, as reflected in the attached study by Willis Shapley on the FY 1991 appropriations. The challenge we face is to channel funds currently earmarked for "pork" projects into competitive, merit-based programs that will strengthen America's educational infrastructure and technological resources.

Though some may say that such a catch-up program for U.S. university infrastructure would reward earlier mismanagement, the fact is that such an effort is necessary if our universities are to meet the unparalleled demands our nation places on them. We must, in some way, restore U.S. university infrastructure to acceptable levels.

Excellence in graduate education and research directly and indirectly affects the quality of undergraduate and precollege education in the sciences and mathematics. In particular, excellence in undergraduate instruction is usually found to be associated with excellence in research, although the character of this research need not be the most expensive. This coupling of research and education has been enhanced substantially in recent years by the Experimental Program to Stimulate Competitive Research (EPSCoR), a merit-based, cost-shared program at the National Science Foundation targeting 17 states that receive relatively little Federal research funding.

Students in this country seek their undergraduate education relatively close to home, as demonstrated in the following table:

	<u>Percent</u>	
<u>Distance, one way</u>	<u>1988</u>	<u>1989</u>
10 miles or less	18.1	17.2
11 to 50 miles	26.8	26.8
51 to 100 miles	14.7	15.9
101 to 500 miles	29.3	29.7
more than 500 miles	11.2	10.4
TOTAL	100.0	100.0
50 miles or less	44.9	44.0

In order to assure an opportunity for an excellent college education for all Americans, academic research of good quality needs to be available on a widely distributed geographic basis. Now, through earmarking of Federal research and facilities funds, we are faced with a process that is not based on merit, is not competitive, and does not necessarily correlate with national priorities. There is a need for a substantial program that will assure better geographical distribution of research funds in support of excellence in university science education. Such a program, however, must be based on a merit-based selection process within overall program parameters.

We also face substantial movement in national attitudes toward teacher preparation and certification. In 1986, a Carnegie Forum on Education and the Economy report recommended that states abandon the baccalaureate degree in education and that teachers in mathematics and science should have majors in their disciplines. This recommendation, not unexpectedly, has received substantial support in the scientific community. Reasons for this are several, including the need for strong subject-matter mastery by teachers preparing students for post-high school study, and the widespread feeling that teaching in the sciences must attract students with higher levels of academic standing than is typical of education majors.

There is now a receptivity in universities to adjust curricula for teachers. Coincidentally, university science faculty now better recognize the magnitude of the precollege education problem and are enthusiastic about becoming a part of the solution. The time is right for movement in this area with development of curricula, subject-matter certification alternatives, and demonstration programs involving university science departments.

This proposed effort complements other efforts of the Administration towards achievement of the National Education Goals. It should be emphasized that the K-12 problem is predominantly a state and local responsibility. At the Federal level, the mathematics and science aspects of the K-12 problem are being addressed by Admiral Watkins' interagency Committee on Education and Human Resources. That effort would be on a parallel track with this one. Taken together, the two efforts would constitute a comprehensive Administration mathematics, science, and engineering educational and facilities initiative.

GOALS OF INITIATIVE

Graduate Education. We still set world standards in graduate education in mathematics, science, and engineering. Our support structure is fundamentally sound, although we face many tough decisions on individual programs and projects. However, the research universities have deferred renovating and building research facilities for at least two decades.

According to a new NSF study, we have accumulated a facilities backlog of approximately \$12 billion.

- o **Goal: Retain our position of world leadership in graduate education in science, mathematics, and engineering.**

Excellence in graduate education in mathematics and science is not enough if our nation is to be a world leader in the 21st century. For example, about half of our doctorates in engineering and physics are now granted to foreign citizens. Clearly, there are failures in our undergraduate and K-12 education programs.

Undergraduate Education. Because almost 50% of American freshman enter a college or university within 50 miles of their homes, there is a need for excellent undergraduate institutions in all parts of the country. In science and engineering, this means providing modest research support, such as that found in EPSCoR. Without at least a modest base of high-quality research, teaching falters. At the same time, it should be emphasized that there is no reason whatever to support less-than-excellent research anywhere; such research neither contributes to teaching nor to regional economic development.

Education at the undergraduate and graduate levels is becoming increasingly expensive. Concern has been expressed about the accessibility of college and university education. This initiative could address this cost issue by making receipt of program funds conditional on bringing overhead and tuition costs under control. This could also be structured to be consistent with the Administration's developing empowerment policies.

- o **Goal: Make quality undergraduate education in mathematics, science and engineering available to students in all parts of the country.**

K-12 Education. A necessary condition for attaining the National Education Goals as they relate to mathematics and science is a talented teacher corps, well-prepared in the subject matter of their disciplines. Admiral Watkins' Committee on Education and Human Resources of the Federal Coordinating Council for Science, Engineering and Technology has placed its highest priority on teacher education and improvement. The President's Council of Advisors on Science and Technology (PCAST), in their discussion of mathematics and science education with the President on December 14, 1990, emphasized the importance of teacher education and retraining as well. This is particularly important at the high school level.

Adequate training and retraining of our mathematics and science teachers is no small task. For it to be effective, reforms are needed in our teacher education, involving broader participation by senior professors in our universities and a normal preparatory path for teachers that includes undergraduate majors in subjects other than education. There is an opportunity for the Federal Government to catalyze this reform.

- o **Goal: Reorient college and university curricula and teaching so as to provide the best education possible for mathematics and science teachers, especially at the high school level.**

MAJOR ELEMENTS OF THE INITIATIVE

- o **University Infrastructure.** University and college research facilities are in dire straits, with a total accumulated shortfall as high as \$12 billion for both renovation and new construction. Emphasis would be on renovation, to make available modern research facilities that are competitive with those in industry

and in our leading competitors overseas. An emphasis on renovation (as contrasted to new construction) is especially important in this period of limited resources because it provides improved quality for the research environment without fostering increases in the numbers of university-based researchers.

- o University Teaching and Related Research. In order to provide high-quality undergraduate opportunities for mathematics, science, and engineering students in all parts of the country, a merit-based grant program would be instituted. Its aim would be to support good research in highly selected areas in a diversified cross-section of colleges and universities, with excellence in instruction as an important consideration.
- o Reform K-12 Teacher Education and Retraining. A new program to support college and university efforts to reform teacher education and enhancement would be initiated. This implies upgraded teacher education programs, greater participation by senior professors, and substantial increases in the number of subject matter majors in mathematics and science. This effort would be coordinated with, and provide support for, alternative certification efforts in the states.

