Originally Processed With FOIA(s):
S; 1999-0093-F

FOIA Number:
S

FOIA MARKER

This is not a textual record. This is used as an administrative marker by the George Bush Presidential Library Staff.

Record Group/Collection:	George H.W. Bush Presidential Records
Collection/Office of Origin:	Speechwriting, White House Office of
Series:	Speech File Backup Files
Subseries:	Chron File, 1989-1993

OA/ID Number:	13817
Folder ID Number:	13817-004

Folder Title:
Goddard Space Flight Center 6/1/92 [OA 7576] [1]

Stack:	Row:	Section:	Shelf:	Position:
G	26	22	5	7

Document No. 330733ss

WHITE HOUSE STAFFING MEMORANDUM

DATE: 5/29/92 ACTION/CONCURRENCE/COMMENT DUE BY: TODAY, 5/29 5:00pm!!

SUBJECT: PRESIDENTIAL REMARKS: ENVIRONMENTAL ADDRESS GODDARD SPACE CENTER - MONDAY, JUNE 1 - 2:00 p.m.

	ACTION	FYI		ACTION	FYI
VICE PRESIDENT	☐	✓	HORNER	☐	☐
SKINNER	☐	✓	MCBRIDE	✓	☐
SCOWCROFT	✓	☐	MOORE	✓	☐
DARMAN	✓	☐	PETERSMEYER	✓	☐
BRADY	☐	✓	PORTER	✓	☐
BROMLEY	✓	☐	ROLLINS	✓	☐
CALIO	✓	☐	SMITH	✓	☐
DEMAREST	✓	☐	YEUTTER	☐	✓
FITZWATER	✓	☐	FINDLAY	☐	✓
GRAY	✓	☐	KAUFMAN	☐	✓
HOLIDAY	✓	☐	MCGROARTY	☐	✓
DELAND	✓		ALBRECHT	✓	

REMARKS:

Please forward your comments directly to Dan McGroarty, RM. 122, x2930, no later than 5:00 p.m., TODAY, FRI. MAY 29, with a copy to this office. Thank you.

RESPONSE:

PHILLIP D. BRADY
Assistant to the President
and Staff Secretary
Ext. 2702

EPA — (260-4700) Admin Off. Allen Rox - EPA Dept Adm. Water Martha -

92 MAY 29

PRESIDENTIAL REMARKS: ENVIRONMENTAL ADDRESS
GODDARD SPACE CENTER
GREENBELT, MARYLAND
MONDAY, JUNE 1, 1992
2:00 p.m.

Thank you, Administrator Dan Goldin, for that ((Senator Mikulski)), ((Administrator Reilly)):

You know, in just over a month on the job, Dan Goldin has supervised the recovery of a satellite on Endeavor's maiden voyage, won a vote to save the space station on the floor of the House, and launched his own "cultural revolution" at NASA. I'd say the "new NASA" is off to a flying start.//

1972(?)

Twenty years ago this month, the leaders of the world gathered in Sweden to talk about the human environment.

The Stockholm Declaration they adopted had a simple conclusion, that: "...through fuller knowledge and wiser action, we can achieve for ourselves and our posterity a better life in an environment more in keeping with human needs and hopes."

Ben Lesser EPA

double ✓

That meeting occurred when the environmental movement was in its infancy. Later that year, -1972- the first Clean Water Act passed the United States Congress. Our EPA at the time was one year old. America, like so many nations around the world, was just beginning to face up to the consequences of (unmitigated) pollution.

Fed. Water Pollution Control Act

→ America's clean water

1948- Federal Water Pollution Control Act was first first fed leg. to deal w/ water pollution

Grady said DDE deriveative of DDT

(Back then,) DDT levels showing up in wildlife around the Great Lakes were eight times what they are today. PCBs were six times as prevalent. (Thousands of miles of rivers and streams

Ben Lesser - EPA
260-5692 OFFICE OF WATER

1972 272,000 stream miles met

36% of total met quality
758,000

Michael Shapiro - 260-7403
EPA-Stat Air Quality

SO_2 #'s not that dramatic

Lead very dramatic; btw 80-90 concentration of lead in air decreased by 90% -

Can say despite econ growth 80-90 air quality has improved

lead decrease 85%

Present sentence trivializes
- effects on central nervous system -
→ toxic pollutant

doesn't work way expressed - not same kind of problem

air has gotten better - good point

were ... and lead

clog ... r in

Clev ... ting the

song ... river, burn

on."

envi ... ned first

in t ... we've

pass ... protect our

air, ... ral areas

and ... es. Today,

Amer ... ve served as

a mo

... of CFC

emissions by eliminating aerosol propellants, which we did in 1978. Other nations are now following suit as they meet their obligations under an international agreement to phase out CFCs.

We were the first nation, back in 1975, to adopt catalytic converters to reduce emissions from our cars and trucks -- European nations are now in the process of adopting them.

In 1982, we began phasing out lead from American gasoline. Today, ambient levels of lead in our air have been cut by 95 percent. Now, several other nations are looking at the possibility of cutting back on leaded gasoline as a means of meeting their clean air objectives.

Mike Shapiro EPA-Clean Air

irritate

clog wrong expression

Environmentally Legacy 89-91 by Reilly

Ben Lesser Water quality

Cuyahoga

dramatic

move accurate

very toxic

Jenn all of page

Bern lesser

Since 1977, carbon monoxide levels in our air have been cut 30 percent; ozone 20 percent; particulate 25 percent; and sulfur dioxide 18 percent. The discharge of suspended solids into our waterways was cut by over 80 percent. And as of 1988, 96 percent of our lakes and reservoirs were found to be fishable and swimmable.

Throughout these two decades since Stockholm, then, America has been the leader in protecting the environment.

In the last four years, we have worked to extend that record -- on every front. The 1990 Clean Air Act will cut emissions of sulfur dioxide in half, emissions of toxic chemicals by ninety percent, and the number of U.S. cities not meeting smog and carbon monoxide standards from over a hundred to a handful by the end of the decade.

We've signed new laws to prevent oil spills by requiring double hulls on oil tankers, to protect the flyways of migratory birds, and to help protect our largest rainforest -- the Tongass. We have fined and jailed polluters in record numbers; placed a moratorium on oil and gas drilling in precious areas of our coasts; added over a billion dollars to our system of parks, wildlife refuges, forests, and public lands; launched a reforestation plan to plant a billion trees a year; and signed international agreements on everything from the transboundary movement of hazardous wastes to the protection of the African elephant.

Globe wording
NASA's Mission to Planet Earth

for spring

BRIAN ~~DALEY~~ (?)
EXEC. SEC. DESIGNATE OF THE NAT'L SPACE COUNCIL

Acks:
NO CONG/SENATE
- Rielly
- Klineberg
- Adm. Gotdin
- Dr. Len Fisk associate dir NASA
- Bryan Daley - getting title
- Mike Deland

Next week, dozens of heads of state will again gather -- in Rio de Janeiro. I will join them, because the United States has a stake -- indeed, every nation has a stake -- in a safer, cleaner world.

And I suppose it is only fitting to come to this center, on the eve of the Rio summit, to talk about my vision for building such a world. To talk about what we have accomplished -- and what we hope to accomplish. To talk about the lessons learned since Stockholm, and about the road ahead.

Goddard, through its invaluable contributions to the understanding and observation of our earth, has in a very real sense made progress at the UNCED meeting possible.

Your work has revealed some fundamental truths about the environmental challenges we face. Jan Ruff:

TIROS-ONE IN 1960 PROVIDED THE FIRST GLOBAL PHOTO (April, 1960)

~~A spacecraft~~ ~~created at~~ ~~managed by~~ A Goddard managed spacecraft provided the world with its first image of Earth from space. In one breathtaking photo, you underlined what volumes of words could not have described better -- that the earth and its atmosphere are our common inheritance. That any solution to the problems facing the earth must involve every nation -- because those problems are global in scope.

Jan Ruff Goddard

It was Goddard scientists who developed the Upper Atmospheric Research Satellite -- UARS --- launched last year, 9/12/91 which is providing us new insight about the ozone layer. The buildup of chlorine in the upper atmosphere, and the depletion of

NASA FACT SHEET

all from NASA FACT SHEET

ozone, are long-term problems, built up over many years. They will require sustained commitment to solve.

And the lion's share of the science that the world is using to understand our climate comes from a program with its heart and soul right here -- the U.S. Global Change Research Program, built around the Earth Observing System that Goddard is developing. We are still learning about the enormously complex challenges this planet faces -- from global warming to El Nino, from biodiversity to desertification. To make the right decisions, we will need to learn as we go. So we need a sustained investment in the knowledge base that makes sound policymaking possible.

At the end of the day, that's what the Rio summit is all about. Policy. Making decisions. And taking action.

Frankly, the United States of America has brought a very no-nonsense approach to the preparations for Rio. We have made it clear that what matters to us, what matters from the perspective of the global environment, and what should matter to those who care about its health, is <u>action</u>.

From the beginning of the climate change negotiations which formed the centerpiece of this conference, we made clear this bias for action.

We offered to host the first round of negotiations at Chantilly, Virginia in 1991. And at that time, we laid on the table an action agenda on climate change -- with specific policy proposals we were implementing or prepared to implement, and with our specific calculations concerning how much we expected to reduce greenhouse gas emissions as a result of those policies. The result was encouraging. We found that our expected year 2000 greenhouse gas emission levels were expected to be below our current levels.

When the science changed, indicating that cutting CFCs would not reduce warming as much as we had thought, we supplemented that plan. Earlier this year, we added a whole range of additional measures -- from EPA's Green Lights program to the range of energy efficiency measures contained in my National Energy Strategy. We again laid our plan on the table -- in specific detail -- showing that our policies would reduce U.S. net greenhouse gas emissions by 125 to 200 million tons a year by the year 2000.

No other nation has laid out such a specific plan of action. And that explains our strategy during the negotiations. That every nation should have a plan of action, with a focus on results -- not rhetoric.

It may not have been widely reported in the press, but in area after area, the U.S. laid down specific proposals, and worked for their adoption. Forests. Oceans. Living Marine Resources. Public participation. Financing.

Make no mistake: America has not retreated, and will not retreat from its leadership role in protecting the global environment.

Today, the United States spends about two percent its Gross National Product -- over 100 billion dollars per year --

protecting the environment from pollution. That investment is scheduled to rise.

That continuing commitment of resources and national energy reflects one central tenet of our policy -- that what counts is performance over the long haul. We may not go to Rio with the best words, but we will go with the best policies.

More importantly, the commitment to act must not end at UNCED. If Rio is a one-shot deal, it will have been a failure.

So when I travel to Brazil next week, I will bring with me several proposals to extend the commitment of the world community into the future. We need not just the will to meet, but the will to act.

To make sure that the process and the institutional capacity for follow-up exists, we will endorse a continuing entity under the auspices of the United Nations -- a Council on Sustainable Development -- to help foster the international cooperation we will need to tackle these global problems.

To strengthen the will to act, I will offer a four point plan of cooperation.

First with respect to climate. The signing of a convention that calls for action plans is just a first step. Now countries must move quickly to develop them. So I will join in proposing a "prompt start" to implementation of climate action plans.

The United States is already well along the road to not only developing but implementing its action plan. But we stand ready to assist others -- particularly the developing countries -- in preparing theirs.

The participation of these developing countries is vital. Over the next three decades, carbon dioxide emissions from the developing countries are projected to triple. While today these nations account for about one quarter of the world's emissions, by the year 2025, they will contribute almost half. So any agreement which ignores the need to include them is destined to fail.

To begin this process, the United States has already committed to help fund country studies that can help these nations identify the sources of emissions and the best means of curbing them.

We have insisted throughout the negotiations that any solution to the climate change problem must be comprehensive -- that is, it should allow for the inclusion of all sources and sinks of greenhouse gases. The agreement we have reached does just this.

One of the most cost effective means of reducing net emissions for many countries will be to enhance greenhouse sinks -- in particular, forests.

So the second point which I will propose in Rio is a major new initiative to protect and enhance the world's forests.

The benefits of forests are many -- they filter the air and water; they provide products from timber and fuelwood to ingredients for Ben and Jerry's Ice Cream; they sequester carbon; and they provide habitat for all manner of living things.

Tropical forests cover just seven percent of the world's surface -- yet they are home to more than half the world's species. And forest loss today contributes about 20 percent of net man made carbon dioxide emissions.

We can jump start progress on addressing global warming and protecting the biological diversity of the earth with a single forceful step on behalf of forests -- and we can do it today.

At the Houston Economic Summit two years ago, I proposed to the leaders of the G-7 countries that we work for a global forest convention. And it remains my hope that the principles leading to such a convention will be agreed at Rio.

But I propose today to move ahead in advance of that formal convention. At Rio, I will ask the other industrialized countries of the world to join me in doubling worldwide forests assistance. The goal of this initiative would be to stabilize world forest cover by the end of this decade.

About $1.35 billion dollars a year are now provided worldwide in forest assistance. I propose to double this amount to $2.7 billion. As a downpayment, the U.S. will increase its bilateral forest assistance by 150 million dollars next year.

Forests today are under stress. In the last decade, tropical forests have disappeared at a rate of over 40 million acres a year.

This initiative would reverse that trend. The assistance can be provided through existing bilateral or multilateral mechanisms. And recipient countries could propose new projects.

The plan is to encourage investor countries to in effect bid on the most effective projects. This down payment on forests will use a market mechanism to achieve the greatest environmental return -- because investments will flow to the projects with the greatest marginal benefit in terms of decreased net emissions or critical habitat preserved.

((We will also act to get our own house in order. We will push Congress to fund our program -- the world's largest reforestation effort -- to plant a billion trees a year. And this week, the Forest Service will adopt new rules to end the clearcutting of our national forests as an acceptable forest practice.))

Saving the forests may be the most effective immediate step the world can take -- but it is not the only one.

The history of the world has been to benefit from technology. Technology has made us more productive, and raised our standard of living. In the U.S., technology has helped us cut pollution, and become more energy efficient as well.

That's one reason that my budget includes an investment of almost a billion dollars in developing the new energy and efficiency related technologies of tomorrow.

It is time for a new generation of clean growth -- the world over. We need a quantum leap in the world's develop, fueled by new, more energy efficient technology -- and yes, I hope much of it will be American technology.

In preparation for the UNCED summit, I met with the Business Council for Sustainable Development -- businessmen from around the world who sense the opportunity presented by a partnership between businesses and governments oriented toward cleaner, more efficient development.

I am pleased to note that hundreds of American businessmen will be travelling to Rio for this conference. I want the opportunities facing them -- and the benefits their goods and services can provide to the rest of the world -- to be long lasting.

So the third part of our plan is to support a broad program of technology cooperation at Rio -- and afterwards. Specifically, I propose to create a Technology Cooperation Corps. This Corps would be teams of U.S. businessmen and women who, with institutional support from the government, would investigate the needs of countries around the world for environmentally sound technology, and knock down the barriers to making it available.

The need for an ongoing program of technology cooperation underscores the point that our ability to address global environmental challenges is evolving -- as indeed is our understanding of the challenges themselves.

So the fourth point of any program for a cleaner future must involve a continued program of research and understanding. This year, we are requesting over $1.4 billion for the U.S. Global

Change Research Program -- that's more than half the money spent on climate research in the entire world.

We want to make sure that this work is useful. That was the point behind our restructuring of the EOS program last year -- to get results faster, cheaper, and better. That's what Dan Goldin is driving for throughout NASA. Today, I am signing a National Space Policy Directive, developed by Vice President Quayle's Space Council, that will place us firmly on this path. By using new technology and smaller satellites, we can move up the timetable for obtaining critical data on global change.

The directive does something else -- it formalizes our policy of making this data available and affordable for scientists and researchers from the public and private sector from all around the world.

We believe in sharing the benefits of our earth observation system -- and I will take that message to Rio. To make that message concrete, we will distribute at UNCED, at no cost, thousands of copies of computer disks -- each with over a billion bytes of data -- with our best information on greenhouse effects.

And upon our return, the U.S. will open this year a Global Change Research Information Office to disseminate this information to governments, businesses, and scientists.

UNCED not only holds out the promise of ushering in an era of sustainable development; it gives us the chance to help launch a new generation of clean growth.

These four steps -- the preparation of solid action plans; a dramatic first step to protect and enhance forests; cooperation in deploying cleaner, more efficient technology; and an ongoing program to develop and share sound science -- can help us seize that opportunity long after the speeches in Rio have been given and the conference is over.

Our predecessors who met at Stockholm had the gift of foresight. They explicitly called for the discussion at Rio to be about both environment and development. They knew, back then, that the two were inextricably linked.

Only a growing economy which provides hope for the future can generate the resources and the will to manage natural assets for the longer term and the common good. But only assets which are so managed can support the growth on which so much human hope is hinged. By definition, for development be successful in the long-term, it must be sustainable.

They couldn't have known how clear the lessons of history would be in the intervening two decades. How it would be revealed for all to see, when the pollution spawned by totalitarianism in Eastern Europe and for former Soviet Union was exposed to the world, that only free markets and democratic systems provide the accountability necessary for a clean environment.

They couldn't have known that, as the leaders of the world prepared to gather for this next earth summit, the specter of nuclear war -- with its unthinkable destruction -- would be calmed as never before in our postwar history.

They couldn't have envisioned that, with a world at peace, a more knowledgeable public, and a commitment from the public and private sectors of virtually every country, those who would be coming to Rio would be poised to launch a new generation of clean growth.

The signers of the Stockholm declaration called the protection and improvement of the environment "the urgent desire of all peoples." They could never have known how far we'd come in these two decades -- and how much further we'd have the potential to go.

Thank you, God bless you, and God bless the United States of America.

# # # # # #

To Dianne

Date ____________ Time 11:50

WHILE YOU WERE OUT

M Mark Koro

of ____________

Phone 301) 286-6255

Area Code / Number / Extension

TELEPHONED		PLEASE CALL	
CALLED TO SEE YOU		WILL CALL AGAIN	
WANTS TO SEE YOU		URGENT	
RETURNED YOUR CALL			

Message ____________

Bobby
Operator

*4341

Mark Koro

Ocean Topography Experiment (TOPEX/POSEIDON)

Objective

The Ocean Topography Experiment (TOPEX/POSEIDON) is designed to: 1) gather information about the global oceans' general circulation and their relationship to climate change using precise measurements of ocean surface topography; 2) increase knowledge of the interaction between atmosphere and ocean, including the exchange of heat and momentum; and 3) make detailed maps of currents, eddies and other features of ocean circulation.

Description

TOPEX/POSEIDON is a joint NASA and French Space Agency (CNES) project that includes two French and three NASA instruments. Using satellite radar altimetry, the mission will make substantial contributions to the understanding of global ocean dynamics. TOPEX/POSEIDON is a vital contribution to two major international ocean/atmosphere research programs: the World Ocean Circulation Experiment (WOCE) and the Tropical Ocean Global Atmospheric (TOGA) program, both of which are components of the World Climate Research Program.