CHARACTERISTICS OF THE INITIATIVE

- o Policy and Goals Enunciated by the President
- o Interagency Effort
 - Strategy and priorities developed by the technical agencies
 - Interagency funding, management, and coordination
- o Partnership with the States and Private Sector
 - Cost sharing in all three elements
 - Integration with economic development objectives
 - Coordinated with precollege education reform efforts
- o Coupled to Reforms in Facility User Fees and University Indirect Cost Accounting
- o Neutral Budget Impact

\$800 Million/year Federal funding (average);
 \$500 M/year for facilities
 \$200 M/year for targeted research in support
 of educational and economic development
 objectives
 \$100M/year for teacher education reform

- **Budget Offsets**

- \$400M from earmarks
 - \$300M from stretched/rescheduled megaprojects
 - \$100M from mathematics and science education programs

- o **5-year Program**

- No extension beyond 5 years contemplated for facilities effort, since once completed universities and colleges should be expected to manage their activities so that use and amortization fees paid as part of federal overhead payments would enable them to maintain their infrastructure at an acceptable quality level for the indefinite future.
- Review of research and related teaching program in four years to determine success and whether to incorporate into research base.
- No extension beyond 5 years contemplated for precollege teacher education reform effort, assuming the reform process complete.

PROGRAM DETAILS

University Infrastructure Program

This 5-year program would contain a mix of merit-reviewed matching grants and reform of amortization schedules and university accounting practices. The objective would be to place renewal of university facilities on a self-sustaining basis by the end of the 5-year period. Among the requirements of the program could be the following:

- a. At least 50/50 non-Federal matching.
- b. A university commitment that user fees for buildings be sequestered for use exclusively in infrastructure areas rather than as, at present, being added to general fund accounts.
- c. Phased in Federal changes in the building depreciation schedules from 50 to 20 years and equipment and instrumentation depreciation schedules from 15 to 5 years to provide an adequate cash flow so that, following the catch-up enabled by this initiative, the universities could and should be expected to be self-sustaining with respect to infrastructure and instrumentation (excluding major research devices).
- d. A Federal commitment to streamline university reporting and accounting procedures to help reduce university administrative costs.

- e. A commitment by universities and colleges that they manage their bureaucracies such that their overhead rates on federal grants stabilize.
- f. A requirement that universities in applying to this initiative pledge to forego acquisition of infrastructure funding through pork channels.
- g. A commitment by universities and colleges that they take measures to stabilize tuition costs.

OPTIONS

The above discussion suggests several options. On the expenditure side the three elements can be separated, although this results in some loss of synergism and broad political appeal. Some options are

- A. Full program, up to \$800 million/year
- B. Facilities only, up to \$500 million/year
- C. Targeted research, up to \$200 million/year
- D. Some combination of two or more of the above

On the budget offset side, there are also options.

- E. Savings from earmarks, up to half the \$800 million identified for FY 1991
- F. Savings from stretched or rescheduled megaprojects can be up to \$300 million or even more
- G. Reprogramming existing mathematics and science education of up to \$100 million can be expected from the current interagency review of a more than \$1.7 billion base program

IMPLEMENTATION

If this initiative, in any of its variants, meets with approval, the State of the Union message would be a very effective vehicle for its announcement.

Academic research and industrial innovation *

Edwin MANSFIELD

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Final version received January 1990

1. Introduction

The purpose of this study is to estimate the extent to which technological innovations in various industries have been based on recent academic research, and the time lags between the investment in recent academic research projects and the industrial utilization of their findings. Because no attempt (to my knowledge) has been made to estimate the social rate of return from academic research,¹ we also make some rough and tentative estimates of this sort. While the results are subject to many limitations discussed below, they should be of interest to public policy-makers concerned with science and technology, as well as to

economists and others that study the process of technological change.

At the outset, it should be noted that I am concerned primarily with recent academic research—that is, academic research occurring within fifteen years of the commercialization of whatever innovation is being considered.² A great many new products and processes are based on relatively old science that to some extent was due to academic research. In estimating the social rate of return from academic research, I ignore such long-term effects of academic research because they are very difficult to measure, because benefits occurring many years after the relevant investment in research are so heavily discounted,³ and because the effects of relatively old science may not be a reliable guide to the present situation. This, like many other features of my estimation procedure, tends to impart a downward bias to the estimated rate of return.

2. New products and processes based on recent academic research

A random sample of 76 major American firms in seven manufacturing industries—information processing, electrical equipment, chemicals, instru-

¹ Relatively few detailed studies of the contribution of academic research to industrial innovation have been carried out. Most seem to have focused on the drug industry. For example, see Mansfield et al. [15, ch. 8] and Schwartzman [24]. Also, Mushkin [26] estimated social rates of return for biomedical research, much of which is carried out at universities and colleges. In addition, Project Hindsight and the Traces study dealt with about 20 weapons systems and five major innovations, and Gellman [7] provided relevant data bearing on this topic.

² The research on which this paper is based was supported by a grant from the Division of Policy Research and Analysis of the National Science Foundation, which of course is not responsible for the views expressed here. My thanks to Leonard Lederman, who was the first to encourage me to work on this project, and to Edward Denison, Rolf Piekartz, and Eleanor Thomas for helpful comments, and to the 76 firms that provided the basic data used in this paper. A preliminary version of this paper was presented at the National Science Foundation at Economics Day at the University of Pennsylvania, and at the 1988 annual meetings of the American Economic Association.

³ By "recent", we mean recent in relation to the time when the innovation occurs. Some observers, particularly in the drug industry, have argued that 15 years is too short, because it often takes longer than this for academic research to be applied. Our reason for using 15 years is to be very conservative. Results based on other time intervals would, of course, be interesting and valuable.

⁴ For example, a dollar of benefits occurring 20 years hence is worth now only about 3 cents if the interest rate equals 0.20.

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Table 1
Percentage of new products and processes based on recent academic research, seven industries, United States, 1975-85

Industry	Percentage that could not have been developed (without substantial delay) in the absence of recent academic research		Percentage that were developed with very substantial aid from recent academic research	
	Products	Processes	Products	Processes
Information processing	11	11	17	16
Electrical	6	3	3	4
Chemical	4	2	4	4
Instruments	16	2	5	1
Drugs	27	29	17	8
Metals	13	12	9	9
Oil	1	1	1	1
Industry mean *	11	9	8	6

Source: See section 2.

* Unweighted mean of industry figures.

ments, drugs, metals, and oil—was chosen.⁴ This sample accounts for about one-third of these industries' total sales in 1985. Data were obtained from each firm's top R&D executives concerning the proportion of the firm's new products and processes commercialized in 1975-85 that, according to these executives (and their staffs) could not have been developed (without substantial delay) in the absence of academic research carried out within 15 years of the first introduction of the innovation.⁵ As indicated in table 1, about 11 percent of these firms' new products and about 9 percent of their new processes could not have been developed (without substantial delay) in the absence of recent academic research.⁶

The percentage of new products and processes based in this way on recent academic research

seems to be highest in the drug industry (which has an obvious interest in the large amounts of medical, biological, and pharmaceutical research carried out at universities) and lowest in the oil industry. To a considerable extent, these interindustry differences with respect to new products can be explained by differences among firms in R&D intensity. A firm's percentage of new products based in this way on recent academic research seems to be directly related to the percentage of its sales devoted to R&D. Holding R&D intensity constant, interindustry differences are not statisti-

⁵ While our initial requests for information and cooperation were made to the firms' chairmen, the respondents were often the top R&D executives who based their responses in part on detailed data obtained from people at lower levels of their organizations. (For further comments on the data, see footnote 11.)

By "substantial delay", we mean a delay of a year or more. Of course, it is always hard to rule out completely the possibility that, in the absence of the relevant academic research, industrial or government researchers might have provided the necessary information; but according to the firms, this would have been extremely unlikely for the innovations they included in this category. As pointed out in section 5 below, they believe that, without the completion of the academic research, it would have taken at least 9 years longer, on the average, for these new products and processes to have been introduced.

⁶ The figures in table 1 for each industry are weighted means of the firm percentages, the weights being the 1985 sales of the firms. The unweighted means of the firm percentages tend to be higher than the weighted means in table 1. The standard errors of the unweighted means are about 2 percentage points.

⁴ The frame for this survey was the list of major firms in these industries in *Business Week*, 23 June, 1986. This list includes all firms spending over \$1 million (or 1 percent of sales, if sales were at least \$35 million) on R&D in 1985. A random sample of 76 of these firms was chosen, and data were obtained from all of them (sometimes after considerable discussion and negotiation) through questionnaires and interviews. The number of firms included in each industry is: information processing, 25; electrical equipment, 14; chemicals, 15; metals, 6; instruments, 7; drugs, 6; oil, 3. An attempt was made to allocate the sample optimally among industries (that is, with sample size being proportional to the total number in each industry times the relevant standard deviation). The sample size of 76 was chosen because it seemed large enough to result in the desired precision. See Cochran [4, ch. 5]. The firms in our sample accounted for about one-third of the sales in the population of firms in these industries in 1985.

IMPORTANT

1. Please correct the proofs carefully; the responsibility for detecting errors rests with the author.
2. Restrict corrections to instances in which the proof is at variance with the manuscript.
3. Recheck all reference data.
4. A charge will be made for extensive alterations.

cally significant.⁷ One of the most important reasons why relatively R&D-intensive firms are more likely than others to carry out innovations based on recent academic research is that they tend to be more closely abreast of such research.

In some cases, new products and processes could have been developed without the findings of recent academic research, but it would have been much more expensive and time-consuming to do so.⁸ In table 1, such cases are designated as ones where development occurred with "very substantial aid from recent academic research". About 8 percent of these firms' new products and about 6 percent of their new processes during 1975-85 fell into this category. Frequently, while it was technically possible for the firm to have developed them without the findings of recent academic research, it seemed economically undesirable to have attempted it. Thus, in a practical sense, many of these innovations could not have been developed (without substantial delay) in the absence of recent academic research.

The percentages in table 1 are somewhat higher than those based on Gellman's study [7] of 121 innovations occurring in these industries during 1953-73 in the United States, which indicated that about 7 percent were based on inventions conceived at universities. (Among innovations designated as "radical breakthroughs", the percentage was 14 percent.) This would be expected since many innovations that are not based on inventions conceived at universities could not be developed (without substantial delay) in the ab-

sence of academic research.⁹ For example, academic research often provides new theoretical and empirical findings and new types of instrumentation that are essential for the development of a new product, but does not provide the specific invention itself. Thus, academic studies by Professors Kipping and Staudinger provided basic information concerning organo-silicon chemistry which laid the groundwork for industrial silicones.¹⁰

3. Academic-research-based products and processes: Sales and savings

While the previous section indicates that about 11 percent of the new products introduced in these industries in 1975-85 could not have been developed (without substantial delay) in the absence of recent academic research, it tells us nothing about the economic importance of these new products. To help fill this gap, data were obtained from each firm concerning the 1985 sales of its new products first commercialized in 1982-85 that could not have been developed (without substantial delay) in the absence of recent academic research. From these data, estimates were made of the total 1985 sales for all such new products first commercialized in 1982-85 by all major firms in each of these industries, the results being shown in table 2.¹¹

The total sales of such new products in 1985 in these seven industries seems to have been about \$24 billion. Because there are large differences among firms in the sample with regard to the 1985 sales of such new products, the estimated total sales figures for individual industries contain large sampling errors. Thus, although the drug, infor-

⁷ Letting P_i be the percentage of the i th firm's new products that could not have been developed (without substantial delay) in the absence of academic research, and R_i be the i th firm's percentage of sales devoted to R&D in 1985, the regression equation

$$P_i = 7.11 + 2.18R_i \quad (R^2 = 0.10).$$

(2.73)

where the t -statistic is shown in parentheses below the regression coefficient. Holding R_i constant, both industry dummy variables and firm size (as measured by 1985 sales) are statistically non-significant.

⁸ Frequently, academic research results in new techniques that enable scientists and engineers in firms and elsewhere to carry out R&D in particular areas more cheaply, quickly, or accurately. For example, high resolution nuclear magnetic resonance spectroscopy, which was based on research at Stanford and Harvard Universities, has become indispensable in many chemical laboratories.