Launch Date:	July 1992
Payload:	5 instruments
Orbit:	66 degree inclination; 1,336 km (721 nm) altitude, nominally circular
Design Life:	3 years; expendables for 5 years total
Length:	5.5 m (18 ft)
Weight:	2,700 kg (5,940 lbs)
Diameter:	3.5 m (11 ft)
Launch Vehicle:	Ariane IV
International Participation:	France

Instruments/Investigations/Principal Investigators

NASA Altimeter (ALT) - (Johns Hopkins University Applied Physics Laboratory)
Solid State Altimeter (SSALT) - (Toulouse Space Center - France)
TOPEX Microwave Radiometer (TMR) - (Jet Propulsion Laboratory)
Determination d'Orbite et Radiopositionement Integre par Satellite (DORIS) - (Toulouse Space Center - France)
Global Positioning System Demonstration Receiver (GPSDR) Experiment - (Jet Propulsion Laboratory)

Mission Events

Program start: October 1986
Satellite contract award: June 1987
Preliminary Design Review: October 1988
Critical Design Review: May 1989
Start sensor integration: May 1991
Satellite delivery: April 1992

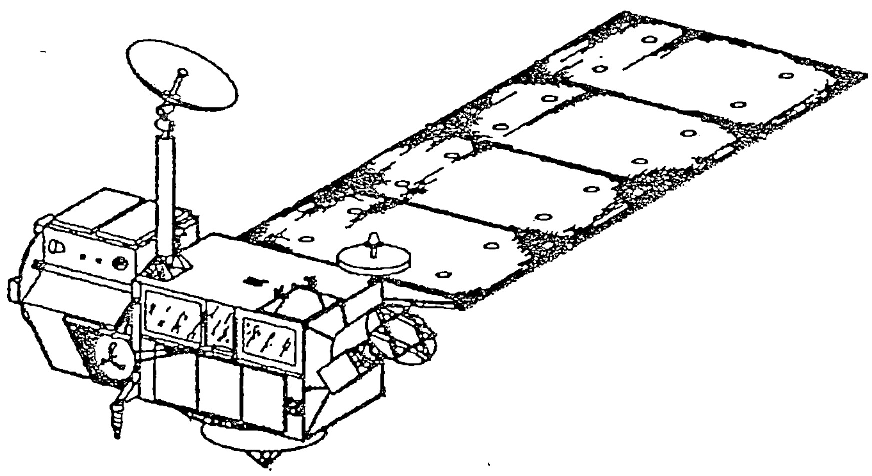
Ocean Topography Experiment (TOPEX/POSEIDON) (Continued)

Management

NASA Headquarters
L. Jones, Program Manager
W. Patzert, Program Scientist
Jet Propulsion Laboratory
C. Yamarone, Project Manager
L. Fu, Project Scientist
French Space Agency (CNES)
J. Fellous, Program Manager
A. Ratier, Program Scientist
M. Dorrer, Project Manager
M. Lefebuke, Project Scientist
Major Contractor
Fairchild Space Company

Status

A Memorandum of Understanding between NASA and CNES was signed March 1987. A contract was awarded to Fairchild for satellite development. Significant progress was made in the manufacture of the satellite subsystems and sensors during 1990. Flight hardware fabrication was completed in early 1991. Integration of the spacecraft bus, instrument module and instruments began in September 1991 and is expected to be completed by April 1992. The spacecraft will then undergo performance and environmental acceptance testing to support a May 1992 delivery of the satellite to the Kourou launch site in French Guiana for integration with the Ariane IV launch vehicle. Launch of TOPEX/POSEIDON is scheduled for July 1992.



Ocean Topography Experiment

THE WHITE HOUSE

WASHINGTON

28 May 1992

MEMORANDUM FOR DAVID DEMARAREST

THROUGH: DAN MC GROARTY

FROM: JEANNIE BUNTON JB

SUBJECT: GODDARD SPACE CENTER WALKTHROUGH

Event: Monday, 1 June 1992

On site: 2-3 P.M.; arrive Greenbelt from David [30 min]

Location: Goddard Space Center; Greenbelt, Md.

Two tiers:1 Tour building 7: POTUS walks by static displays and models relating to "Mission Planet Earth" -- visuals relate to ozone layer, deforrestation, Earth observation system, oceanic circulation; no press; background: sci-fi; right out of James Bond as Mel put it [yes Mel was the lead today]

Tour building 10: POTUS photo opp with TOPEX satellite [joint project with France]:oceanography satellite to be launched sometime July 92; TOPEX/POSEIDON mission will define the surface height of world oceans with an accuracy and precision for studies of ocean circulation, variability of circulation and tides

2 Remarks in Auditorium [Building 8]: Off Stage Announce at 2:45 p.m.; backdrop 14'X 14' photo of the planet earth [from Apollo 17]

Audience: 400 Goddard employees [civil service and contract]; dignitaries: EPA Administrator Bill Reilley; Cong. Connie Morella, Cong. Hoyer, Sen. Mikulski, NASA Admin. Dan Goldin; Goddard Center Dir. Dr. John Klineberg

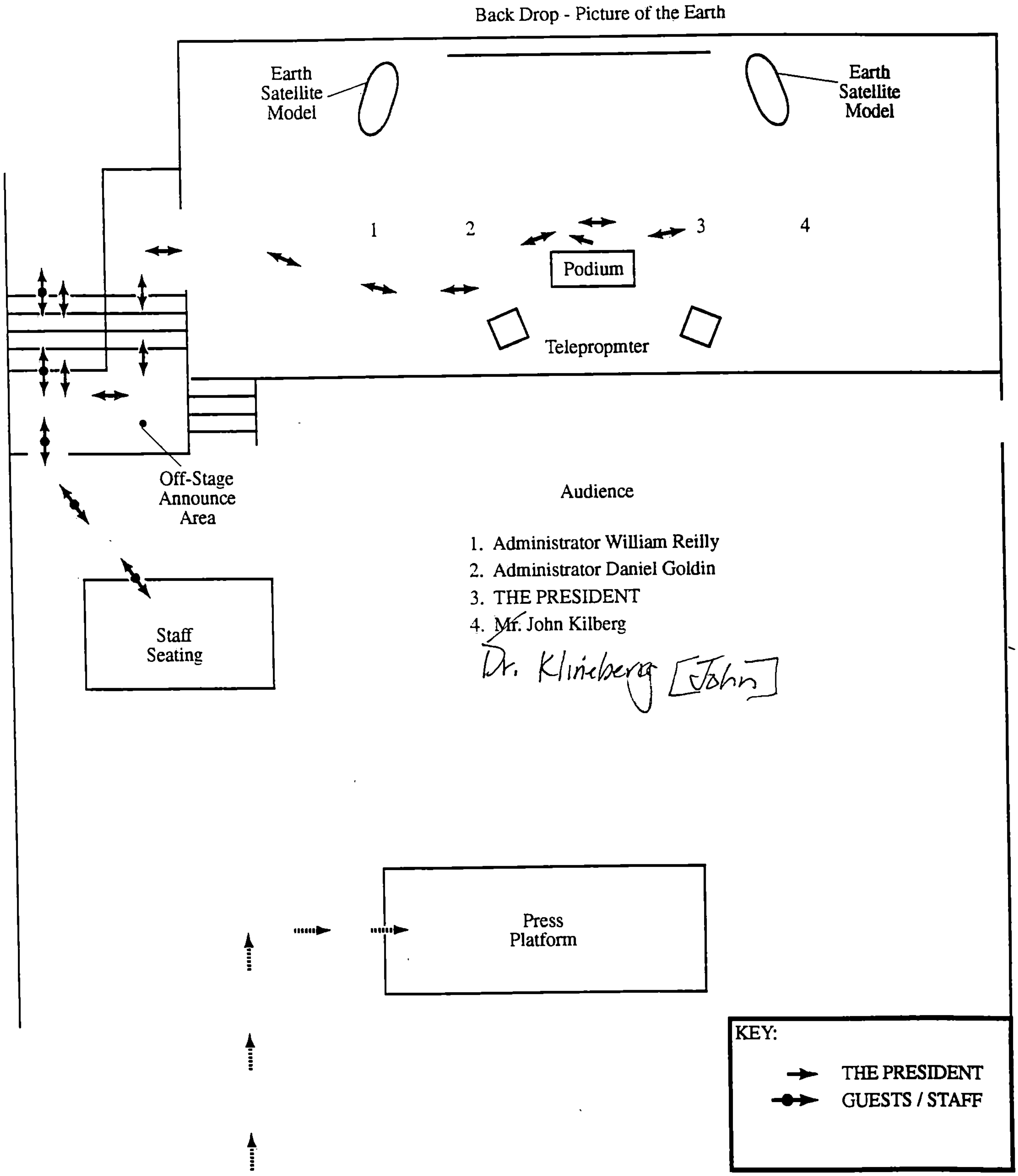
Klineberg intro Goldin; Goldin intro POTUS

+++++Teleprompter ordered++++++

CONTACTS: LEAD - Mark Koro PRESS - Bobby Carr
TRIP - Patty Conrad WHCA - Debbie McGhee

GODDARD PIO - Jan Ruff (301) 286-6255
Assistant - Carl Polesky ext. 8982

TAB E
GREENBELT, MARYLAND
NASA Goddard Space Flight Center
Building 8 - Auditorium
Overview Diagram
Monday, June 1, 1992



THE WHITE HOUSE

WASHINGTON

SCHEDULE OF THE PRESIDENT

FOR

WASHINGTON, D.C.

MONDAY, JUNE 1, 1992

EVENTS:

Tour and Briefing Goddard Space Flight Center
Address Goddard Space Flight Center Employees

DRESS:

Men - Business Suit
Women - Day Dress

CONTACTS:

Office of Presidential Advance
Ed Murnane - 202/456-7565

Trip Coordinator
Patricia L. Conrad - 202/456-7565

ADVANCE:

Mark Koro	- LEAD	Brad Edgar	- SITE
Bobby Carr	- PRESS	Lloyd Owens	- SITE
Gary Hollis	- USSS	Tina Rosenblatt	- PRESS SITE
Wayne Justice	- MIL. AIDE		
Debbie McGee	- WHCA		
Lee Viverette	- HMX		

WEATHER:

Partly Cloudy/Low 70's

SCHEDULE OF THE PRESIDENT

FOR

WASHINGTON, D.C.

MONDAY, JUNE 1, 1992

GUEST AND STAFF INSTRUCTIONS:	
1:00 pm	Vans depart West Basement en route Goddard Space Flight Center.
	Immediately following event, Guests and Staff not manifested on Nighthawk II will be escorted to vans for return to White House.

1:30 pm THE PRESIDENT boards Marine One and departs Camp David, Maryland en route Goddard Space Flight Center.

(Flying Time: 30 Minutes)

2:00 pm THE PRESIDENT arrives Goddard Landing Zone, Goddard Space Flight Center and proceeds to Motorcade.

Met by:

Mr. Daniel Goldin
Administrator, NASA

Mr. John Klineberg
Director, Goddard Space Flight Center

Mr. Peter Burr
Deputy Director, Goddard Space Flight Center

2:05 pm THE PRESIDENT boards Motorcade and departs Goddard Landing Zone en route Building Seven.

MOTORCADE ASSIGNMENTS:

Lead	M. Koro
Spare	Doctor B. Farish
LIMO	THE PRESIDENT
Follow Up	
Control	Mil. Aide
Support	M. Fitzwater M. Lukens Official Photographer Medic
WHCA	
Camera I	J. Herrick
Staff I	
Guest I	Adm. Reilly D. Goldin J. Klineberg
Staff Van	All Remaining Staff
Press Van I	M. Busch
Press Van II	

(Drive Time: 5 Minutes)

2:10 pm — THE PRESIDENT arrives Building Seven and proceeds to Tour Area.

Met by:

Mr. Len Fisk
Associate Administrator at NASA for Space Science and Applications

EVENT: TOUR AND BRIEFING OF GODDARD SPACE FLIGHT CENTER

EXPANDED POOL

TOUR

2:12 pm — THE PRESIDENT arrives Tour Area and begins participation in Tour and Briefing.

2:32 pm — THE PRESIDENT concludes participation in Tour and Briefing, departs Tour Area and proceeds to Motorcade.

2:35 pm — THE PRESIDENT boards Motorcade and departs Building Seven en route Building Eight.

MOTORCADE ASSIGNMENTS:

Same as on Arrival.

(Drive Time: 5 Minutes)

2:40 pm — THE PRESIDENT arrives Building Eight and proceeds to Auditorium Off-Stage Announcement Area.

2:42 pm THE PRESIDENT arrives Auditorium Off-Stage Announcement Area and holds briefly.

NOTE: Stage Guests will be announced at this time.

EVENT: ADDRESS GODDARD SPACE FLIGHT CENTER EMPLOYEES

OPEN PRESS

OFF-STAGE ANNOUNCEMENT

REMARKS

TELEPROMPTER

2:45 pm THE PRESIDENT is announced onto Stage and proceeds to Seat.

2:46 pm Mr. Goldin gives brief remarks.

2:50 pm THE PRESIDENT is introduced for Remarks by Mr. Daniel Goldin, NASA Administrator.

2:51 pm THE PRESIDENT Remarks.

3:05 pm THE PRESIDENT concludes Remarks, departs Stage and proceeds to Motorcade.

NOTE: Six police photos will be taken at this time.

3:10 pm THE PRESIDENT boards Motorcade and departs Building Eight, Goddard Space Flight Center en route Goddard Landing Zone.

MOTORCADE ASSIGNMENTS:

Same as on Arrival.

(Drive Time: 5 Minutes)

3:15 pm THE PRESIDENT arrives Goddard Landing Zone and proceeds to Marine One.

3:20 pm THE PRESIDENT boards Marine One and departs Goddard Landing Zone, Greenbelt, Maryland en route White House.

MARINE ONE:

THE PRESIDENT
S. Skinner
Gen. Scowcroft
M. Fitzwater
D. Valdez
B. Farish
Doctor
Mil. Aide
2 USSS

NIGHTHAWK II

LCDR W. Justice
M. Lukens
6 USSS
WHCA T/O
Medic

(Flying Time: 10 Minutes)

3:30 pm THE PRESIDENT arrives White House.

THE WHITE HOUSE

WASHINGTON

VISIT OF THE PRESIDENT

TO

WASHINGTON, D.C.

MONDAY, JUNE 1, 1992

EVENT: Tour and Briefing of Goddard Space Flight Center

DATE: Monday, June 1, 1992

TIME: 2:10 pm - 2:30 pm

LOCATION: Tour Area, Building Seven, Goddard Space Flight Center

ATTENDEES: 5

PRESS: Expanded Pool

SCENARIO: THE PRESIDENT arrives Goddard Landing Zone, Goddard Space Flight Center, Greenbelt, Maryland and is met by: Mr. Daniel Goldin, Administrator, NASA; Mr. John Klineberg, Director, Goddard Space Flight Center; and Mr. Peter Burr, Deputy Director, Goddard Space Flight Center. Following the greetings, THE PRESIDENT boards Motorcade and departs Landing Zone en route Building Seven. Upon arrival at Building Seven, THE PRESIDENT is met by Mr. Len Fisk, Associate Administrator at NASA for Science and Applications. Following the greeting, THE PRESIDENT proceeds to Tour Area. THE PRESIDENT arrives Tour Area and begins participation in Tour and Briefing. THE PRESIDENT concludes participation in Tour and Briefing, departs Tour Area and proceeds to Motorcade. THE PRESIDENT boards Motorcade and departs Building Seven en route Building Eight.

THE PRESIDENT will tour: a Thermal Chamber display; a SAMPEX Satellite Payload, designed by three Laurel, Maryland High School students which will be launched in a satellite in June 1992; a series of static displays of NASA Earth Satellite missions concerning deforestation and earth observation systems; and the TOPEX Satellite which collects oceanographic information and will be launched in July 1992.

THE WHITE HOUSE

WASHINGTON

VISIT OF THE PRESIDENT

TO

WASHINGTON, D.C.

MONDAY, JUNE 1, 1992

EVENT: Address Goddard Space Flight Center Employees

DATE: Monday, June 1, 1992

TIME: 2:40 pm - 3:05 pm

LOCATION: Auditorium, Building Eight, Goddard Space Flight Center

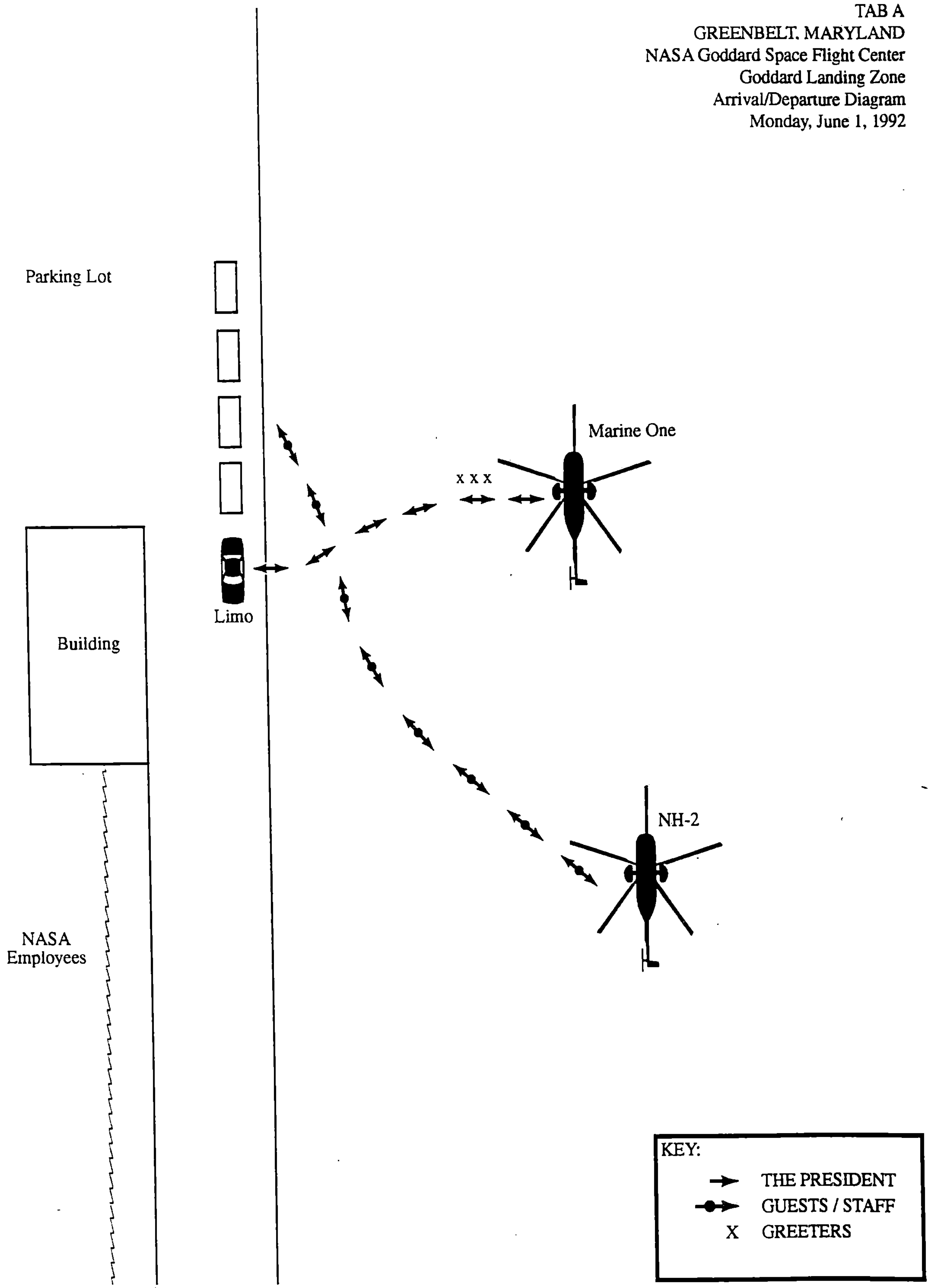
ATTENDEES: 350

PRESS: Open

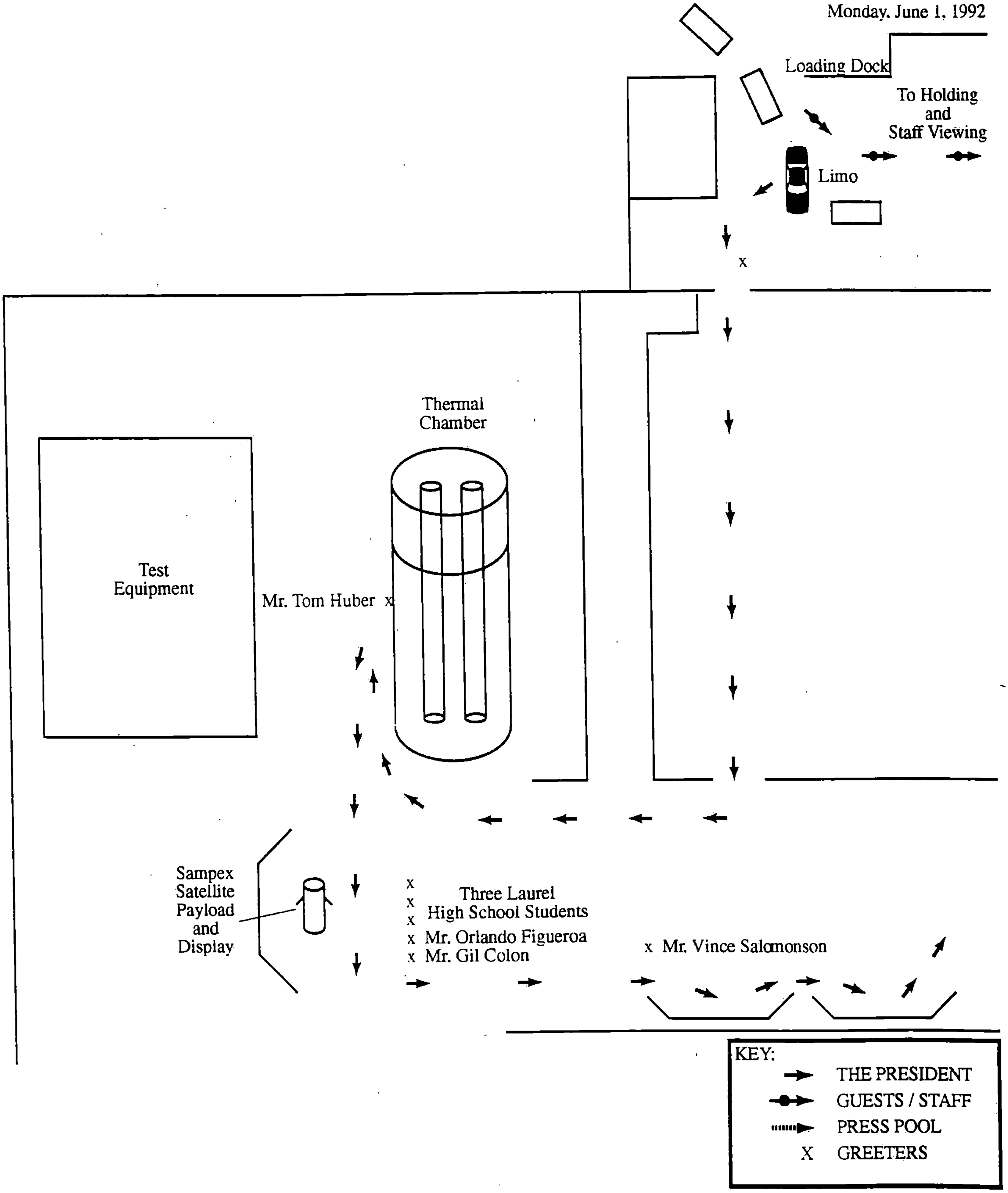
SCENARIO: THE PRESIDENT arrives Building Eight and proceeds to Auditorium Off-Stage Announcement Area. THE PRESIDENT arrives Auditorium Off-Stage Announcement Area and holds briefly. THE PRESIDENT is announced onto Stage and proceeds to Seat (Enter Stage Right). Mr. Daniel Goldin, Administrator, NASA gives brief remarks and introduces THE PRESIDENT for Remarks. THE PRESIDENT Remarks. THE PRESIDENT concludes Remarks, departs Stage and proceeds to Motorcade (Exit Stage Right). (NOTE: Six police photos will be taken at this time.) THE PRESIDENT boards Motorcade and departs Building Eight, Goddard Space Flight Center en route Goddard Landing Zone. THE PRESIDENT arrives Goddard Landing Zone, boards Marine One and departs Goddard Space Flight Center, Greenbelt, Maryland en route White House.