⁹ In the drug industry, table 1 shows that about 27 percent of the new products could not have been developed (without substantial delay) in the absence of recent academic research. This percentage is considerably higher than the percentage of drug discoveries made by the universities. According to ~~Kipping~~ et al. [15] and Schwartzman [24], the latter figure may have been 10 or 15 percent. As noted in the text, the reason why the figure in table 1 is higher than the latter figure is that academic research often results in findings that are necessary but not sufficient for the discovery or improvement of a drug. Industrial R&D must be carried out to extend, supplement, and focus the findings of the academic R&D. (In addition, of course, some of the differences may be due to sampling errors, which are discussed in footnote 34.)

¹⁰ Jewkes, Sawers and Stillerman [8, pp. 296-299].

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Mansfield

mation processing, and electrical equipment industries seem to have the largest sales of new products of this sort, these differences could be due in substantial measure to sampling errors. Given our objectives, the important figures are the seven-industry totals (\$24 billion and \$17.1 billion) which, although they have substantial sampling errors, are sufficiently precise to be useful. (Note too that these totals are quite consistent with McGraw-Hill [10] data.¹²)

¹¹ To make this estimate, we multiplied the number of major firms in each industry by the mean 1985 sales of such products of the firms in the sample. A major firm is defined here as one that is big enough to be included in the *Business Week* list cited in footnote 4. Many of the firms went to a considerable amount of trouble to provide reasonably accurate data. For other firms, the data are rough, but we tried in a variety of ways to make sure that the executives had what seemed to be a solid basis for their estimates. Nonetheless, data of this sort have obvious limitations, and should be treated with appropriate caution.

¹² The results in tables 1 and 2 seem to be quite consistent with McGraw-Hill's survey of business plans for research and development expenditures [10], which provides data for five of our seven industries. In its 1982 survey, McGraw-Hill asked the respondents what percentage of their 1985 sales would be in new products introduced for the first time in 1982-85. If this percentage for the k th industry is L_k , if the k th industry's 1985 sales equal M_k , if the percentage of new products in the k th industry that could not have been developed (without substantial delay) in the absence of recent academic research is N_k , and if the total sales during 1985 of new products commercialized in 1982-85 that could not have been developed (without substantial delay) in the absence of recent academic research is Y_k :

$$Y_k = L_k M_k N_k.$$

Inserting our estimates of N_k in table 1 in this equation, together with ~~the~~ estimates of L_k and the actual values of M_k , we find that the resulting estimates of Y_k for these five industries are close to our estimates of Y_k . The differences generally can be attributed to sampling errors.

The McGraw-Hill data cannot be used to check our results for the drug and information processing industries, because these data are not available for them. To obtain data concerning L_k for these two industries, we contacted leading firms in each industry, which provided us with rough estimates. For the information processing industry, the resulting estimate of Y_k is reasonably similar to our estimate of Y_k . But in the drug industry, it is much lower than our estimate of Y_k . According to some leading R&D executives in the drug industry, this is because our estimate of L_k for this industry is too low. But if this is not the case, and if our estimate of Y_k for this industry is too high, our final results will not be affected very much. For example, even if this estimate were double what it should be, the social rate of return in table 4 would be 26 percent, which is not very different from the figure of 28 percent given now.

Turning to new processes, data were obtained from each firm in our sample concerning the savings during 1985 from new processes first commercialized in 1982-85 that could not have been developed (without substantial delay) in the absence of recent academic research. From these data, estimates were made of the total savings during 1985 from such new processes for all major firms in each industry.¹³ The seven-industry total was about \$7.2 billion, as shown in Table 2. The information processing industry seemed to have greater savings than the other industries, but the sampling errors in the figures for individual industries are very large. The important figures are the seven-industry totals (\$7.2 billion and \$11.3 billion) which, while they contain substantial sampling errors, are accurate enough to be useful.

4. Time lags between academic research and industrial innovation

To understand the relationship between academic research and industrial innovation, we need data regarding the length of the time lags between academic research findings and the commercialization of the innovations based on these findings. Information concerning these time lags was obtained from the firms in our sample. For each firm's new products and processes introduced in 1975-85 that could not have been developed (without substantial delay) in the absence of recent academic research, data were obtained concerning the mean time interval between the relevant academic research finding and the first commercial introduction of the product or process. If more than one such research finding was required for the development of the innovation, this time interval was measured from the year when the last of these findings was obtained.¹⁴

¹³ To make this estimate, we multiplied the number of major firms in each industry by the mean 1985 savings from such processes of the firms in the sample. For some firms, these savings data, like the sales data discussed in footnote 11, are rough. Our comments at the end of footnote 11 apply to these data as well.

¹⁴ Because not all of the firms could provide data of this sort, and because others sometimes could only approximate these dates, the results contain errors, but the averages in table 3 should be reasonably accurate.

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Table 2

Estimated sales of new products based on recent academic research and estimated savings from new processes based on recent academic research, seven industries, United States, 1985 ^a

Sales or savings	Innovations that could not have been developed (without substantial delay) in the absence of recent academic research	Innovations that were developed with very substantial aid from recent academic research
Total 1985 sales by major firms of new products first commercialized in 1982-85 and based on recent academic research:		
Billions of dollars	24.0	17.1
Percent of total sales of major firms	3.0%	2.1%
Total 1985 savings by major firms due to new processes first commercialized in 1982-85 and based on recent academic research:		
Billions of dollars	7.2	11.3
Percent of total costs of major firms	1.0%	1.6%

Source: See section 3.

^a The seven industries that are included are listed in table 1.

As shown in table 3, the mean time lag in these industries was about 7 years.¹⁵ In general, it appears that the time lag tends to be longer in larger firms, which is consistent with the view that development often takes longer in larger firms. Also, some small firms are formed to commercialize the results of academic research. When size of firm is held constant, the average lag tends to be greater in the metals industry than in the others, but the sample size in this industry is rather small, so this finding should be viewed with considerable caution. Letting D_i be the mean time lag (in years) for the i th firm,

$$D_i = 5.72 + 0.38S_i + 5.68Y_i \quad (R^2 = 0.30), \quad (1)$$

(2.25) (2.95)

where S_i is the 1985 sales (in billions of dollars) of the i th firm and Y_i is a dummy variable that equals 1 if the i th firm is a metals firm and zero otherwise.¹⁶

For each firm's new products and processes introduced in 1975-85 that were developed with very substantial aid from recent academic research, similar sorts of data were obtained. As shown in table 3, the average lag for these innovations was 6.4 years, which is close to our result for

innovations that could not have been developed (without substantial delay) in the absence of recent academic research.