The backdrop for Remarks will be a large photo from space of the earth. The Press Platform is straight on at a 50 ft. throw.

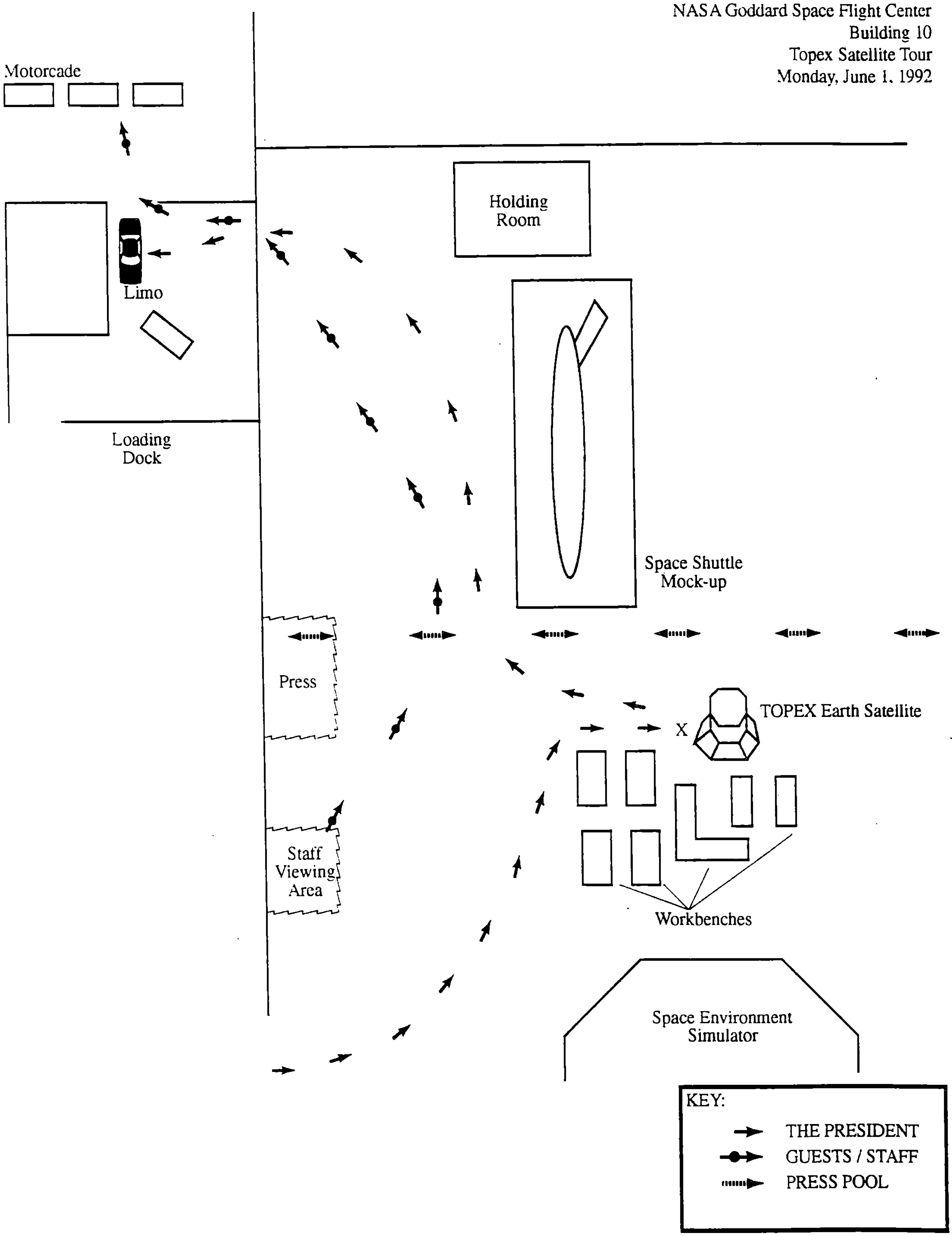
TAB A
GREENBELT, MARYLAND
NASA Goddard Space Flight Center
Goddard Landing Zone
Arrival/Departure Diagram
Monday, June 1, 1992



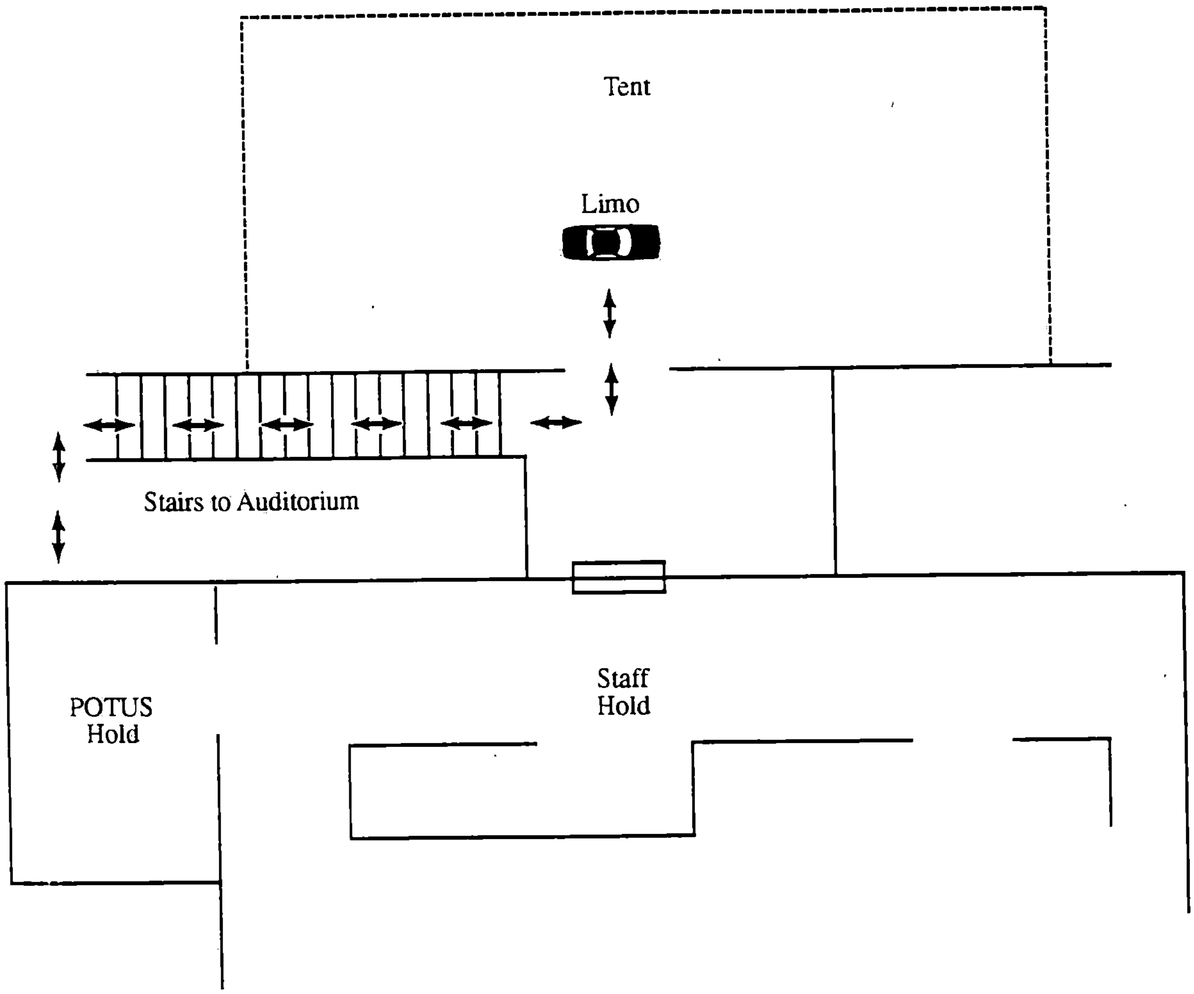
TAB B
GREENBELT, MARYLAND
NASA Goddard Space Flight Center
Building 7
Tour Site
Monday, June 1, 1992



TAB C
GREENBELT, MARYLAND
NASA Goddard Space Flight Center
Building 10
Topex Satellite Tour
Monday, June 1, 1992



TAB D
GREENBELT. MARYLAND
NASA Goddard Space Flight Center
Building 8 - Auditorium
Arrival/Departure Diagram
Monday, June 1. 1992



KEY:

→ THE PRESIDENT

THE WHITE HOUSE

WASHINGTON

May 28, 1992

Hi!

MEMORANDUM FOR JEANE BUNTON
RESEARCH ASSISTANT
OFFICE OF COMMUNICATIONS

FROM: JANE BARNETT
ASSOCIATE DIRECTOR
OFFICE OF PUBLIC LIAISON

Jane

SUBJECT: RIO SPEECH

Enclosed is some more information from Laurel Springs School about their environmental efforts. I thought this might be useful for the upcoming Rio speech?

Laurel Springs Environmental Project
P.O. Box 1440
Ojai, CA 93024

May 22, 1992

Dear Ms. Leonard,

Thank you very much for your kind response. Our class was very excited to hear from you. We have enclosed a blank Earth Treaty as well as some completed Earth Treaties for you to look at. The blank one is for you to comple if you so desire. The main purpose is for you to make a promise - most importantly to yoursel to do certain things to help the earth, to talk ab places in nature you love, or just feelings you have about the earth in general.

We hope this will provide you with the insight to our project that you needed. If you need anything more, please feel free to contact us.

Sincerely,
Rivkeh Wolk
Student Administrator

EARTH TREATY

Laurel Springs Environmental Project

P.O. Box 1003, Ojai, California 93024

Laurel Springs School
P.O. Box 1440
Ojai, CA 93024
5/20/92

Jane Barnett Leonard
The White House
Office of Public Liaison
Washington, DC

Dear Ms. Leonard,

Thank you for your letter and interest in the Laurel Springs School Environmental Project. We are excited about the inspiring work that our students are doing and appreciate your acknowledgement of them.

I have enclosed copies of "Earth Treaties" from 5 different schools we have gone to. We have found that these Treaties (developed by the Center for International Cooperation), give students a tremendous opportunity to make a commitment to becoming responsible and involved individuals. The Earth Treaties give children from different walks of life and racial backgrounds a chance to work together for a common purpose. It has been a very moving experience to read the Treaties written by these children.

The Laurel Springs students asked me to enclose a blank "Earth Treaty" for you. They wanted me to tell you that these treaties are written by individuals of all ages and they didn't want you to feel left out. Rivkeh Wolk, one of our students, has written you a personal letter about this.

I have also enclosed a poster that was printed by the United Nations Environmental Project in honor of the 1992 UN Youth Forum. We were one of only 11 schools from around the world that was highlighted.

We would be honored to travel to Washington, and personally give President Bush the Earth Treaties we have collected this year, copies of which will be presented at the Earth Summit in Brazil. I believe it would be very rewarding for our students to talk with President Bush and this would send a message to all students that every child counts and can make a difference.

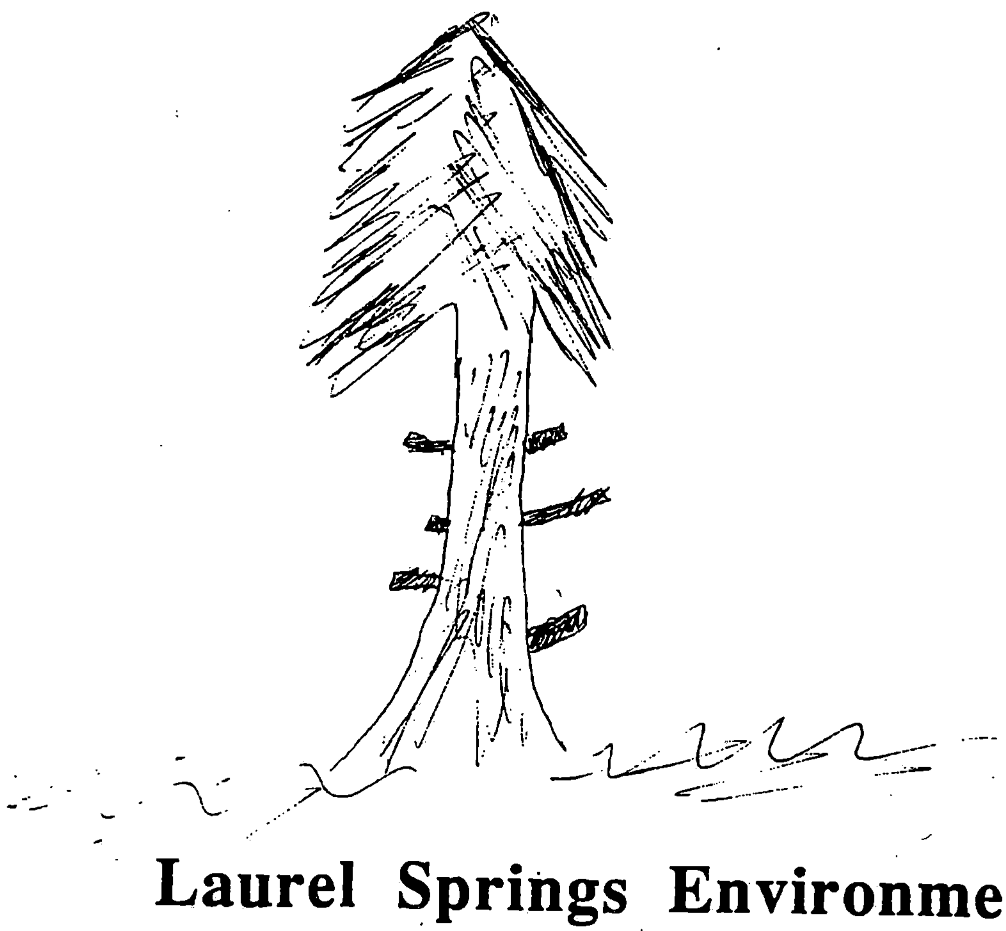
Sincerely,

Marilyn Mosley, Director

EARTH TREATY

Dear Wild life Yosemite Valley,

Next time I visit you I
will plant a tree & clean up any garbage you might
have, I visit you about 4 times a year becau
my Dad lives right next door to you. I love
your Pine & redwood trees. They are so beautifu
I love nature & always will & will clean up your
envirment.



Sincerely,
Josh

Laurel Springs Environmental Project

P.O. Box 1003, Ojai, California 93024

EARTH TREATY

Dear Mother Earth,

I ponder now and think of that special place in the Mountians of Aspen, Colorado. I think of the love I feel for that spot. The clean air, freshly rained trees and abundant nature surounding me. How I awed at how all of these Basalt rocks, how these giant boulders, were put in this one spot. I in my inexperience with nature find myself rationalizing that perhaps a heli-copter, or a large gas filled bulldozer pushed them down this slope to my backyard. Ah, but no, it is Nature. I reall bounding down these redish rocks, like a skier. It is truly a maze of boulders. The first time I climbed up them it was a feat to reach the top.

Now the verdure of my mind recalls the first snow, and the wonder it brings to me, and I thank you.

I feel my comittment in persearving this for my children.

– jacob narayan

Laurel Springs Environmental Project

P.O. Box 1003, Ojai, California 93024

EARTH TREATY

Dear Friend,

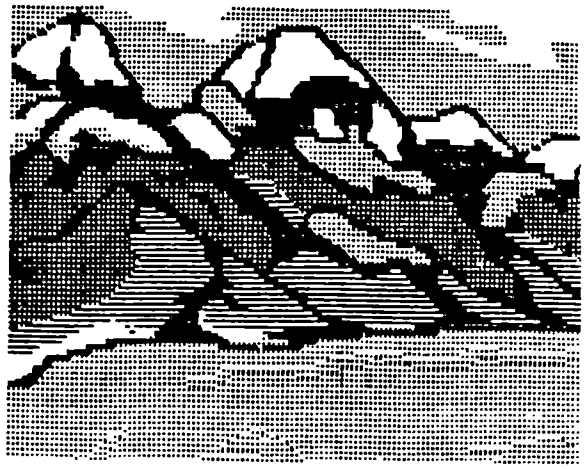
I really love your beautiful beaches and big waves. I dread the sight of toxins and pollution in the faces of your waves. The death of all marine life will surely follow. I refuse to let thi happen. The action I will take will be great. Too bad I don't know where to begin. Never fear friend, becau: LUGGIE is hear to save you.

Your Friend,
[signature]

Laurel Springs Environmental Project

P.O. Box 1003, Ojai, California 93024

EARTH TREATY



para emejorar el mundo
ana recoder la basura
para que todas partes
del mundo esten limpios
y tambien para que
no se coman la vasura
los animales y tambien
que este bien limpia
la plalla y nos puedamos
vañar

Maritza

Laurel Springs Environmental Project

P.O. Box 1003, Ojai, California 93024

Amber Pape, Laura [illegible], Marc Holden, Adam Norton, Cody Pape.