It is interesting to note that Gellman [7] found almost precisely the same average lag for academic-research-based innovations in 1953-73 (his average was 7.2 years). Also, an analysis of Gellman's data indicates that academic-research-based innovations tend to be carried out by much smaller firms than other innovations. Whereas about 20 percent of other innovations were carried out by firms with under 100 employees, almost 60 percent of these innovations were carried out by such small firms, some of which were probably established to exploit the relevant academic research.¹⁷

¹⁷ Of course, one should bear in mind that Gellman's data are in many regards not comparable with ours. Besides the differences pointed out in the last paragraph of section 2, it is worth noting that, whereas the lag can be longer than 15 years for innovations in Gellman's sample, this cannot be the case in ours, because we are concerned entirely with innovations based on recent academic research. Also, in this comparison (but not in that in the last paragraph of section 2), his data pertain to all industries, not just to those included here. Nonetheless, it is reassuring to find that his results are so close to ours.

Note too that there is no contradiction between our finding here that academic-research-based innovations tend to be carried out by small firms and our findings in footnote 7. The latter are based entirely on data for major firms.

¹⁵ The standard error of each of the overall means in table 3 is about 0.6 years.

¹⁶ In equation (1), the t -statistics are shown in parentheses below the regression coefficients.

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5. The social rate of return from academic research: The basic model

To calculate the social rate of return from the investment in academic research, we must compare the stream of social benefits if this investment takes place with what it would have been without this investment, holding constant the amount invested in non-academic research. In other words, we are interested in what would happen if the resources devoted to academic research were withdrawn—and not allowed to do the same or similar work elsewhere.¹⁸ Specifically, suppose that all academic research were to be terminated permanently at the end of year $t-1$.

Without the investment in academic research in year t , the findings of this research (on which new products and processes are based) would not be available, thus preventing or delaying the development and introduction of the new products and processes based on these findings. According to the firms in our sample, it would have taken at least 9 years longer, on the average, for the new products and processes in tables 1–3 (that were based on academic research) to have been introduced. But since estimates of this sort obviously are subject to large errors, we make the more conservative assumption that it would have taken 8 years for this to occur. As we shall see, our findings change relatively little, even if we assume that this average delay is much less (for example, 3 years).

The social rate of return from the investment in academic research in year t is the interest rate that makes the present value in year t of the extra social benefits due to the earlier introduction of these new products and processes equal to the

¹⁸ Note that we focus on the rate of return from the entire investment in academic research, not the rate of return from an extra dollar spent on academic research. While the latter rate of return is of great significance, we cannot estimate it with the existing data. Our objective is not to allocate the growth in output among various contributing factors, as in Edward Denison's pioneering work (for example, Denison [5]). Instead, it is to estimate the extent of the social benefits which would have been forgone in the absence of recent academic research, which obviously is a *very* extreme. In interpreting the results, it is important that this be borne in mind (see section 7). For interesting discussions of other relevant considerations, see Kendrick [9] and Nelson [21].

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Table 3

Average time lag between a recent academic research finding and the first commercial introduction of a new product or process based on this finding, seven industries, 1975–85

Industry	Innovations that could not have been developed (with a substantial delay) in the absence of recent academic research (mean number of years)	Innovations that were developed with very substantial aid from recent academic research (mean number of years)
Information processing	7.0	6.2
Electrical	5.3	4.9
Chemical	6.8	7.3
Instruments	4.2	4.2
Drugs	8.8	10.3
Metals	9.8	5.7
Oil ^a	N.A.	N.A.
Industry mean ^b	7.0	6.4

Source: See section 4.

^a Reliable data could not be obtained for a sufficiently large number of innovations to allow us to present figures for this industry.

^b Unweighted mean of industry figures.

investment in academic research in year t . This is an incremental rate of return, since it is the rate of return from only the final installment of the total investment required to bring forth the relevant academic research findings. Absent the investment in year t , the findings of this research would not have been produced (without considerable delays), but this investment is not the total investment required to elicit these findings. Because of the cumulative nature of science, this total investment may have extended over decades or centuries. Nonetheless, for policy-makers who must decide how much to invest next year in academic research, this incremental rate of return is of primary significance. Past investments in academic research are sunk costs, and the social rate of return from next year's investment is what counts.

To calculate this rate of return, we assume, based on the average time interval in table 3, that the new products and processes made possible by the investment in academic research in year t are introduced 7 years later (that is, in year t' , where $t' = t + 7$). The social benefits from the innovations commercialized in year t' that are based on academic research in year t are assumed to con-

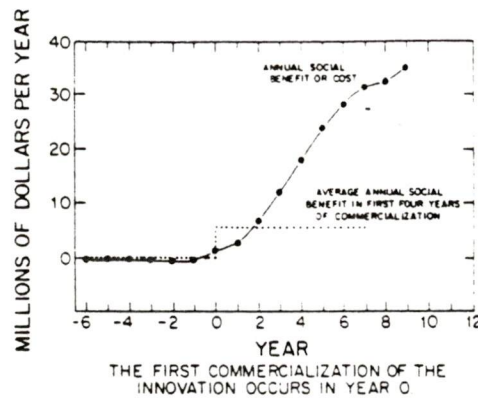


Fig. 1. Annual social benefit or cost, by year, from first commercialization of innovation, mean for 53 industrial innovations. Source: Foster Associates [6], Mansfield et al. [13], and Nathan Associates [17].

continue up to year $t' + 7$ (and no longer) at their average annual level in the first four years after commercialization, and to be zero before year t' . This, as explained in the following paragraphs, is a very conservative assumption.