EARTH TREATY

1/25/92

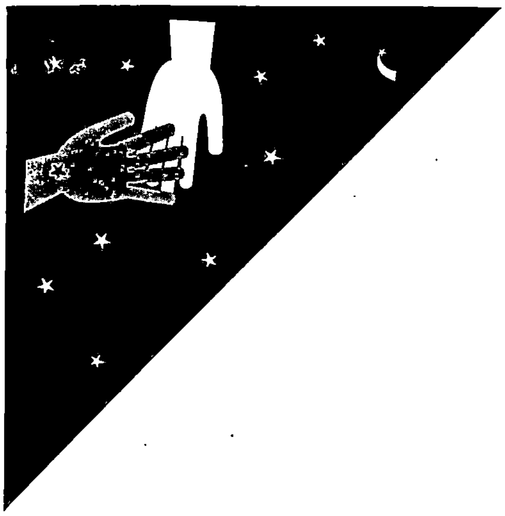
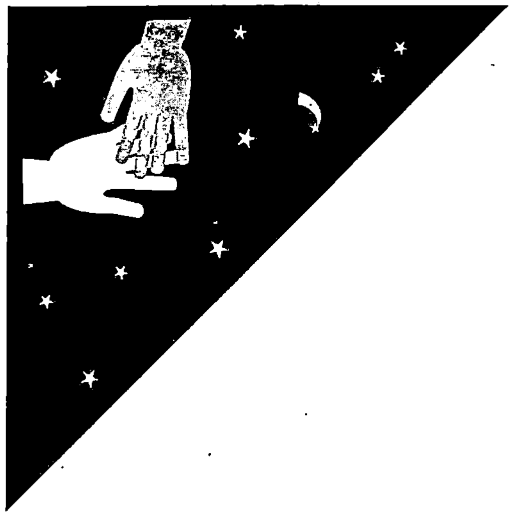
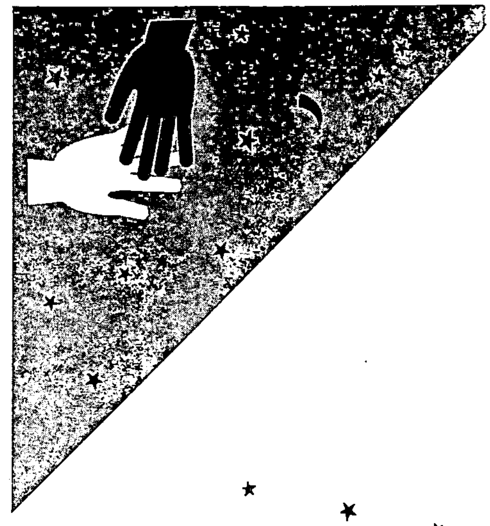
Dear Mother Earth,

\# Vernal Falls, Yosemite,
your rainbow mist
totaly inspired me,
360 stone steps in all,
your dew covered trees stood so tall,
We promise to protect and provide,
Upon your future we must decide,
Pollution here will not reside,
we hope will result in your rebirth.

Sincerely,
The children from the Santa Ynez Valley Family Scho.

Laurel Springs Environmental Project

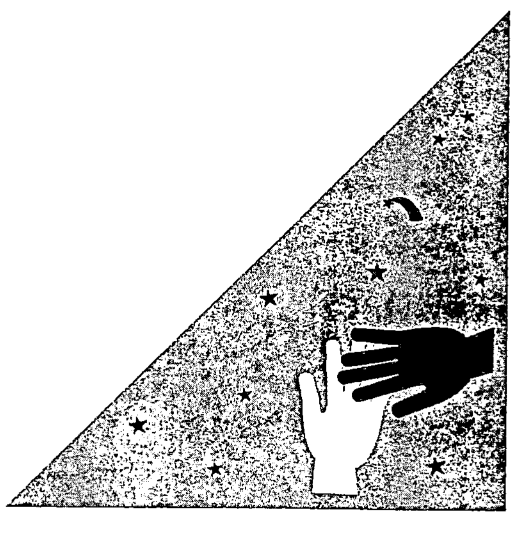
P.O. Box 1003, Ojai, California 93024


GLOBAL YOUTH FORUM '92
CASE STUDIES

MAY 14 - 15, 1992, UNITED NATIONS, NEW YORK CITY






RELEASE: 92-64

EUVE SATELLITE TO EXPLORE NEWLY OPENED WINDOW

The extreme ultraviolet is one of the least-studied portions of the electromagnetic spectrum. Now, with the launch of NASA's Extreme Ultraviolet Explorer (EUVE) satellite, this new window on the universe will be opened to detailed study.

EUVE, NASA's 67th Explorer mission, will be the first satellite to make both spectroscopic and wide-band observations over the entire extreme ultraviolet (EUV) region. It is scheduled for launch aboard a McDonnell Douglas Delta II expendable launch vehicle from Cape Canaveral Air Force Station, Fla., on June 4, 1992. EUVE is designed to operate for at least 18 months from a 340-mile Earth orbit and will orbit the Earth every 96 minutes.

This unique satellite consists of four telescopes -- the most powerful set of EUV telescopes ever flown. Three instruments will map the entire sky to determine the existence, direction, brightness and temperature of sources of extreme ultraviolet radiation. The fourth instrument is designed to make spectroscopic observations to determine the composition and temperature of the EUV sources discovered during the sky mapping. Some of the objects EUVE is likely to detect and study are white dwarf stars, binary star systems and the hot outer atmospheres (coronae) of stars similar to the sun.

From the many objects of astronomical interest discovered during the EUVE all-sky survey and other objects already thought to be observable in the extreme ultraviolet, guest observers will propose to study targets using the spacecraft's fourth instrument, the extreme ultraviolet spectrometer.

The EUVE is one of a long line of relatively low-cost, small-to-moderately sized missions that make up the Explorer program. Since the Explorer Program began in 1958, these missions have given scientists worldwide a new understanding of astronomy and astrophysics, providing them an opportunity to probe nearly every region of the electromagnetic spectrum from infrared radiation to gamma rays.

Goddard Space Flight Center, Greenbelt, Md., is responsible for the design, construction, integration, checkout and operation of EUVE. The spacecraft's science instrumentation was designed, constructed and calibrated by the Space Science Laboratories of the University of California, Berkeley. The EUVE is managed by Goddard for NASA's Office of Space Science and Applications.

- end -

Small-Class Explorers (SMEX)

Objective

The objectives of the Small-Class Explorers (SMEX) are to enable new areas of exploration and special topic investigations in space astrophysics, and atmospheric and space plasma physics; and to provide a quick reaction research capability, through small sized missions and frequent launch opportunities.

Description

SMEX payloads are modest size, modest capability payloads, up to 500 pounds, which make major contributions a number of NASA's space science and applications disciplines.

The Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX) will be a Zenith-pointing satellite in near-polar orbit which will carry a payload of four particle detectors, each of which addresses a subset of the required measurements. The instruments can measure the electron and ion composition of energetic particle populations from approximately 0.4 million electron Volts (MeV)/nucleon to hundreds of MeV/nucleon using a coordinated set of detectors of excellent charge and mass resolution, and with higher sensitivity than previously flown instruments. SAMPEX will: 1) provide measurements on how some ions from partially ionized plasmas such as the solar corona and the very local interstellar medium are energized to nearly the speed of light by shocks or other means and reach the Earth; and, 2) monitor fluxes of fast electrons which come from space onto the Earth's atmosphere and are important in the chain of chemical reactions leading to the formation and depletion of ozone.

The Fast Auroral Snapshot Explorer (FAST) will collect measurements of electrical and magnetic fields and simultaneously correlate these with their effects on the electron and ions at altitudes of 350 to 4,200 kilometers with very high time resolution. These observations will be complemented by data from other spacecraft at higher altitudes, which will be observing fields and particles and photographing the aurora from above, thus placing FAST observations in global context. At the same time, auroral observatories and geomagnetic stations on the ground will provide measurements on how energetic processes that FAST observes affect the Earth.

The Submillimeter Wave Astronomy Satellite (SWAS) will be a three-axis stabilized, stellar-pointing spacecraft launched into a 38 degree, 600 kilometer, circular orbit. It will have a 71 centimeter off-axis Cassegrain antenna, state-of-the-art heterodyne receivers cooled to 150 degrees Kelvin (K) by passive radiators, and the highest quality Acousto-Optical Spectrometer (AOS) to be provided by the Federal Republic of Germany (FRG). In less than 20 minutes of integration, SWAS will be able to measure the full range of predicted H_2O, O_2, C, $_{13}CO$, and $H_{2\,18}O$ abundances in any giant molecular cloud core within 1 kiloparsec. Of particular importance, the AOS will permit simultaneous observation of four of these lines at any one time, thus maximizing the observing efficiency and substantially increasing confidence in the spatial coincidence of maps made in the various lines. Local clouds (diameter less than 1 kiloparsec), such as Orion, Taurus, Ophiuchi, and Perseus, will be mapped in each of the four lines. A survey of galactic Giant Molecular Clouds will be performed, and a number of gas rich extra-galactic sources, such as the Magellanic Clouds, will be observed.

Small-Class Explorers (SMEX) (Continued)

Description (Continued)

	SAMPEX	FAST	SWAS
Launch Date:	June 1992	September 1994	June 1995
Payload:	4 particle detectors	4 instruments	telescope & receivers
Orbit:	82 degree inclination; 550 x 657 km (297 x 355 nm) altitude, circular	83 degree inclination; 350 x 4,200 km (189 x 2,268 nm), altitude, non-Sun synchronous	38 degree inclination; 600 km (324 nm) altitude
Design Life:	3 years	1 year	3 years
Length:	1.5 m (5 ft) (stowed)	0.86 m (3 ft) (stowed)	1.65 m (5 ft)
Weight:	158 kg (348 lbs)	162 kg (356 lbs)	218.6 kg (482 lbs)
Diameter:	0.86 m (3 ft) (stowed)	1.17 (stowed)	.97 m (3 ft)
Launch Vehicle:	SCOUT	Enhanced Pegasus	Pegasus
International Participation:	FRG	None	FRG

Instruments/Investigations/Principal Investigator

SAMPEX

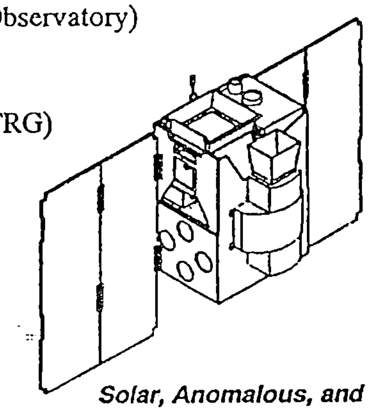
Principal Investigator - G. Mason (University of Maryland)
Low Energy Ion Composition Analyzer (LEICA) - (University of Maryland)
Heavy Ion Large Telescope (HILT) - (Max Planck Institute for Extraterrestrial Physics - FRG)
Mass Spectrometer Telescope (MAST) - (California Institute of Technology)
Proton-Electron Telescope (PET) - (California Institute of Technology)

FAST

Principal Investigator - C. Carlson (University of California-Berkeley)
Electric Field Plasma Experiment - (University of California-Berkeley)
Quadrispherical Electrostatic Electron Analyzer - (University of California-Berkeley)
Time-of-flight Energy Angle Mass Spectrograph - (University of New Hampshire and Lockheed Palo Alto Research Laboratory)
Magnetometer - (University of California-Los Angeles)

SWAS

Principal Investigator - G. Melnick (Smithsonian Astrophysical Observatory)
Antenna, Star Tracker, Instrument Integration - (Ball Aerospace)
Submillimeter Heterodyne Receiver (SHR) - (Millitech)
Acousto-Optical Spectrometer (AOS) - (University of Cologne - FRG)

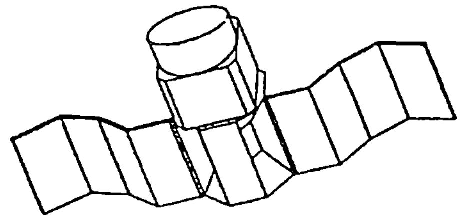


Solar, Anomalous, and Magnetospheric Particle Explorer

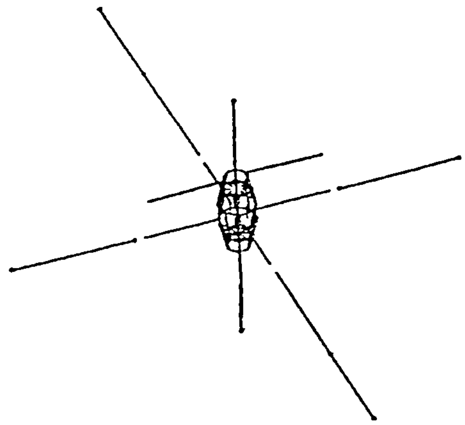
Small-Class Explorers (SMEX) (Continued)

Management

NASA Headquarters
D. Gilman, Program Manager
V. Jones, SAMPEX Program Scientist
L. Caroff, SWAS Program Scientist
E. Whipple, FAST Program Scientist
Goddard Space Flight Center
O. Figueroa, Project Manager
D. Baker, Project Scientist
G. Colon, SAMPEX Mission Manager
D. Betz, SWAS Mission Manager
G. Chin, SWAS Mission Scientist
T. Gehringer, FAST Mission Manager
Major Contractors
University of Maryland (SAMPEX)
California Institute of Technology (SAMPEX)
Max Planck Institute (SAMPEX)
Aerospace Corporation (SAMPEX)
Smithsonian Astrophysical Observatory (SWAS)
Ball Aerospace (SWAS)
University of Cologne (SWAS)
Millitech (SWAS)
University of California-Berkeley (FAST)
Lockheed Palo Alto Research Laboratory (FAST)
University of New Hampshire (FAST)



Submillimeter Wave Astronomy Satellite



Fast Auroral Snapshot Explorer

Status

<u>SAMPEX</u>
Critical Design Review (CDR) was completed in June 1990. Instrument integration began in September 1991. Currently in flight integration for a June 1992 launch.

<u>FAST</u>
Preliminary Review completed in November 1991. Currently being developed and built for a 1994 launch.

<u>SWAS</u>
Concept Review was completed during June 1990. The instruments and spacecraft began development in December 1991 for a 1995 launch.

NASA Facts

National Aeronautics and
Space Administration

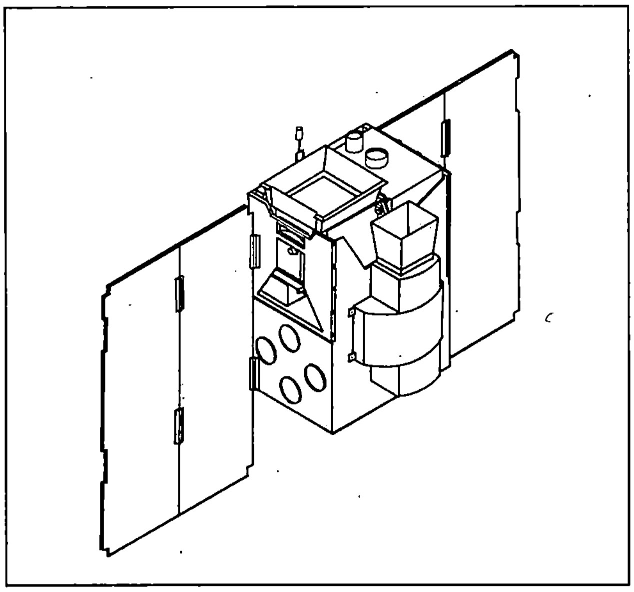
Goddard Space Flight Center
Greenbelt, Maryland 20771
AC 301 286-8955

Small Explorer (SMEX) Program

The Small Explorer Project (SMEX) is a NASA initiative to provide frequent flight opportunities for relatively inexpensive space missions. This international program involves spacecraft which weigh approximately 400 pounds (180 kg) each and can be launched into Earth orbit by Scout and Pegasus launch vehicles.

In spite of their small size, SMEX missions will investigate some of the most important questions raised in astrophysics and space physics. The program will conduct focused investigations which probe conditions in unique parts of space, complement major missions, prove new scientific concepts or make significant contributions to space science in other ways.

Capitalizing on availability of mature or developed instrumentation to carry out scientific investigations allows SMEX missions to be accomplished quickly and frequently. It is a goal of the SMEX Program to bring each mission to launch readiness within three years after the start of detailed design activities.



SAMPEX

By having a short development time and small size, the SMEX missions allow critical training opportunities for the next generation of scientists and engineers.

The SMEX program is managed by the Engineering Directorate of Goddard Space Flight Center in Greenbelt, MD, for NASA's Office of Space Science and Applications. The project manager for SMEX is Orlando Figueroa. Project scientist is Dr. Daniel N. Baker. The Program Manager at NASA Headquarters is Dr. David A. Gilman.

Background

The Small Explorers are part of NASA's Explorer Program which since 1958 has launched small and moderate-sized science mission payloads into space. Explorer missions have served both to pioneer new fields of space science and to investigate in detail one particular aspect of science.

With the launch of the Japanese Solar-A mission in August 1991, 68 U.S. and cooperative-international scientific space missions have been part of the Explorer Program

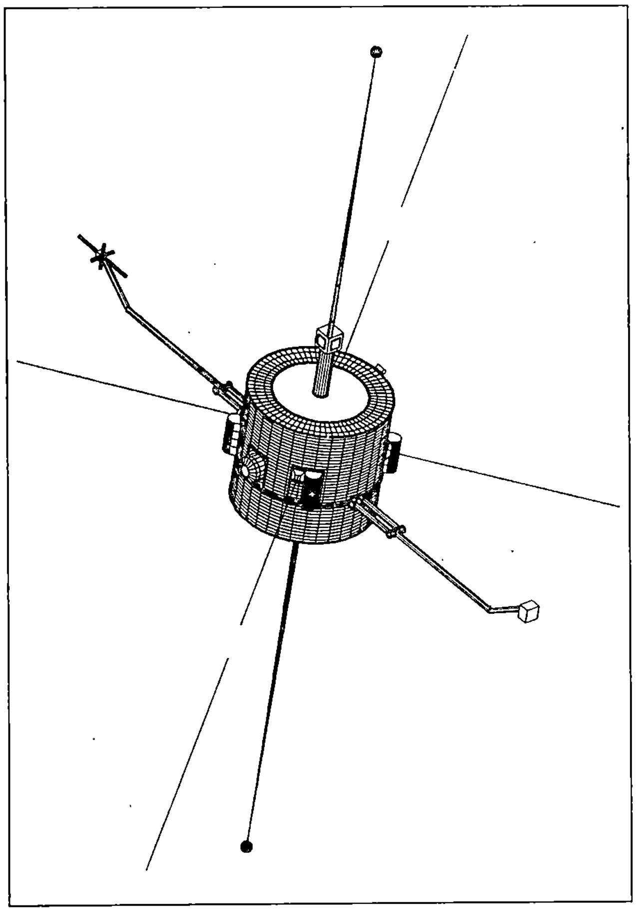
For example, the Goddard-managed International Ultraviolet Explorer (IUE), continues to operate after more than 13 years in Earth orbit. The Cosmic Background Explorer (COBE), which is making dramatic contributions towards the scientific understanding of the origins of the universe, is another example of an Explorer mission managed by Goddard.

The Missions

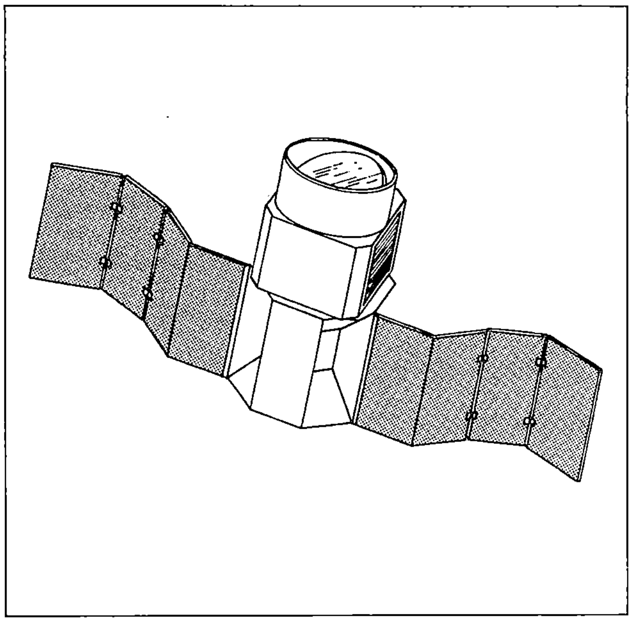
Three SMEX missions are currently approved. They are as follows:

- **SAMPEX** – The Solar Anomalous Magnetospheric Particle Explorer, scheduled for launch in June 1992, will collect data from unique parts of the Earth's magnetic field in order to study solar energetic particles, anomalous cosmic rays, galactic cosmic rays and magnetospheric electrons. Of the four instruments on SAMPEX, two were flown previously as Get Away Special (GAS) experiments on the space shuttle. Dr. Glenn M. Mason, University of Maryland, College Park, is principal investigator and there are 10 Co-Investigators from American and German institutions. The mission manager for SAMPEX is Gilberto Colon.