Figure 1 shows the average annual stream of social benefits and costs for the 53 industrial innovations studied in Mansfield et al. [14], Foster Associates [6], and Nathan Associates [17], the three principal sources of data on this topic.¹⁹ For the innovations based on academic research in year t , we are replacing the time form of social benefits and costs in fig. 1 with the dotted line shown there. This dotted line underestimates the average social benefits in the years after the commercialization of the innovation, as well as the social costs (due to investment in applied R&D, plant and equipment, and startup activities) prior to year t' . On balance, this is a very conservative assumption, if the time form of social benefits (savings from new processes, profits from new products, and benefits to those other than the innovator) and costs is at all similar to that of the 53 innovations included in fig. 1. If the interest rate is 0.25, the discounted net social benefits based on this assumption are about half of their actual value. If the interest rate is lower, this

¹⁹ Three of Nathan's innovations had to be omitted because of incomplete data. A fourth was excluded because the timing of the social benefits from this innovation was affected dramatically—and very atypically—by the outbreak of an epidemic. The costs and benefits in fig. 1 are in constant dollars.

assumption is even more conservative.

The reason why the social benefits stop in year $t' + 7$ is that we make the conservative assumption that, in the absence of academic research, the relevant research findings would have been obtained (through industrial, government, or other research) in time to permit the introduction of the new products and processes based on these findings in year $t' + 8$ —that is, 8 years after they would have been introduced if the investment in academic research in year t had been made. Hence, after year $t' + 7$, there are no social benefits in excess of those that would have accrued without academic research in year t .²⁰ Note once again that the firms in our sample regard this assumption of a 8-year delay as being conservative (that is, on the low side).²¹

Thus, based on the very conservative assumptions described in this section, if we want to estimate the social rate of return from the annual investment in academic research during 1975–78, we must find the value of i which satisfies the following equation:

$$X \left[\frac{1}{(1+i)^7} + \frac{1}{(1+i)^8} + \cdots + \frac{1}{(1+i)^{14}} \right] = C, \quad (2)$$

where C is the annual investment in academic research during 1975–78, and X is the annual social benefit from this investment.

²⁰ This assumes that the average social benefit during the first four years after commercialization is about the same if the innovation is delayed 8 years as if it is not delayed. Whether or not this is true will vary from case to case, but since benefits 8 years or more after commercialization are so heavily discounted, the results are not influenced much by this assumption. Moreover, it is a conservative assumption so long as the delay does not increase the annual social benefit from the innovation, which seems unlikely in most cases.

²¹ In considerable part, this long delay occurred because industrial researchers often had little or no incentive to do the kinds of work that academic researchers carried out. Whereas the academic research underlying the innovations in tables 1–3 was of interest to academic researchers (and to the federal agencies that financed much of it), it often seemed to be of little or no direct use to firms; and even when it did seem to be of use, there often was no effective means for the firms to appropriate the benefits.

6. Academic research during 1975-78: Estimated rate of return

To solve equation (2) for i , we need the values of C and X . With regard to C , we use the world-wide investment in academic research, since academic science is in many respects an international enterprise, and firms in all countries draw on the findings of foreign as well as domestic academic research. OECD data and Campbell [2,3] are used to estimate the annual investment during 1975-78 in academic research (other than the social sciences and psychology) in the OECD countries and the Soviet Union (which, according to the National Science Foundation, ²² carry out almost all of the world's scientific and technological activities). Because of the difficulties in distinguishing R&D from teaching (and for other reasons), the resulting estimate of C (which is expressed in 1985 dollars ²³) is rough. ²⁴ Fortunately, our results are not very sensitive to reasonable variations in this estimate.

To estimate X , the first thing to note is that, since there is a 7-year lag, the investment in academic research during 1975-78 results in new products and processes commercialized in 1982-85. Let b_{ij} be the social benefit during year $t' + j$ (where $j = 0, \dots, 3$) from the i th new product or process (based on academic research) commercialized in year t' . If we define $B(t')$ as $\sum_i \sum_{j=0}^3 b_{ij} / 4$, where the first summation is over all of the new products and processes commercialized in year t' that were based on academic research, it follows that $B(t')$ is the sum of the social benefits accruing ~~annually~~ from the new products and processes commercialized in year t' that were based on

annually

²² National Science Foundation [18, p. 4]. According to the National Science Foundation [18, p. 278] about 11 percent of academic R&D in the United States in 1975-78 went for the social sciences, psychology, and other research not concerned with engineering or the physical, environmental, mathematical, or life sciences. In other countries like Japan, this percentage may be higher [18, p. 206], but to be conservative, we assume that the U.S. percentage is true in all countries. This may tend to bias the estimated rate of return downward.

²³ Like the National Science Foundation, we use the GNP deflator to convert to 1985 dollars. As pointed out in Mansfield [11], this deflator has important weaknesses, but for present purposes it should be good enough. While it may result in some downward bias in C , this bias will be too small to affect the results materially.

recent academic research, if one accepts the very conservative assumption in section 5—that is, if we assume that the annual social benefits equal their average annual level in the first four years after commercialization.

Under this very conservative assumption, X equals the mean value of $B(t')$ during 1982-85.

²⁴ For a description of the OECD data, see OECD [22]. Data for 1975-78 were provided by Allison Young of OECD. For the United States, the OECD figures exceed the NSF figures, because they include capital spending and federally funded research and development centers administered by universities. Since work by the centers is not included in our definition of academic research, the R&D performance of these centers is deducted from the OECD figures.

To estimate academic research expenditures in the Soviet Union, we use Campbell's figures [3] for 1975-78 and his dollar-ruble conversion ratio for 1976 and 1977. See Campbell [2].

There are several important problems in these data. For one thing, unsponsored research by U.S. faculty members is omitted. According to the National Science Foundation [19], about 16 percent of engineering research in universities was unsponsored in 1978, as well as about 22 percent of research in the physical sciences, 13 percent in the life sciences, and 16 percent in the environmental sciences. Thus, to take account of unsponsored research, the American figure should be increased. Also, some spending by states on research at state universities, if it is not designated as research, is omitted. On the other hand, Japan counts all of its university teaching budget as academic research, which means that its figure for university R&D is too high. See *Science*, 2 October 1987. According to experts in the field, there is no reason to believe that the OECD figures for all member countries as a whole are biased downward.