• **FAST** – The Fast Auroral Snapshot Explorer will investigate the processes thought to be responsible for producing the Earth's aurora. In studying these processes, FAST will complement investigations carried out simultaneously by missions of the International Solar Terrestrial Physics (ISTP) Program. FAST is scheduled for launch in September 1994. There are five instruments on FAST, four of which are similar to instruments that will be carried to other parts of space by the ISTP missions. Dr. Charles W. Carlson, University of California, Berkeley, is the principal investigator for FAST. There are four Co-Investigators from U.S. institutions. Mission manager for FAST is Timothy Gehringer.



FAST



SWAS

• **SWAS** – The Submillimeter Wave Astronomy Satellite is scheduled for launch in 1995. It will investigate the physical conditions, chemical composition, and energy release of immense, interstellar clouds of molecules and will relate these results to the formation of stars and planetary systems. SWAS will prove a new scientific concept by pioneering the investigation of these clouds at important radio frequencies that can only be seen from space. The principal investigator is Dr. Gary J. Melnick, of the Harvard-Smithsonian Center for Astrophysics, Cambridge, MA. Dr. Melnick will head a team of 11 Co-Investigators from institutions across the U.S. and Cologne, Germany. Both instruments on SWAS are similar to instruments used in ground observatories. The mission manager for SWAS is David Betz.

An Announcement of Opportunity for future Small Explorer missions is expected to be released in the first half of 1992.

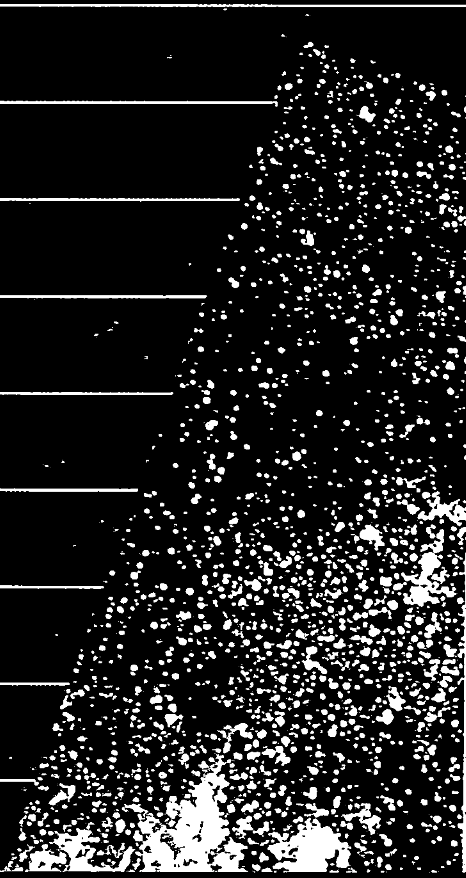
NASA

National
Aeronautics and
Space
Administration

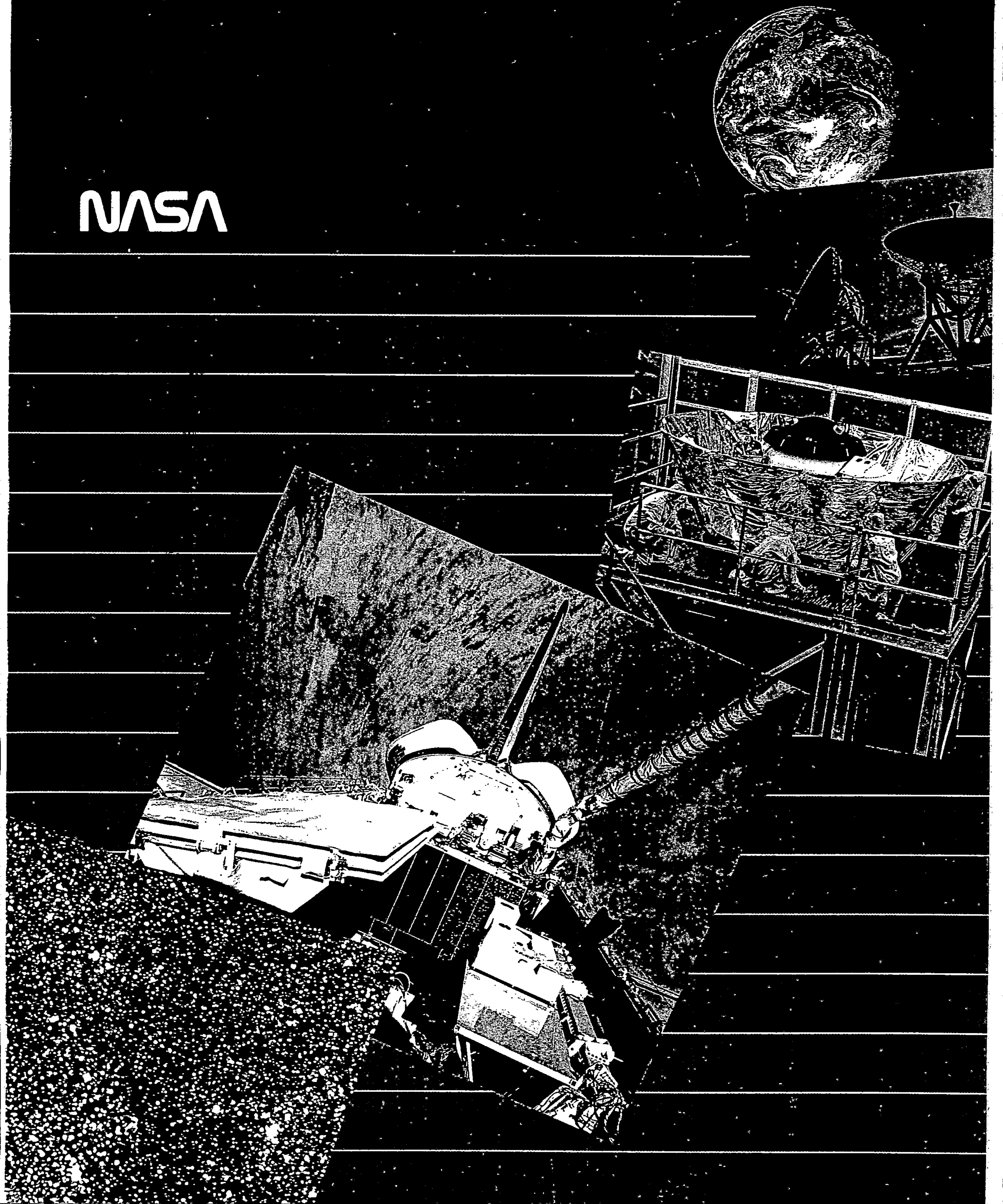
Goddard Space Flight Center

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771



Working Together
You and Goddard Space Flight Center

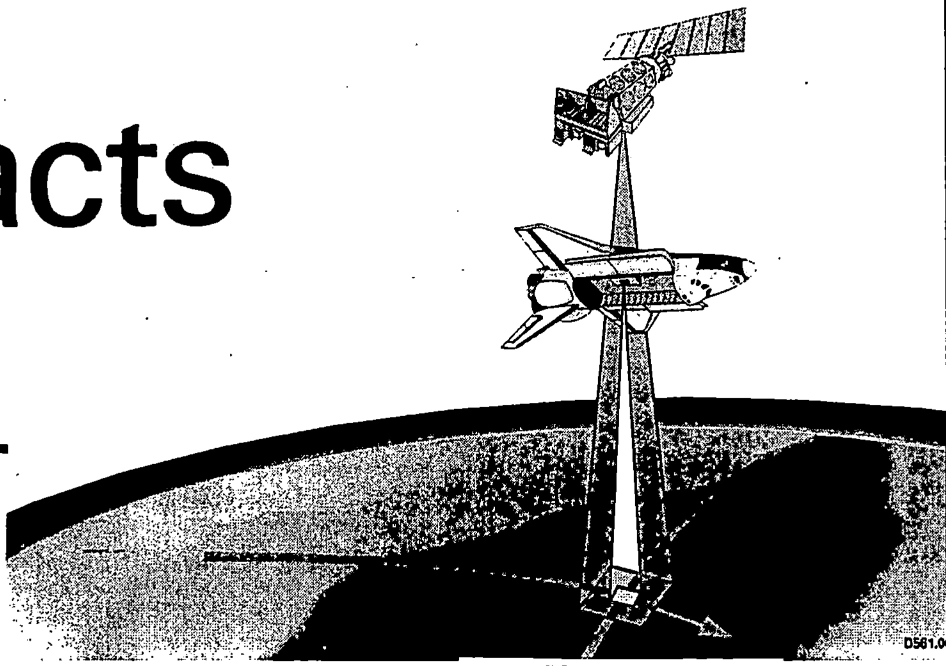


NASA

NASA Facts

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771
AC 301 286-8955



SSBUV In Orbit Calibration

SHUTTLE SOLAR BACKSCATTER ULTRAVIOLET (SSBUV) INSTRUMENT

The Shuttle Solar Backscatter Ultraviolet (SSBUV) instrument was developed by NASA's Goddard Space Flight Center to compare the observations of several ozone measuring instruments aboard the National Oceanic and Atmospheric Administration's NOAA-9 and NOAA-11 satellites and the NIMBUS-7 satellite. The SSBUV data are used to calibrate these instruments to ensure the most accurate readings possible for the detection of atmospheric ozone trends.

The SSBUV will help scientists solve the problem of data accuracy caused by calibration drift of Solar Backscatter Ultraviolet (SBUV) instruments on these satellites. The SSBUV uses the Space Shuttle's orbital flight path to assess instrument performance by directly comparing data from identical instruments aboard the NOAA spacecraft and the NIMBUS-7 as the space shuttle and the satellite pass over the same Earth location within an hour.

These orbital coincidences can occur 17 times a day.

The satellite-based SBUV instruments estimate the amount and height distribution of ozone in the upper atmosphere by measuring the incident solar ultraviolet radiation and ultraviolet radiation backscattered from the Earth's atmosphere. The SBUV measures these parameters in 12 discrete wavelength channels in the ultraviolet. Because ozone absorbs in the ultraviolet wavelengths, an ozone measurement can be derived by comparing the amount of incoming solar radiation to the amount backscattered by the atmosphere.

Working with Other Instruments

For STS-45, SSBUV is co-manifested with the ATLAS-1 payload which carries a compliment of Earth and Space science experiments. Currently, SSBUV is co-manifested with ATLAS on its next four flights scheduled through 1996.

Among other measurements, several Upper Atmosphere Research Satellite (UARS) instruments also will measure ozone. Simultaneous measurements by SSBUV and ATLAS with the UARS instruments will be a unique opportunity to tie in the detailed observations of the physics and chemistry of the stratosphere being made by UARS with the regular on-going SBUV ozone observations. These data sets can then be used as a baseline for detecting long-term changes in the stratosphere.

SSBUV's value lies in its ability to provide precisely calibrated, or verified, ozone measurements. The instrument is calibrated to a laboratory standard before flight, then is recalibrated during and after flight to ensure its accuracy. These laboratory standards are routinely calibrated at the National

Institute of Standards and Technology. The rigorous calibration provides a highly reliable standard to which data from the SBUV instruments can be compared.

Previous Flights

The three previous SSBUV flights occurred on STS-34 in October 1989, STS-41 in October 1990 and STS-43 in August 1991. NASA's goal is to fly SSBUV missions approximately once a year between 1989 and 2000 to provide precise calibration measurements across a full 11-year solar cycle.

After SSBUV's flight last August, the instrument was checked out at Kennedy Space Center, to make certain everything was working. The tape recorders then had their information removed and the data was sent to GSFC for processing. The payload was sent back to Goddard where the instrument was checked out and recalibrated. Then the payload was refurbished with new avionics, which interfaces with the orbiter power, data and command systems. Other repairs and hardware enhancement were made, SSBUV was reassembled, requalified and sent back to Kennedy Space Center. All of this happened in only four months. At the same time, data from previous flights are being reprocessed. All of this is accomplished with a team of only 12.

SSBUV's impact on our ability to accurately detect ozone trends was expected after approximately four flights. Data from the first flight has already been used to estimate ozone trends in the upper stratosphere since 1980. These results show a depletion of about 8 percent over 10 years, which is consistent with predictions of ozone depletion.

The SSBUV instrument and its flight support electronics, power, data and command systems are mounted in the space shuttle's payload bay in two flight canisters, that together weigh 900 pounds (410 kilograms). The Instrument Canister holds the SSBUV instrument, its aspect sensors and in-flight calibration system. Once in orbit, a motorized door assembly opens the canister to allow the SSBUV to view the Sun and Earth and closes to provide contamination protection and to perform in-flight calibrations. The Support Canister contains the avionics which includes the power, data, and command systems.

SSBUV will now obtain power from the space shuttle and will receive real-time ground commands and data acquisition which overcomes many operational limitations SSBUV was under on previous flights. This will allow enhanced SSBUV data gathering capabilities and an ability to coordinate measurements with the ATLAS and UARS instrument compliments. SSBUV commands will be sent from a Payload Operations Control Center (POCC) at Johnson Space Center, Houston, TX. SSBUV data will be received at Johnson and the Marshall Space Flight Center, Huntsville, AL. Marshall is responsible for managing the ATLAS payload and for integrating SSBUV science requirements into the mission timeline.

Ernest Hilsenrath of GSFC is the Principal Investigator, Don Williams is the Mission Manager. SSBUV is managed by GSFC for NASA's Office of Space Science and Applications.

#####

February 1992

NASA Status Report

National Aeronautics and
Space Administration

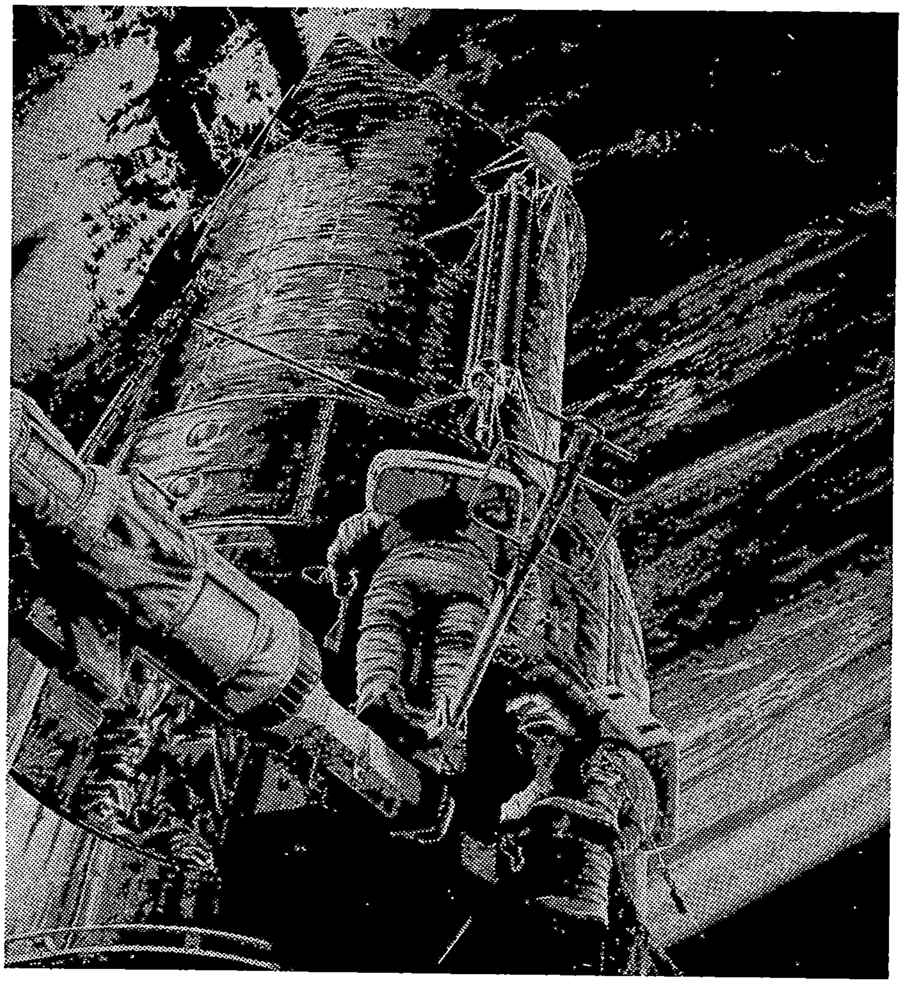
NASA Headquarters
Washington, DC

March 1992

The Hubble Space Telescope:
Report on Plans for the HST Servicing Mission

Background

The Hubble Space Telescope (HST) was launched on April 24,1990. By June 1990, two problems were discovered: spherical aberration of the primary mirror and jitter caused by the solar arrays. Image processing and spacecraft control software have compensated somewhat for both of these problems, but servicing is necessary to fix them. HST was designed for on-orbit servicing, to repair and refurbish the observatory and to upgrade its capabilities by installing advanced instruments. On-orbit servicing will permit correction of the spherical aberration and the solar array jitter.



Conceptual illustration of astronauts replacing instruments during the Hubble Space Telescope servicing mission.

(Ball Aerospace Systems Group, artist, Scott Kahler)

Mission Goals and Planning

The primary objective of the first HST servicing mission is to correct for spherical aberration in HST's primary mirror and replace faulty solar arrays.

The major constraint on NASA's ability to service HST on this mission is the amount of work that can be completed during the planned Space Shuttle flight. The current plan provides for 3 days of extravehicular activity (EVA) servicing, a day to redeploy HST and another day to assure the safe return of the Space Shuttle (for example, by manually closing the cargo bay doors if necessary). This amount of on-orbit work time provides for two optical fixes—the Wide Field/ Planetary Camera II (WF/PC II) and the Corrective Optics Space Telescope Axial Replacement (COSTAR); replacement of the solar arrays, two pairs of gyros and one gyro electronics box; and enough additional time to replace another subsystem that will be identified at a later date.

During the ongoing mission preparation, NASA is investigating methods to improve the efficiency of the work, so that any extra EVA time would provide a margin to assure the critical work required to restore essential HST capabilities is completed.

Mission Overview

Currently scheduled for launch in late 1993-early 1994, the orbiter will rendezvous with HST on the third day of the flight. HST will then be captured and secured in an upright position in the cargo bay for servicing. Working in pairs, on alternating days, the four EVA crewmembers will be spending three 6-hour work days performing the repairs.

Development has begun on astronaut simulations of on-orbit servicing operations to rehearse and optimize EVA repair work at Johnson Space Center's Weightless Environment Training Facility and Marshall Space Flight Center's Neutral Buoyancy Simulator (these large water tanks simulate the weightless environment of space). Early EVA training on individual components began this March. Other key events that will affect planning for the mission include the selection of a flight crew and a Shuttle cargo integration review in late 1992. Meanwhile, planning teams, including representatives of NASA Headquarters, Goddard Space Flight Center, Johnson Space Center, and Kennedy Space Center, will continue working on detailed and comprehensive procedures and time lines for this challenging mission.

Mission Cargo

Wide Field/Planetary Camera II

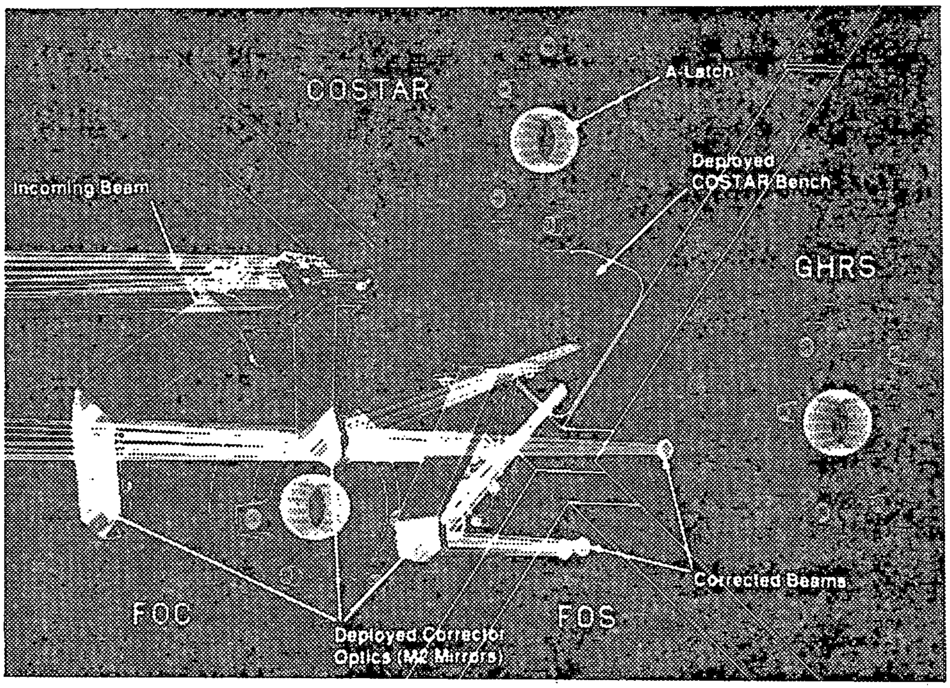
The Jet Propulsion Laboratory team that built HST's Wide Field/Planetary Camera (WF/PC) began developing a spare instrument in 1985. When the Hubble's mirror was found to be flawed, NASA and the WF/PC science team immediately began working on an optical correction that could be built into WF/PC II. The new design incorporates an optical correction by the refiguring of relay mirrors already in the optical train of the cameras. Each relay mirror is polished to a new "prescription" that will compensate for the incorrect figure on HST's primary mirror. Small actuators will fine-tune the positioning of these mirrors on orbit, ensuring the very precise alignment that is required.

Through a servicing bay door built into the side of HST, astronauts will slide out the 610-pound, wedge-shaped WF/PC I, as they would a giant drawer, and replace it with WF/PC II. The new instrument will have three wide field cameras and one planetary camera instead of the original eight. The WF/ PC II team chose to reduce the number of cameras to four in order to develop a system to align the corrective relay mirrors on-orbit remaining on schedule and within budget. Improved Charged Coupled Devices (CCDs) that were not available when the first WF/PC was built will be incorporated in WF/ PC II to improve its sensitivity, particularly in the ultraviolet.

WF/PC II is proceeding within its budget and, despite the complexity of the task, is on schedule to be delivered from the Jet Propulsion Laboratory to NASA's Goddard Space Flight Center in the spring of 1993. WF/PC II will be tested with spacecraft and ground system simulators there before being sent to Kennedy Space Center to be integrated with the Space Shuttle.

Corrective Optics Space Telescope Axial Replacement (COSTAR)

COSTAR was invented by the Hubble Space Telescope Strategy Panel, a group of scientists and engineers brought together at the Space Telescope Science Institute in the fall of 1990 to consider how to fix HST. Being built by Ball Aerospace under contract to



Functional illustration of the Corrective Optics Space Telescope Axial Replacement (COSTAR). It will use precisely shaped mirrors to correct for the spherical aberration.

(Ball Aerospace Systems Group)

NASA, COSTAR has no detectors or cameras. It will use precisely shaped mirrors to correct for the spherical aberration.

Through a servicing bay door, astronauts will pull out the 487-pound, phone-booth-sized High Speed Photometer (HSP) and install in its place the identically sized COSTAR. Once in place, COSTAR will deploy a set of mechanical arms, no longer than a human hand, that will place corrective mirrors in front of the openings that admit light into three of HST's observing instruments (the Faint Object Camera, Faint Object Spectrograph, and Goddard High Resolution Spectrograph).

COSTAR's corrective mirrors will refocus light relayed by HST's primary mirror before it enters these instruments. COSTAR will restore the optical performance of these instruments very close to the original expectations.

The HST team decided that COSTAR would displace the High Speed Photometer because the photometer does proportionately less science than any one of HST's other four instruments.

Less than a year after beginning development, COSTAR passed a major milestone—the critical design review. The project remains within budget and on schedule, with no major technical problems.

Solar Arrays

HST's deployable solar arrays, provided by the European Space Agency (ESA), create a jitter problem that interferes with spacecraft stability. The arrays were designed to accommodate the expansion and contraction caused by heating and cooling as the Hubble moves in and out of daylight in its 90-minute orbits. However, a compensation device that allows for the expansion and contraction of the solar array blankets does not expand and contract as smoothly as expected. ESA has redesigned a set of spare solar arrays to reduce the jitter to an acceptable level. A critical design review took place during January 1992. All participants in the HST program were pleased with the redesign, and ESA is fully committed to its role as a partner in the program.

Gyros

Three gyros are required to point and track HST; three more gyros are on board as backups. One of HST's six gyros failed in December 1990, and a second one failed in June 1991. Two of the four gyros contain components that are suspected of causing the failures. While these failures have not affected HST's performance, replacing the failed hardware will increase system reliability. If time permits on the servicing mission, astronauts will remove and replace two Rate Sensor Units (RSU) and an Electronic Control Unit (ECU)—each housing a pair of gyros. The replacement units are flight-qualified spares that are being

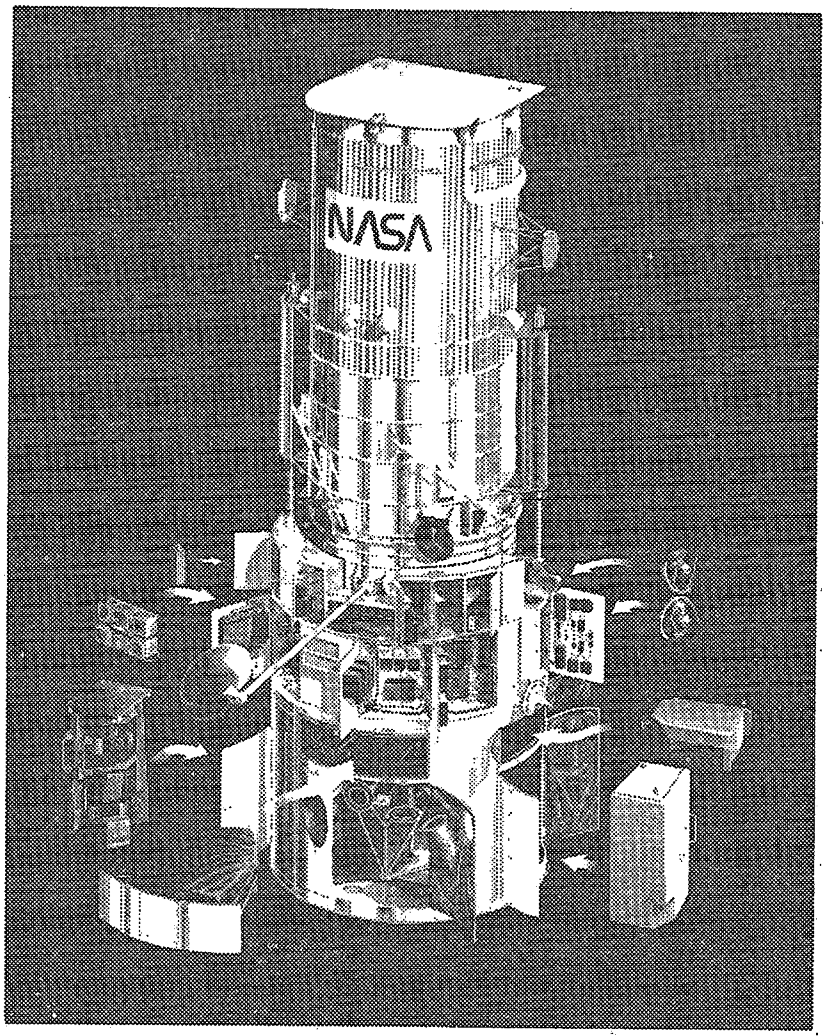
rebuilt to replace the suspected point of failure (a hybrid circuit). The first RSU and ECU are scheduled to be delivered to Goddard Space Flight Center in the summer of 1992; the second RSU is to be delivered in the spring of 1993.

Servicing/Support Equipment

From the very beginning, HST was designed for servicing in space, and many of its subsystems were designed to be modular, standardized, and accessible. HST has 49 different modular subsystems designed for servicing, ranging from small fuses to scientific instruments. HST also features 225 feet of handrails and 31 footholds to aid EVA crews in servicing tasks. More than 80 tools, ranging from screwdrivers to special hardware designed specifically for HST servicing, are available for use on this mission.

Conclusion

The Hubble Space Telescope servicing mission is a challenging and complex endeavor, but all elements of mission planning are on schedule, and EVA simulations will begin in March 1992. The Astrophysics Division will continue to report on the evolution of plans for the HST servicing mission.



Instruments, batteries, computers, and other essential components in the equipments bays are accessible through doors for easy removal and replacement. These items, called Orbital Replacement Units, are designed for servicing in space.

(Gordan Raney, artist, Lockheed)

NASA Status Report

National Aeronautics and
Space Administration

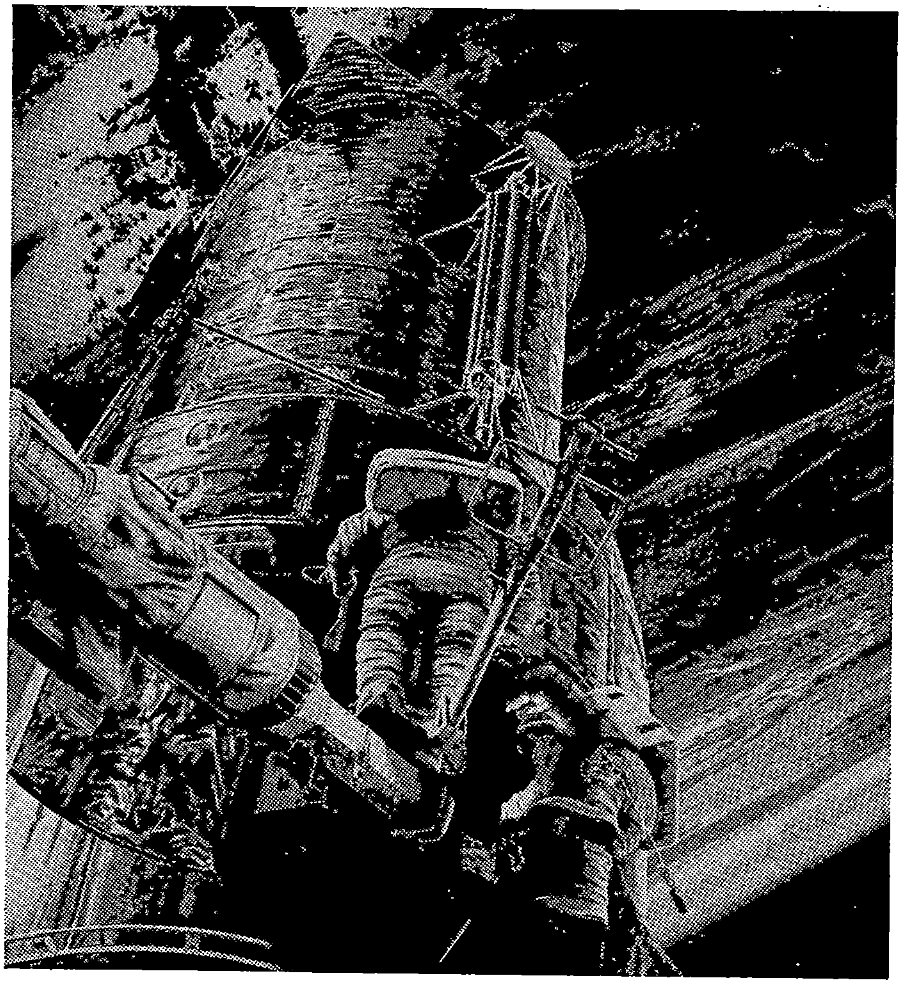
NASA Headquarters
Washington, DC

March 1992

The Hubble Space Telescope:
Report on Plans for the HST Servicing Mission

Background

The Hubble Space Telescope (HST) was launched on April 24,1990. By June 1990, two problems were discovered: spherical aberration of the primary mirror and jitter caused by the solar arrays. Image processing and spacecraft control software have compensated somewhat for both of these problems, but servicing is necessary to fix them. HST was designed for on-orbit servicing, to repair and refurbish the observatory and to upgrade its capabilities by installing advanced instruments. On-orbit servicing will permit correction of the spherical aberration and the solar array jitter.



Conceptual illustration of astronauts replacing instruments during the Hubble Space Telescope servicing mission.

(Ball Aerospace Systems Group, artist, Scott Kahler)

Mission Goals and Planning

The primary objective of the first HST servicing mission is to correct for spherical aberration in HST's primary mirror and replace faulty solar arrays.

The major constraint on NASA's ability to service HST on this mission is the amount of work that can be completed during the planned Space Shuttle flight. The current plan provides for 3 days of extravehicular activity (EVA) servicing, a day to redeploy HST and another day to assure the safe return of the Space Shuttle (for example, by manually closing the cargo bay doors if necessary). This amount of on-orbit work time provides for two optical fixes—the Wide Field/ Planetary Camera II (WF/PC II) and the Corrective Optics Space Telescope Axial Replacement (COSTAR); replacement of the solar arrays, two pairs of gyros and one gyro electronics box; and enough additional time to replace another subsystem that will be identified at a later date.

During the ongoing mission preparation, NASA is investigating methods to improve the efficiency of the work, so that any extra EVA time would provide a margin to assure the critical work required to restore essential HST capabilities is completed.

Mission Overview

Currently scheduled for launch in late 1993-early 1994, the orbiter will rendezvous with HST on the third day of the flight. HST will then be captured and secured in an upright position in the cargo bay for servicing. Working in pairs, on alternating days, the four EVA crewmembers will be spending three 6-hour work days performing the repairs.

Development has begun on astronaut simulations of on-orbit servicing operations to rehearse and optimize EVA repair work at Johnson Space Center's Weightless Environment Training Facility and Marshall Space Flight Center's Neutral Buoyancy Simulator (these large water tanks simulate the weightless environment of space). Early EVA training on individual components began this March. Other key events that will affect planning for the mission include the selection of a flight crew and a Shuttle cargo integration review in late 1992. Meanwhile, planning teams, including representatives of NASA Headquarters, Goddard Space Flight Center, Johnson Space Center, and Kennedy Space Center, will continue working on detailed and comprehensive procedures and time lines for this challenging mission.

Mission Cargo

Wide Field/Planetary Camera II

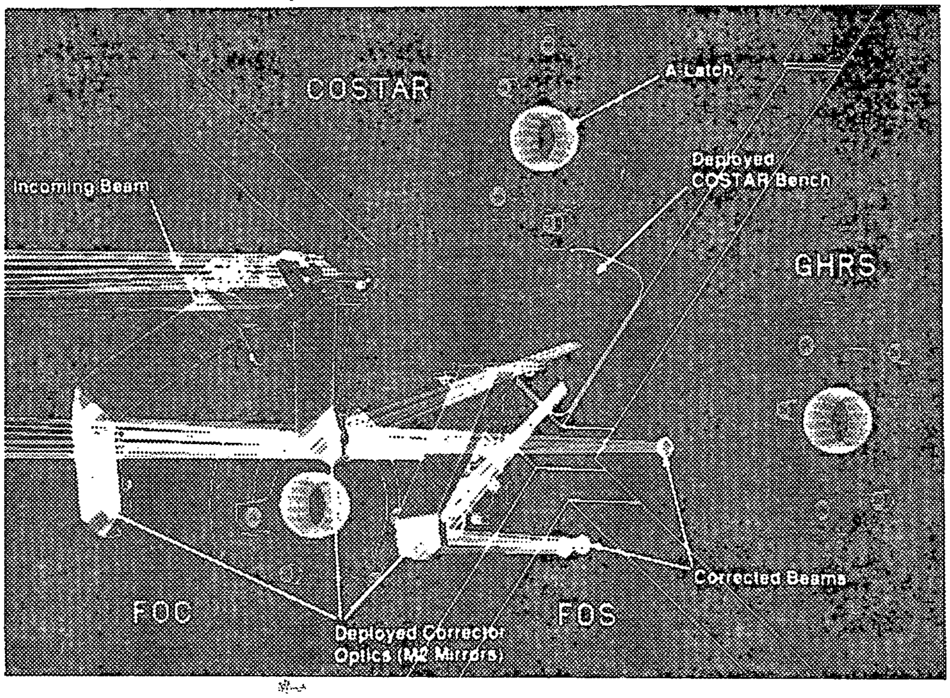
The Jet Propulsion Laboratory team that built HST's Wide Field/Planetary Camera (WF/PC) began developing a spare instrument in 1985. When the Hubble's mirror was found to be flawed, NASA and the WF/PC science team immediately began working on an optical correction that could be built into WF/PC II. The new design incorporates an optical correction by the refiguring of relay mirrors already in the optical train of the cameras. Each relay mirror is polished to a new "prescription" that will compensate for the incorrect figure on HST's primary mirror. Small actuators will fine-tune the positioning of these mirrors on orbit, ensuring the very precise alignment that is required.

Through a servicing bay door built into the side of HST, astronauts will slide out the 610-pound, wedge-shaped WF/PC I, as they would a giant drawer, and replace it with WF/PC II. The new instrument will have three wide field cameras and one planetary camera instead of the original eight. The WF/ PC II team chose to reduce the number of cameras to four in order to develop a system to align the corrective relay mirrors on-orbit remaining on schedule and within budget. Improved Charged Coupled Devices (CCDs) that were not available when the first WF/PC was built will be incorporated in WF/ PC II to improve its sensitivity, particularly in the ultraviolet.

WF/PC II is proceeding within its budget and, despite the complexity of the task, is on schedule to be delivered from the Jet Propulsion Laboratory to NASA's Goddard Space Flight Center in the spring of 1993. WF/PC II will be tested with spacecraft and ground system simulators there before being sent to Kennedy Space Center to be integrated with the Space Shuttle.

Corrective Optics Space Telescope Axial Replacement (COSTAR)

COSTAR was invented by the Hubble Space Telescope Strategy Panel, a group of scientists and engineers brought together at the Space Telescope Science Institute in the fall of 1990 to consider how to fix HST. Being built by Ball Aerospace under contract to



Functional illustration of the Corrective Optics Space Telescope Axial Replacement (COSTAR). It will use precisely shaped mirrors to correct for the spherical aberration.

(Ball Aerospace Systems Group)

NASA, COSTAR has no detectors or cameras. It will use precisely shaped mirrors to correct for the spherical aberration.

Through a servicing bay door, astronauts will pull out the 487-pound, phone-booth-sized High Speed Photometer (HSP) and install in its place the identically sized COSTAR. Once in place, COSTAR will deploy a set of mechanical arms, no longer than a human hand, that will place corrective mirrors in front of the openings that admit light into three of HST's observing instruments (the Faint Object Camera, Faint Object Spectrograph, and Goddard High Resolution Spectrograph).

COSTAR's corrective mirrors will refocus light relayed by HST's primary mirror before it enters these instruments. COSTAR will restore the optical performance of these instruments very close to the original expectations.

The HST team decided that COSTAR would displace the High Speed Photometer because the photometer does proportionately less science than any one of HST's other four instruments.

Less than a year after beginning development, COSTAR passed a major milestone—the critical design review. The project remains within budget and on schedule, with no major technical problems.

Solar Arrays

HST's deployable solar arrays, provided by the European Space Agency (ESA), create a jitter problem that interferes with spacecraft stability. The arrays were designed to accommodate the expansion and contraction caused by heating and cooling as the Hubble moves in and out of daylight in its 90-minute orbits. However, a compensation device that allows for the expansion and contraction of the solar array blankets does not expand and contract as smoothly as expected. ESA has redesigned a set of spare solar arrays to reduce the jitter to an acceptable level. A critical design review took place during January 1992. All participants in the HST program were pleased with the redesign, and ESA is fully committed to its role as a partner in the program.

Gyros

Three gyros are required to point and track HST; three more gyros are on board as backups. One of HST's six gyros failed in December 1990, and a second one failed in June 1991. Two of the four gyros contain components that are suspected of causing the failures. While these failures have not affected HST's performance, replacing the failed hardware will increase system reliability. If time permits on the servicing mission, astronauts will remove and replace two Rate Sensor Units (RSU) and an Electronic Control Unit (ECU)—each housing a pair of gyros. The replacement units are flight-qualified spares that are being

rebuilt to replace the suspected point of failure (a hybrid circuit). The first RSU and ECU are scheduled to be delivered to Goddard Space Flight Center in the summer of 1992; the second RSU is to be delivered in the spring of 1993.