Martin and Irvine [16] have made a careful study of academic research financed by government in France, Germany, Japan, the Netherlands, the United Kingdom, and the United States. Including estimates of unsponsored research by faculty members, they estimate the amount that was spent on academic research financed by general university funds and academic, separately budgeted, research in these six countries in 1975. Since these countries account for about 86 percent of all OECD academic research, according to the OECD data, a reasonable estimate of the OECD total academic research supported by government in 1975 is their figure divided by 0.86. Including the Soviet Union, the total (excluding psychology, social sciences, vocational studies, and humanities) provides no indication that our estimate of C is on the low side.

Nonetheless, even if our estimate of C were 25 percent too low, our results would not be changed, except in detail. The social rate of return is 25 percent (rather than 28 percent, as shown in table 4). Neglecting the benefits to users from new products, the social rate of return is 8 percent (rather than 10 percent, as shown in table 4).

That is,

$$X = \sum_{t'=1982}^{1985} B(t')/4 = \sum_{t'=1982}^{1985} \sum_{j=0}^3 B(t', j)/16. \quad (3)$$

where $B(t', j) = \sum_i b_{ij}$. (That is, $B(t', j)$ is the sum of the social benefits in year $t' + j$ accruing from the new products and processes commercialized in year t' that were based on recent academic research.) Under this conservative assumption, the sum of the social benefits during 1985 of all of the new products and processes first commercialized in 1982–85 that were based on recent academic research is:

$$B_{85} = \sum_{t'=1982}^{1985} B(t', 1985 - t'). \quad (4)$$

Assuming for simplicity that the effects of j on $B(t', j)$ are independent of those of t' on $B(t', j)$,²⁵ we can approximate X by $B_{85}/4$. (Note that X , like C , is in 1985 dollars.)

²⁵ Put differently, we assume that the changes over time (during the first 4 years) in the sum of the social benefits accruing from the new products and processes commercialized in year t' (that were based on recent academic research) are the same, regardless of whether $t' = 1982, 1983, 1984$, or 1985. In other words, if we constructed an annual social benefits curve (like that in fig. 1) for the sum of all innovations commercialized in 1982, its slope (for number of years = 0, ..., 3) is assumed to be the same as for innovations commercialized in 1983, 1984, or 1985. This assumption seems to be a reasonable first approximation. Without much more detailed data (which do not presently exist), some assumption of this sort must be made.

For a simple case where the effects of j are independent of those of t' , take the situation where $B(t', j) = f(t') + g(j)$. Under these circumstances, it follows from equations (3) and (4) that

$$X = \bar{f} + \bar{g}, \quad (5)$$

and

$$B_{85} = 4(\bar{f} + \bar{g}), \quad (6)$$

where

$$\bar{f} = \sum_{t'=1982}^{1985} f(t')/4$$

and

$$\bar{g} = \sum_{j=0}^3 g(j)/4.$$

Obviously, $X = B_{85}/4$, which is the point made in the text.

As is well known, the social benefits from a new process consist of the savings to the innovator plus whatever net benefits accrue to others, and the social benefits from a new product consist of the increased gross profits (cash flow adjusted for effects on displaced products) of the innovator plus the net benefits to users.²⁶ To make a conservative estimate of B_{85} , we begin by adding the savings from the new processes in the left-hand column of table 2 to the gross profits (cash flow adjusted for effects on the profits of displaced products) from the new products in the left-hand column of table 2.²⁷ However, this figure must be adjusted for three reasons. First, we have assumed that the investment in academic research resulted in no social benefits from the new products and processes developed "with substantial aid" from recent academic research. In fact, it seems reasonable to assume that at least half of these new products and processes would not have been developed (without substantial delay) in the absence of academic research. Thus, half of the savings from the processes and gross profits from the products in the right-hand column of table 2 are added to the above figure.²⁸

Second, we have assumed that only American firms enjoy savings and profits from innovations based on academic research. Even in the 1960s, when America was far more dominant technologically than in 1982–85, the National Science

²⁶ For a much more detailed and complete discussion of the measurement of the social benefits from a new process or product, see Mansfield et al. [13].

²⁷ As explained in Mansfield et al. [13], gross profit—that is, profit without depreciation being deducted—is the relevant concept here. To estimate gross profit, we multiplied the estimated 1985 sales of the products that could not have been developed without recent academic research by the average ratio of gross profit (net profit plus depreciation) to sales in 1985 in the relevant firms, the latter ratio being obtained from the firms' accounting records. Next, a rough adjustment was made to allow for the fact that the new products' profits were partly at the expense of older products (sold by other firms as well as by the innovators) they partially or entirely displaced [13]. Based on interviews with company executives, the resulting gross profit figures are reasonable, but rough.

²⁸ Here too we assume that there would be an 8-year delay in the absence of academic research. To see what the effects would be if we made the even more extreme assumption that academic research resulted in no social benefits from the new products and processes developed "with substantial aid" from recent academic research, see table 4.

Foundation [20] estimated that American firms carried out only slightly more than half of the major innovations in the leading OECD countries. Based on this and more recent evidence,²⁹ it appears that a conservative estimate of the worldwide savings and gross profits in 1985 from new products and processes first commercialized in 1982–85 that were based on recent academic research would be double the American figure obtained in the previous paragraph. (Note that, even if we were to assume that they were only 1.5 times the American figure, our results would change relatively little.)

Third, we have assumed that new products and processes based on recent academic research result in no social benefits other than to the innovator, which is ridiculously conservative.³⁰ For the product innovations in Mansfield et al. [13], the benefit to users during the first four years after their introduction was about eight times as great as the gross profit from these products, even though in some cases we must ignore the effects on the profits of displaced products, thus reducing the ratio of benefits to users to gross profit.³¹ (For the product innovations in Foster Associates [6]) and Nathan Associates [17], the ratio was even higher.) Based on a small random sample of academic-research-based innovations, this 8-to-1

ratio seems to be too low.³² Nonetheless, we make the seemingly conservative assumption that this ratio prevails for new products.³³ For new processes, we ignore social benefits other than to the innovator.

The resulting estimate of X , together with our estimate of C , implies that the estimated social rate of return—that is, the value of i in equation (2)—is 28 percent. Of course, the roughness of this figure should be emphasized, but it is noteworthy that the estimated rate of return is so high, given the many ways in which it has been biased downward. Among other things, we have ignored: (1) the social benefits from innovations based on academic research in all industries other than the seven in table 1; (2) the increases in annual social benefits from innovations based on academic research after their first four years of commercialization; and (3) the social benefits from innovations based on academic research findings that are commercialized more than 15 years after the findings or that are introduced by non-major firms.