Servicing/Support Equipment

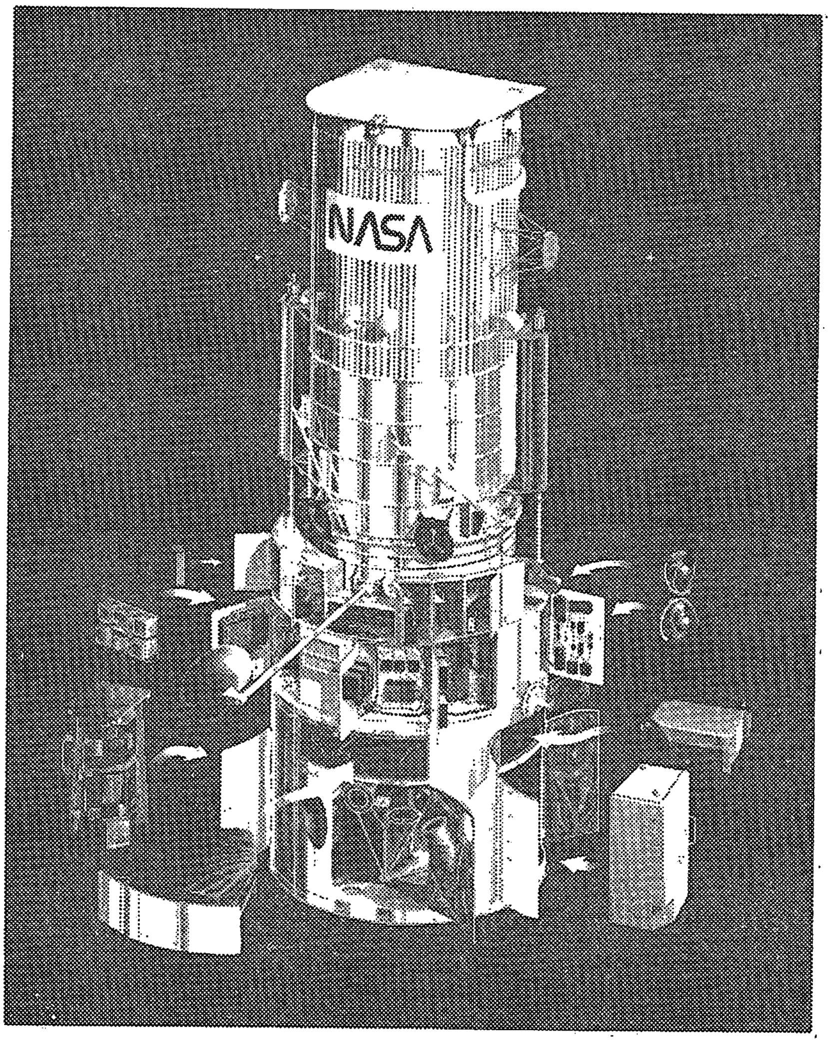
From the very beginning, HST was designed for servicing in space, and many of its subsystems were designed to be modular, standardized, and accessible. HST has 49 different modular subsystems designed for servicing, ranging from small fuses to scientific instruments. HST also features 225 feet of handrails and 31 footholds to aid EVA crews in servicing tasks. More than 80 tools, ranging from screwdrivers to special hardware designed specifically for HST servicing, are available for use on this mission.

Conclusion

The Hubble Space Telescope servicing mission is a challenging and complex endeavor, but all elements of mission planning are on schedule, and EVA simulations will begin in March 1992. The Astrophysics Division will continue to report on the evolution of plans for the HST servicing mission.

Instruments, batteries, computers, and other essential components in the equipments bays are accessible through doors for easy removal and replacement. These items, called Orbital Replacement Units, are designed for servicing in space.

(Gordan Raney, artist, Lockheed)



NASA Facts

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771
AC 301 286-8955

NASA'S OZONE STUDIES

Barely half a decade ago, stratospheric ozone depletion was mainly of interest to atmospheric scientists. Today it is a worldwide environmental concern that has been addressed by several international accords. Ozone depletion epitomizes the environmental problems humans face today: it is global; it is the direct but unintended result of human industry; and remedying it will have direct and indirect economic consequences. Since the mid-1970s, NASA has been in the forefront of research into why and how the ozone layer in the stratosphere, or upper atmosphere, undergoes regular dramatic changes.

Ozone, a molecule made up of three oxygen atoms, shields life on Earth from the harmful effects of the ultraviolet radiation of the Sun. The increased amounts of ultraviolet radiation that would reach the Earth's surface because of ozone depletion could increase the incidence of skin cancer and cataracts in humans and may harm crops and interfere with marine life.

Because the risks of ultraviolet radiation are so serious, scientists all over the world are working to determine how much of the ozone-related change in the atmosphere is caused by humans and how much is attributable to natural processes, such as the shift in atmospheric dynamics, volcanic activity or the solar cycle.

Studies have shown that ozone depletion is caused by complex, coupled chemical reactions. Recent data has indicated that man-made chlorofluorocarbons (CFCs), used in refrigeration, electronics and other industries, are capable of altering the levels of atmospheric ozone. Continued build-up of CFCs is expected to lead to additional ozone loss worldwide. Ongoing studies are essential to provide the necessary understanding of the causes of ozone depletion.

For decades, NASA has pioneered the study of the atmosphere in order to improve life on Earth. The agency's commitment to environmental research is continuing with Mission to Planet

Earth, a coordinated series of ground-based, airborne and space-based programs designed to study the Earth as a single, global environmental system. By analyzing and collecting data from a variety of experiments, missions and satellites, NASA scientists hope to contribute to humanity's better understanding its influences on the atmosphere and the rest of the environment. Within Mission to Planet Earth, NASA's on-going commitment to ozone studies includes current and future missions. Five of the projects are detailed below.

TOMS

Since its launch aboard NASA's Nimbus-7 polar-orbiting satellite in 1978, the Total Ozone Mapping Spectrometer (TOMS) has provided reliable, high-resolution mapping of global total ozone on a daily basis. TOMS, managed by NASA's Goddard Space Flight Center (GSFC), Greenbelt, Md., is the primary source of high-resolution global maps about the total ozone content of the atmosphere.

Analyses of TOMS data have traced in detail the annual development of the Antarctic "ozone hole," a large area of intense ozone depletion that occurs between late August and early October. The ozone hole was discovered through British ground-based observations in the mid-1980s, but analysis of TOMS data indicates it has existed since at least 1979.

Recent studies by Goddard scientists using more than 11 years of TOMS data have revealed that the reductions in ozone over the mid-northern latitudes are approximately twice as severe as previously believed. The possibility that increased ultraviolet radiation could reach the Earth's surface during the beginning of the growing season raises questions of significant economic, environmental and health effects.

A long-term, consistent record of ozone levels is essential to understanding and predicting ozone depletion. To ensure that ozone data will be available throughout the next decade, NASA will continue the TOMS program using U.S. and foreign launches. On Aug. 15, 1991, the Soviet Union launched a Meteor-3 satellite carrying a TOMS instrument. A third TOMS will be launched aboard a Pegasus booster in 1993, and the Japanese Advanced Earth Observations Satellite (ADEOS) will carry a fourth TOMS when it launches in 1995.

UARS

Launched Sept. 12, 1991, the Upper Atmosphere Research Satellite (UARS) will help scientist better understand the energy input, chemistry and dynamics of the upper atmosphere and the coupling between the upper and lower atmosphere. UARS, the first satellite dedicated to studying stratospheric science, will focus on the processes that lead to ozone depletion, complementing and amplifying the measurements of total ozone made by TOMS.

Ten UARS instruments will provide the most complete data on upper atmospheric energy inputs, winds, and chemical composition ever gathered. Taken together these observations constitute a highly integrated investigation of the nature of the upper atmosphere. In its first two weeks of operation, UARS data confirmed existing ozone-depletion theories by providing three-dimensional maps of ozone and chlorine monoxide near the South Pole during development of the 1991 ozone hole. UARS, developed and managed by GSFC, ultimately will provide information that nations around the world can use to make decisions on environmental policies.

ATLAS

The Atmospheric Laboratory for Applications and Science (ATLAS), a series of Space Shuttle-Spacelab missions, will carry two instruments to measure ozone and other chemicals in the upper atmosphere, complementing and expanding measurements made by UARS. ATLAS will investigate how Earth's atmosphere and climate are affected by the Sun and by the products of industrial complexes and agricultural activities. Scientists from six countries will conduct 12 investigations in atmospheric science, solar physics, space plasma physics and astronomy.

ATLAS-1, scheduled to be launched aboard Space Shuttle Atlantis in early 1992, will be the first in an 11-year series of missions to study long-term interactions between the atmosphere and the Sun. Later missions dedicated to Earth science are planned at about one-year intervals. The series of flights will return data from very highly calibrated instruments that will help scientists study trends in the atmosphere and complement long-term satellite measurements. The ATLAS missions are managed by Marshall Space Flight Center, Huntsville, Ala.

AIRBORNE RESEARCH

Not all of NASA's ozone research is conducted from space. Periodic expeditions that fly instruments through the atmosphere aboard research aircraft have greatly expanded our understanding of ozone depletion. Airborne expeditions over both the Arctic and Antarctic have led scientist to conclude that chemical reactions involving human-produced chlorine are the main cause of ozone depletion in the upper atmosphere.

NASA, in conjunction with the National Oceanic and Atmospheric Administration, the National Science Foundation and industry, has conducted two airborne campaigns: over the Antarctic (1987) and Arctic (1989). The second Airborne Arctic

Stratospheric Expedition began in October 1991, with ER-2 flights over the North Pole from Fairbanks, Alaska. It will continue through March 1992 with ER-2 flight out of Bangor, Maine, and DC-8 flight from the Ames Research Center, Mountain View, Calif. Ames in the managing center for NASA's airborne research programs.

SSBUV

The Shuttle Solar Backscatter Experiment (SSBUV), a highly calibrated instrument developed at Goddard for periodic flights aboard the Space Shuttle, determines ozone levels by measuring reflected ultraviolet light. SSBUV measures the total amount and height distribution of ozone in the upper atmosphere and collects data to calibrate ozone-measuring instruments on other satellites. Scientists directly compare the SSBUV and satellite-instrument data as the two pass over the same Earth location within an hour. These orbital coincidences can occur 17 times a day.

SSBUV has flown three times: on STS-34 (October 1989), STS-41 (October 1990) and STS-4333 (August 1991). The next planned mission is ATLAS-1/STS-45 (early 1992) and regular flights are scheduled through the 1990s.

SAGE

The Stratospheric Aerosol and Gas Experiment (SAGE), was first launched in 1979 aboard the Applications Explorer Mission B spacecraft and provided ozone measurements using the solar occultation technique until 1981. The application of this technique represented the first global, high vertical resolution data set for stratospheric ozone. It is the vertical measurement orientation and self-calibrating feature which distinguishes SAGE measurements from those of other space instruments.

SAGE II began operation with the Earth Radiation Budget Satellite in 1984 and is still healthy today, making important contributions to studies of the Antarctic ozone hole with high resolution scrutiny of ozone, water vapor and polar stratospheric clouds. Most recently, SAGE observed large changes in lower stratospheric ozone in the northern polar region caused by energetic protons released from the Sun during intense solar flares.

The most important result of SAGE measurement has been the combination of data from both missions, along with the data from the SAM II experiment on Nimbus-7, which monitors long-term changes in ozone.

SAGE is managed by Langley Research Center, Hampton, VA.

The Future--Mission to Planet Earth

These five complementary projects are important to understanding the dynamic processes that can lead to ozone depletion. As part of NASA's Mission to Planet Earth, the agency's ozone depletion studies are designed to observe the Earth of a global scale.

Mission to Planet Earth is NASA's contribution to the multi-agency U.S. Global Change Research Program. The centerpiece to Mission to Planet Earth is the Earth Observing System (EOS), a series of environmental research satellites planned to begin launches in 1998. The EOS program will continue and integrate the measurement by TOMS, ATLAS, UARS and SSBUV, and will provide the first coordinated, simultaneous measurements of the interactions of the atmosphere, oceans, land surfaces and biosphere. Early versions of the EOS Data and Information System will incorporate existing ozone data for the widest possible distribution to international researchers.

####

January 1992

Office of the Director

In 1959, the Goddard Space Flight Center was established and, while its charter has changed and grown, its preeminence in space and Earth sciences, communications and tracking, data management, development of spacecraft and spacecraft-borne instruments, operations, and management has been demonstrated throughout its history.

During its first three decades, the Center developed more than 40 satellites in-house; managed the development of more than 160 satellites for NASA; launched over 175 payload-carrying Delta rockets; flew scientific payloads on over 2,500 sounding rockets and 550 balloons; and provided tracking, communications, and data handling for the Agency.

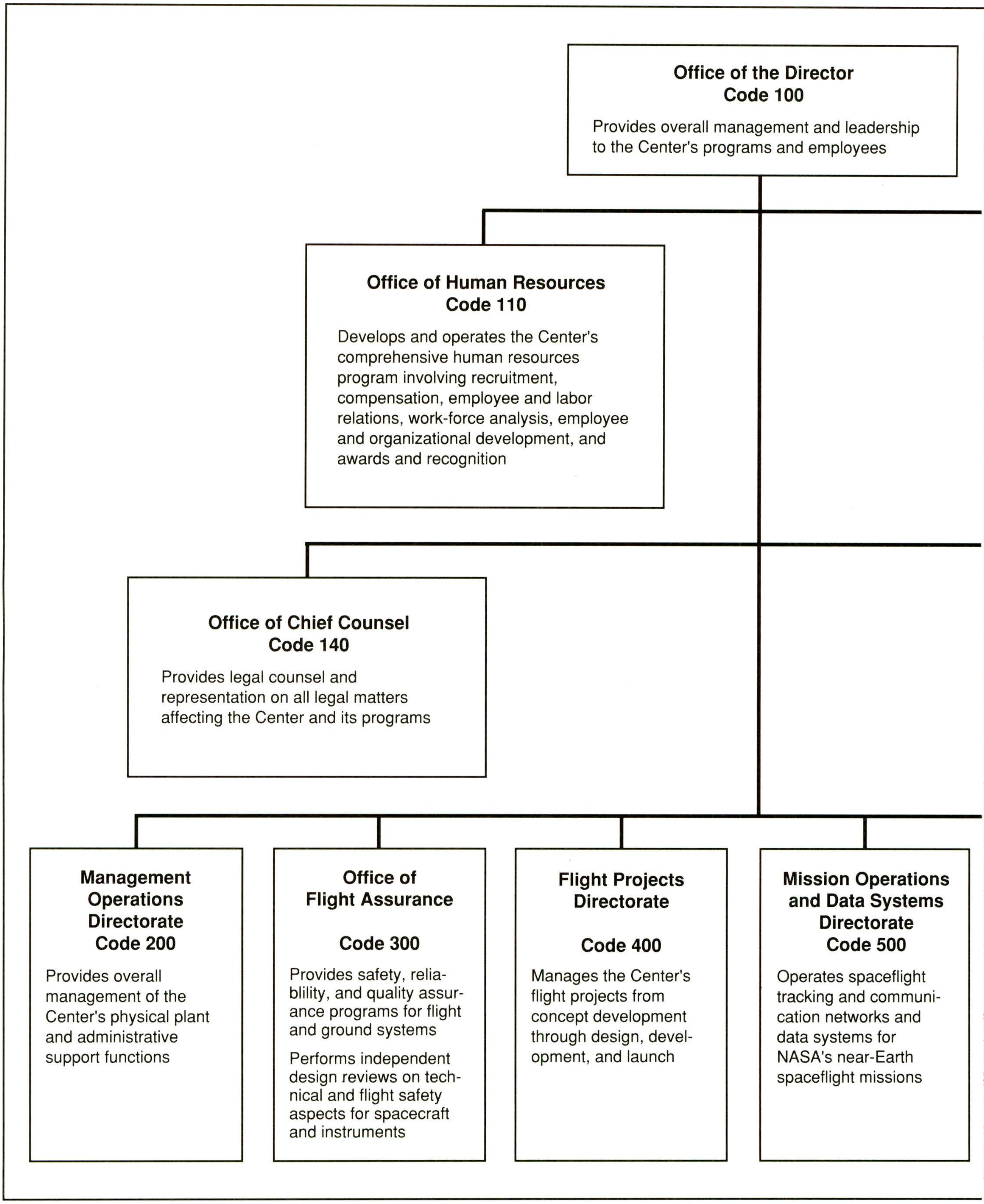
Goddard's scientific and engineering activities literally extend from the depths of the oceans to the edge of the universe. Goddard scientists have pioneered the development of many of the current space and Earth sciences disciplines. Goddard space scientists are involved in astrophysical research, in space physics, and in Solar System exploration. Studies in these disciplines reveal the nature of the terrestrial environment and the nature and evolution of planets, stars, galaxies, and the universe. Goddard Earth scientists are exploring the causes of global change by examining the dynamics, energetics, and chemistry of the atmosphere along with the interaction of land and oceans and the geodynamics and geophysics of the solid earth.

Observations from space are made possible by spacecraft and their instruments developed and operated at the Center. Goddard engineers and technicians develop technologies and engineer solutions to complex problems in sensor development, optics, control systems, communication and data systems for operations, and science data management.

At any point in time, Goddard is involved in the management and development of 14 to 16 major projects that include smaller payloads, such as Hitchhiker, sounding rockets and research balloons, and major programs that span decades, such as the Tracking and Data Relay Satellite System and the Earth Observing System.

The Goddard Space Flight Center is a national resource. Its facilities, laboratories, and equipment provide the capability to build complex scientific satellites in-house, such as the Cosmic Background Explorer, which examines the evolution of the universe, and to manage satellite development, mission operations, data systems, and science.

The most significant resource of the Center is its 4,000 employees. These are the scientists, engineers, technicians, managers, and administrative and support personnel whose creativity and work are synonymous with the Goddard Space Flight Center.


Office of the Director
Code 100
Provides overall management and leadership to the Center's programs and employees
Office of Human Resources
Code 110
Develops and operates the Center's comprehensive human resources program involving recruitment, compensation, employee and labor relations, work-force analysis, employee and organizational development, and awards and recognition
Office of Chief Counsel
Code 140
Provides legal counsel and representation on all legal matters affecting the Center and its programs
Management Operations Directorate
Code 200
Provides overall management of the Center's physical plant and administrative support functions
Office of Flight Assurance
Code 300
Provides safety, relia-blility, and quality assurance programs for flight and ground systems
Performs independent design reviews on technical and flight safety aspects for spacecraft and instruments
Flight Projects Directorate
Code 400
Manages the Center's flight projects from concept development through design, development, and launch
Mission Operations and Data Systems Directorate
Code 500
Operates spaceflight tracking and communication networks and data systems for NASA's near-Earth spaceflight missions

Equal Opportunity Programs Office
Code 120

Coordinates and evaluates Centerwide Equal Opportunity Programs

Manages the EEO Complaint System

Fosters Center involvement with community and educational institutions

Office of Public Affairs
Code 130

Disseminates information on Goddard activites to the public and news media

Conducts space-oriented education programs and teacher workshops

Office of the Comptroller
Code 150

Provides the central overview of Center budgets and resource planning activities

Analyzes and forecasts program and institutional resource requirements

Office of University Programs
Code 160

Provides the focal point of Goddard program activities with colleges and universities

Space Sciences Directorate

Code 600

Conducts scientific studies in high-energy astrophysics, astronomy, solar physics, and extraterrestrial physics

Engineering Directorate

Code 700

Conducts a broad program of technical research, and design, development, and test for spaceflight programs, including in-house engineering and fabrication of instruments and satellites

Suborbital Projects and Operations Directorate
Code 800

Conducts NASA's Sounding Rocket Program and Balloon Program, operates a research airport, and provides tracking and communications for mission operations

Earth Sciences Directorate

Code 900

Conducts scientific studies on Earth's atmosphere; land, ocean, and atmosphere interactions; and geodynamics and geophysics of the solid earth

Skill Needs

There are opportunities within the Office of the Director requiring general business, law, economics, or liberal arts backgrounds, such as:

Office of Human Resources

- Human Resource Specialists
    - Staffing
    - Classification
    - Labor and Employee Relations
    - Employee Development
    - Organizational Development
- Program Analysts
- Computer Systems Analysts

Equal Opportunity Programs Office

- EEO Specialists
- Program Analysts

Office of Public Affairs

- Public Affairs Specialists
- Educational Specialists
- External Liaison Specialists

Office of Chief Counsel

- General Attorneys

Office of the Comptroller

- Resource Analysts
- Operations Research Analysts
- Program Analysts

Management Operations Directorate

The Directorate serves as City Manager to the Center, providing business and institutional support services to accomplish Goddard's mission at both the Greenbelt and Wallops Island facilities. The organization prides itself on service to its customers and on finding ways to improve these services within a complex Federal environment.