Moreover, as shown in table 4, the estimated rate of return is 23 percent, even if we exclude all social benefits from innovations developed with substantial aid from academic research. Going to an even more conservative extreme, the figure is

²⁹ According to the National Science Foundation [18, p. 203] the United States carried out 39 percent of the industrial R&D in these industries in seven countries (Japan, Germany, the United Kingdom, France, Canada, Italy, and the United States). Since many countries, including the Soviet Union, are omitted, the percent of world R&D must be well below 39 percent. According to Gellman's data [7], the proportion of innovations based on academic research in other countries (Canada, France, Germany, Japan, and the United Kingdom) was as high as in the United States, and the average time lag was not significantly different.

³⁰ For a description of methods to estimate the benefits to users, see Mansfield et al. [13]. Even without the work of the past decade or so, it is obvious that the exclusion of the benefits to industrial and individual users results in a gross under-estimate of the social benefits, since the benefits of new products are passed on (in substantial measure) to users (including consumers).

³¹ This pertains to the first 4 years after commercialization, which is the period used here to estimate benefits. One reason why the ratio is relatively high is that profits often are lower than in later years.

³² Because the direct estimation of the benefits of an innovation to users is a very laborious and expensive process, we have had to limit this part of our study to ten new products in these industries that were based on recent academic research. These products were randomly chosen. In every case, the ratio of the benefits to users to the innovator's gross profit (in the first four years after the product's introduction) exceeded 8. These results, taken in combination with the findings of Mansfield et al. [13], Foster Associates [6], and Nathan Associates [17], which provide detailed estimates for about 40 new products, seem to provide substantial evidence that the 8-to-1 ratio is conservative.

³³ It would be preferable, of course, to make direct estimates of the benefits to users, rather than to make crude estimates based on this ratio, but existing resources do not permit such an ambitious undertaking. In table 4, it is shown that the estimated social rate of return is 10 percent even if the benefits to users are assumed to be zero. Thus, even if this ratio were too high, the rate of return would still be substantial.

Note too that we ignore the benefits to imitators of new products based on recent academic research, as well as the benefits to customers of firms that carried out process innovations based on recent academic research. These benefits can, of course, be considerable.

Table 4
Estimated rate of return from worldwide investment in academic research in 1975-78, based on alternative assumptions

Assumption	Rate of return (%)
Including half of innovations developed with substantial aid from academic research	
Including estimated benefits to users from new products	28
Excluding benefits to users from new products	10
Excluding all innovations developed with substantial aid from academic research	
Including estimated benefits to users from new products	23
Excluding benefits to users from new products	5

Source: See section 6.

10 percent (not excluding all social benefits from innovations developed with substantial aid from academic research) or 5 percent (excluding all social benefits from innovations developed with substantial aid from academic research), even if we ignore all social benefits to users from new products based on recent academic research.³⁴

7. Conclusions

Because the results of academic research are so widely disseminated and their effects are so fundamental, subtle, and widespread, it is difficult to identify and measure the links between academic research and industrial innovation. This paper

³⁴ There are sampling errors in the estimated rates of return in table 4. Since our sample was randomly chosen, rough estimates can be made of these sampling errors. Because there is considerable variation among firms and because the sample size in some industries is quite small, the figures for individual industries in table 2 contain very large sampling errors. However, what is important here is the sum of the industry figures for savings from new processes plus gross profits from new products. If we include half of the innovations developed with substantial aid from academic research, as well as the benefits to users from new products, the probability is 0.975 that the rate of return exceeds 15 percent, based on the assumptions in the previous section. Note too that the estimates by Mushkin [26] of the social rate of return from biomedical research are about 50 percent, which exceed those in table 4.

presents, apparently for the first time, data concerning the percentage of new products and processes that, according to the innovating firms, could not have been developed (without substantial delay) in the absence of recent academic research. Since these data were obtained from key technical and managerial personnel of the innovating firms, they merit attention, although they, like other such survey data, are rough and contain sampling errors.

Our findings suggest that about one-tenth of the new ~~products~~ and processes commercialized during 1975-85 in the information processing, electrical equipment, chemicals, instruments, drugs, metals, and oil industries could not have been developed (without substantial delay) without recent academic research. The average time lag between the conclusion of the relevant academic research and the first commercial introduction of the innovations based on this research was about 7 years (and tended to be longer for large firms than for small ones). A very tentative estimate of the social rate of return from academic research during 1975-78 is 28 percent, a figure that is based on crude (but seemingly conservative) calculations and that is presented only for exploratory and discussion purposes. It is important that this figure be treated with proper caution and that the many assumptions and simplifications on which it is based (as well as the definition of a social rate of return used here) be borne in mind. While interesting, it is by no means a full or satisfactory solution to the long-standing—and extraordinarily difficult—problem of evaluating the payoff to society from academic research. It is at best a very crude beginning.

Nonetheless, our results provide convincing evidence that, particularly in industries like drugs, instruments, and information processing, the contribution of academic research to industrial innovation has been considerable. Needless to say, this does not mean that other inputs like industrial research, plant and equipment, labor and management have not been important as well. But whereas the contribution of these other inputs generally is taken for granted, the role of academic research sometimes has been regarded as far more questionable. Our results, while they do not address the very difficult question of how to allocate the social returns between academic and industrial research, indicate that, without recent academic

products

research, there would have been a substantial reduction in social benefits. This really is what the estimated social rate of return, as defined above, is saying.

To prevent misunderstanding, it may be worthwhile to conclude by recognizing that the rationale for academic research extends far beyond the sorts of narrowly defined economic benefits considered here. Obviously, knowledge concerning the universe is important for its own sake, and the education of students, which occurs in many academic research projects, is socially important as well. Nonetheless, it is interesting to find that, even if academic research is judged in these relatively restricted terms, its role seems to be substantial.³⁵

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³⁵ It should also be emphasized that our results do not rest on the so-called linear model of innovation, which assumes that universities first perform basic research, the results of which are transferred to industry, which in turn does the development leading to the innovation. As is well known, this linear model is often violated. For example, academic research frequently occurs in response to R&D carried out, and problems encountered, in industry. Our analysis in no way assumes that the linear model is true. It is just as valid if the relevant academic research is in response to industrial research.

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