Divisions in our organization accomplish the following roles:

- The Financial Management Division oversees billings, payments, and accounting services for the Center.
- The Patent Counsel staff provide specialized legal advice.
- The Facilities Engineering Division plans, designs, and constructs institutional and research facilities and is responsible for all engineering alterations to existing facilities.
- The Plant Operations and Maintenance Division maintains the Center's buildings, roads, and grounds and provides power, heating, and other utilities support.
- The Procurement organizations acquire the supplies, services, and hardware necessary to support the Center's programmatic and institutional activities.
- The Logistics Management Division provides complete logistics support to the Center including transportation services, property management, mail services, and supply management.

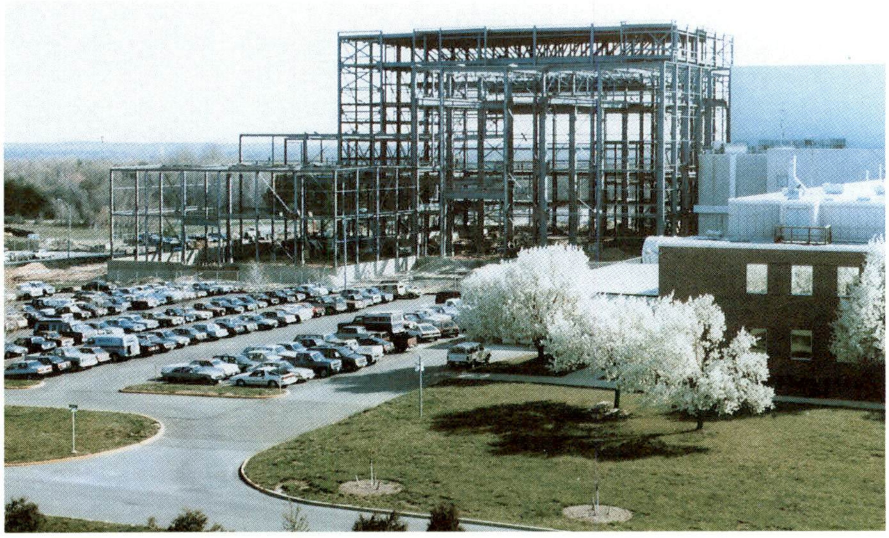
The Goddard Library, employing the latest information technology, is considered a valuable resource to the Goddard community.

- The Information Management Division provides computing support for all administrative functions, as well as library services, and a full range of graphics and publication services.
- The Health, Safety and Security Office provides health, safety, security, fire protection, and emergency medical services, and manages complex environmental issues.

Patent Counsel
The office assists the Center's scientists and engineers in evaluating inventions for patent potential, patent preparation, and patent prosecution. We also support procurement personnel in the area of intellectual property rights and contract monitoring to ensure contractor compliance with provisions in the NASA patent rights clause and new technology clause.

Health, Safety and Security
Our programs focus on the health and safety of our employees, as well as on Center security—from the guards at the gate to national security communications. A unifying theme in all programs is the management of risks consistent with the "open campus" environment enjoyed by Goddard employees. As a major initiative, we are implementing a keycard access control system to heighten security in an unobstructive manner. Additionally, we have taken a proactive role in dealing with the complex environmental issues that we are facing at Greenbelt and Wallops.

Financial Management
The Division is responsible for financial management activities and associated budget and accounting functions for the Center. We support Goddard's programmatic goals through accurate and timely financial information and guidance. We have undertaken major efforts to enhance our accounting systems capabilities, to streamline reporting capabilities for our customers, and to actively support the development of the NASA Financial Accounting Information System (NAFIS). Improving communication and service delivery to our customers is a major organizational commitment.



Spacecraft Systems Development and Integration Facility during contruction (top) and after completion (bottom). It is the largest laminar flow clean room of its type.

Logistics Management
We provide complete logistics support at Greenbelt and Wallops. Activities include logistics support to the flight projects and technical communities for procurement and management of their technical parts stock, transportation of scientific instruments and spacecraft, and storage of space-flight hardware. The Division provides supply services, including a 12,000-line-item supply system, and has accountability for $1 billion of property. Transportation services include traffic management, package engineering, material handling, shipment of goods, a large vehicle fleet, and personnel travel arrangements. We also manage the Greenbelt Mail Services Center, the furniture and carpet program, and office space planning and design.

Procurement
Eighty-eight percent of the Center's budget is spent through the

contracting process. The procurement function includes institutional acquisitions (facilities, construction, commercial, and small purchases), procurement policy, pricing and analysis, and acquisition for Goddard's major space projects. Our procurements approach $2 billion annually, including approximately 4,800 large contractual actions and 17,800 small purchases (under $25 K). Goddard has led NASA in simplifying the complex procurement process, including initiatives to reduce lead-time on Goddard's major procurements and to automate the small purchases system.

Project Engineer designing a building structural system on a Computer-Aided Design and Drafting workstation.

Information Management

A broad scope of services is offered to Goddard customers. We support all administrative computing, and our systems analysts create automated systems best suited to our customers' needs. The Library is a state-of-the-art resource to the technical communities at both Greenbelt and Wallops. Our photographers document each phase of spacecraft development, and the computer graphics facility produces full-color slides and transparencies. We operate Information Technology Centers—unique, computerized, self-paced learning laboratories—at both sites.

Facilities Engineering

The Division plans, designs and constructs Goddard's facilities. Recent major construction includes the Second Tracking and Data Relay Satellite System (TDRSS) Ground Terminal, which is a second ground station for the TDRSS, and the Spacecraft Systems Development and Integration Facility, the largest clean room of its kind. The Division will undertake a major challenge in constructing the Center's "Eastern Campus" to support the President's "Mission to Planet Earth." These new facilities will greatly enhance our effectiveness in processing data and in conducting complicated global scientific research. At Wallops, we are constructing an integrated control center for airfield and rocket launch operations and are restoring several miles of seawall on Wallops Island. The Division is also in the process of revitalizing our services for small construction projects.

Plant Operations and Maintenance

This Division maintains our buildings, utilities, grounds, roads and is responsible for the physical plants at Greenbelt and Wallops. We have undertaken major initiatives to improve Center maintenance and utility operations including a multimillion-dollar effort to renovate Goddard's aging facilities and utility systems, and plans to construct a "Cogeneration Power Plant" at Greenbelt to provide electricity and steam at lower cost than at present. The Division also will be expanding its capabilities to include minor alteration and modification services to its customers at Greenbelt.

Preparing for contract negotiation.

Skill Needs

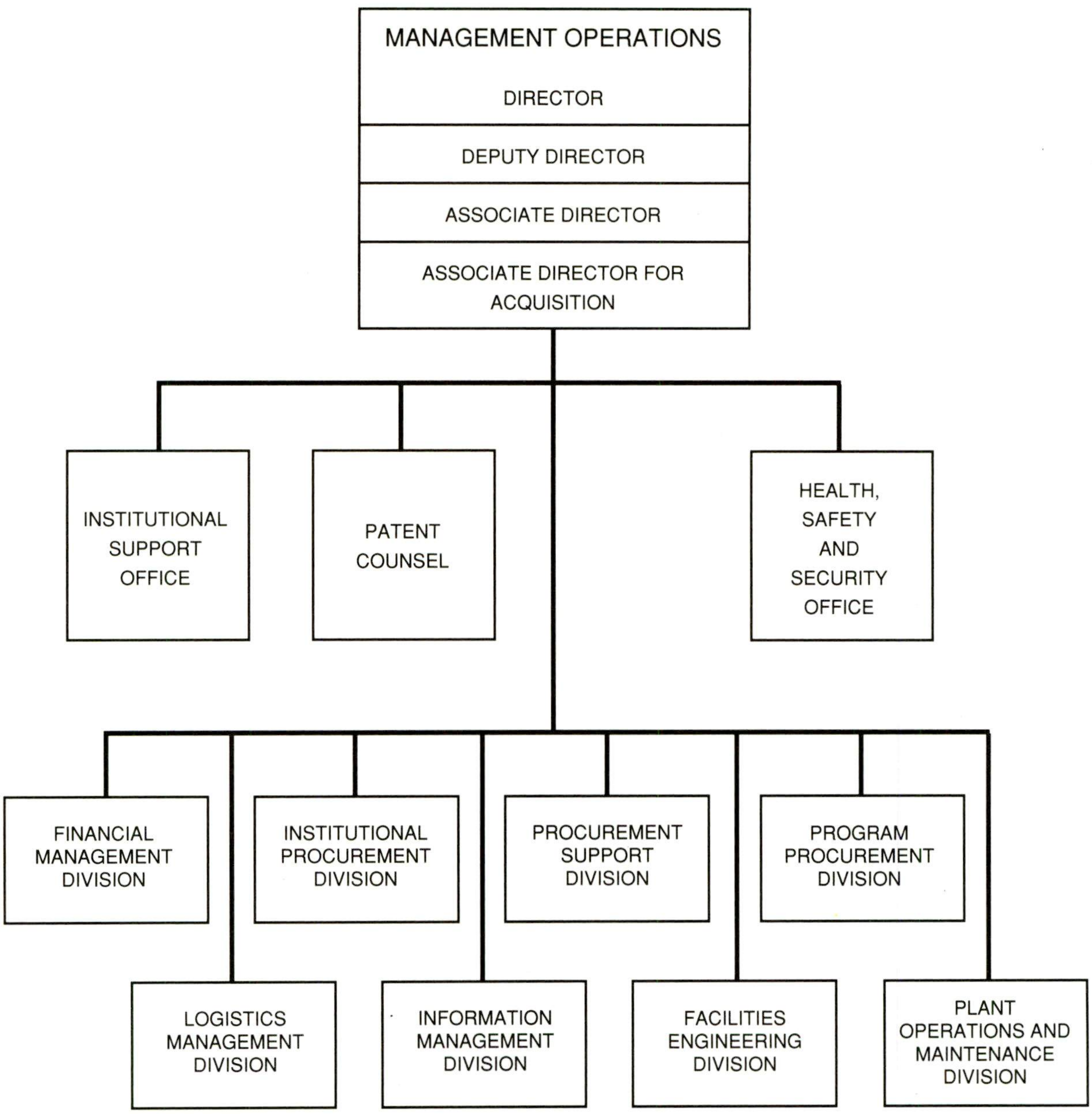
There are opportunities within the Management Operations Directorate requiring general business, economics, liberal arts or backgrounds such as:

Engineers:
- Environmental
- Civil
- Mechanical
- Electrical

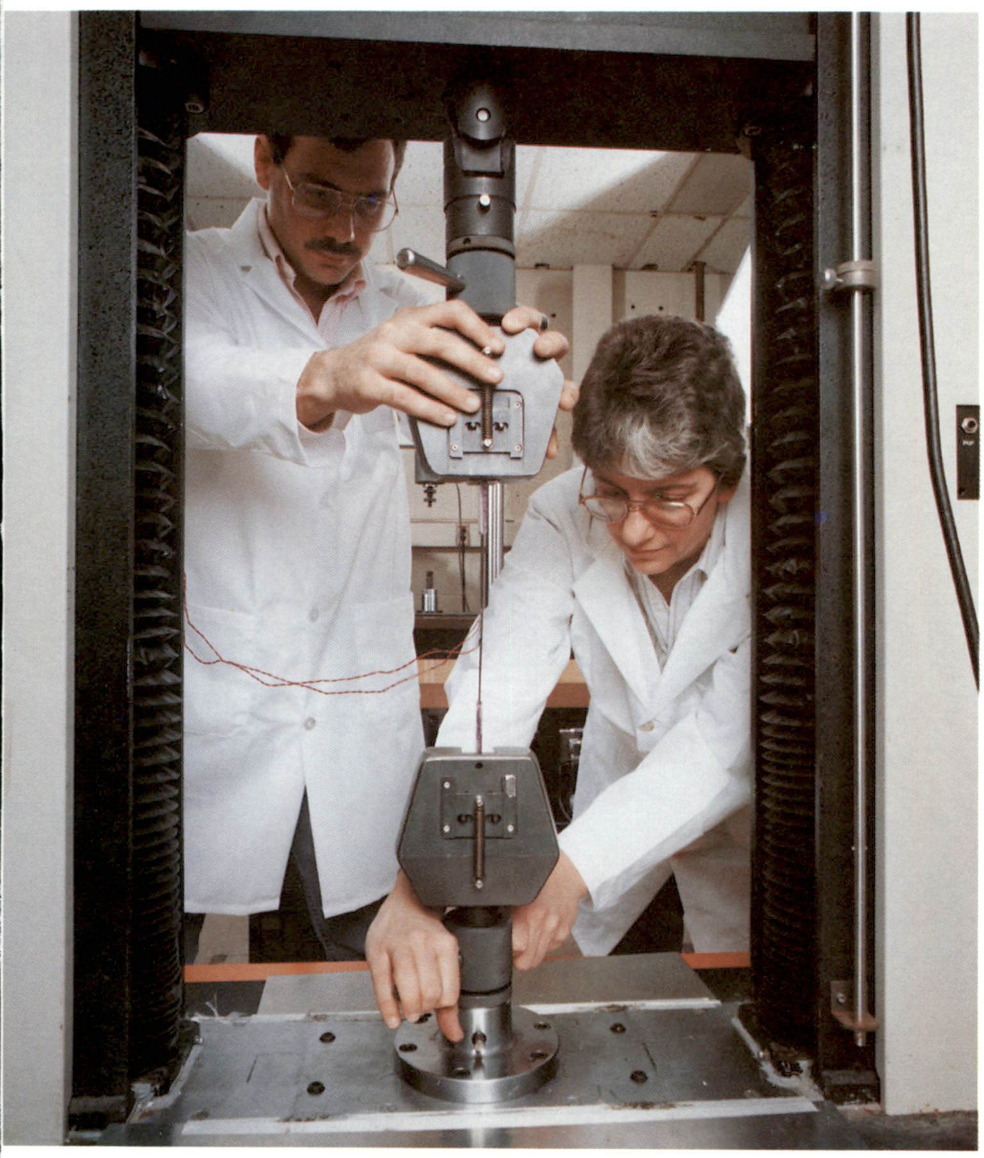
Architects

Accountants
Budget Analysts
Financial Analysts
Systems Analysis and Development Specialists
Computer Science Specialists

Cost/Price Analysts
Patent Attorneys
Legal Technicians
Boiler Plant Operators
High-Voltage Electricians
Logistics Specialists



Office of Flight Assurance



Conducting a tensile test in the Materials Laboratory.

The technical flight safety aspects of all Goddard's flight projects, including spacecraft, launch vehicle operational ground systems, and scientific instruments, must be reviewed before, during, and after launches. This ensures that they meet Center goals for mission success and reliability. The Office of Flight Assurance conducts those reviews and provides technical support and guidance to all flight programs. We develop general policy requirements for quality assurance, parts and material control, environmental testing, verification, reliability, flight-system safety, and software assurance.

Office activities include:

- Ensure flight readiness through identification and correction of anomalies.

- Work closely with flight project teams to establish and implement policy and requirements for test verification, system safety, reliability, product and software assurance, and reliable parts and materials.

- Provide lab testing and analysis for parts and materials.

- Ascertain that the functional requirements of NASA and Goddard are met in purchasing materials and supplies, and prepare documentation for the technical specifications and, if necessary, the contract provisions.

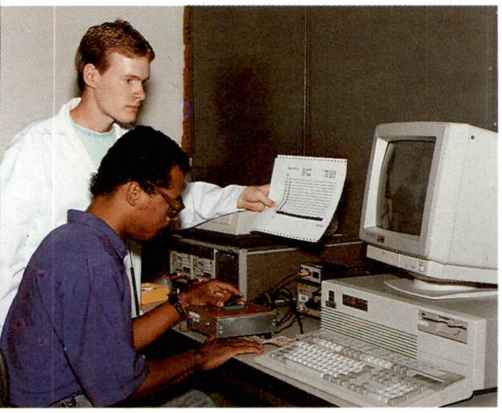
- Evaluate plans, proposals, and procedures for all flight projects to ensure they meet requirements.

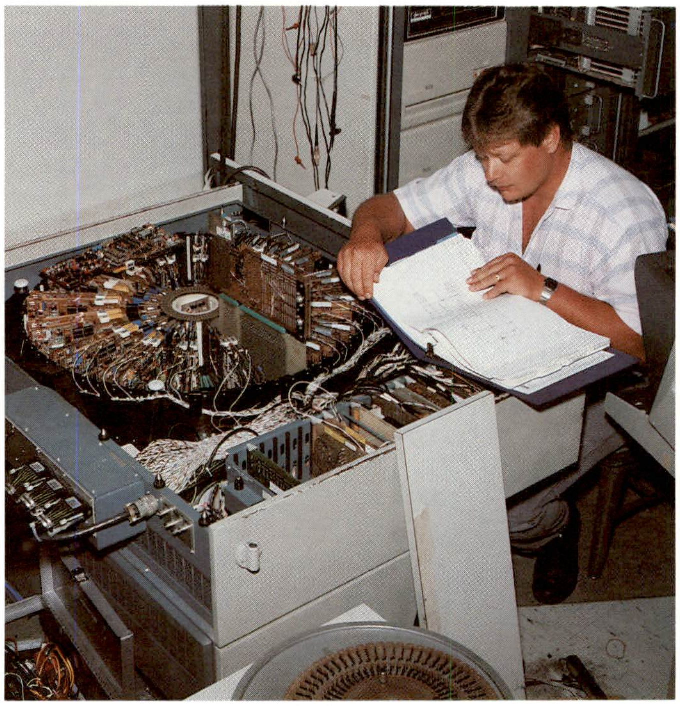
Systems Review Office

Using a small cadre of the Center's more experienced technical experts, this Office reviews all flight projects beginning at the conceptual design stage and progressing to the final flight readiness review. Potential problems are identified and resolved before we recommend mission launch to the Center Director. All Center-managed projects, as well as many other Government and international programs, are provided Flight Assurance support as required.

The Parts Branch

Reliability engineers in the Parts Branch develop and maintain plans and procedures for assuring the procurement, testing, and use of flight-quality parts. We provide parts expertise to determine suitability, reliability, and quality of parts.





ABOVE: Automated Test Equipment (ATE) semi-automatic setup for performing test plots.

RIGHT: Working in the Parts Testing Laboratory, ATE room, on a digital microcircuit tester.

This Branch determines and designates NASA standard electrical, electronic, and electromechanical (EEE) parts and documents. We prepare the Parts Application Handbook and participate in the parts standardization program. The Parts Engineering Section maintains expertise for EEE parts and microelectronic devices while the Parts Technology Section studies radiation effects and electronic packaging process technology, and provides expertise in EEE parts areas, such as microcircuits and certain electromechanical parts.

The Materials Branch

This Branch provides technical support in materials science, technology, and applications. These experts are the Center's focal point for consultation, control, and review of all materials, materials systems, and designs for flight missions. As such, our staff investigate all spacecraft materials problems and their resolution and assist management in arriving at materials policy goals and guidelines for qualified flight hardware. We also support cooperative ventures with other Government agencies, educational institutions, and private industry to develop improved, more reliable materials.

The Metals Section provides engineering expertise in metallurgy, mechanical engineering, fracture mechanics, tribology, and inorganic chemical analysis. The Polymers

Section specializes in organic chemical analysis, polymer research, inorganic chemical analysis, polymer degradation, modeling polymer processing, gas kinetics, materials outgassing kinetics, and gaseous and particulate contamination in space. The Ceramics Section focuses on optical materials and coatings, electronic materials, measurements and instrumentation systems, and

environmental testing while the Composites Section works with composite and brittle materials.

The Assurance Requirements Office

Our senior safety and reliability experts develop and implement policies and requirements for environmental testing, verification, reliability system safety, and software assurance for safe, reliable space systems. We establish test and design factors of safety, test levels, and durations at appropriate levels of assembly and related analytical requirements. Staff within the System Safety Branch develop system safety policies and requirements for special missions.

The Assurance Management Office

Our Flight Assurance Managers and Product Assurance Engineers are assigned to Goddard projects; they manage all aspects of performance assurance, from negotiating resources to garnering support from other offices. They constantly assess hardware and software quality and status and provide feedback both for the project and the Office. As part of the ever-evolving Office of Flight Assurance, they provide feedback to the Director on the effectiveness of assurance programs.

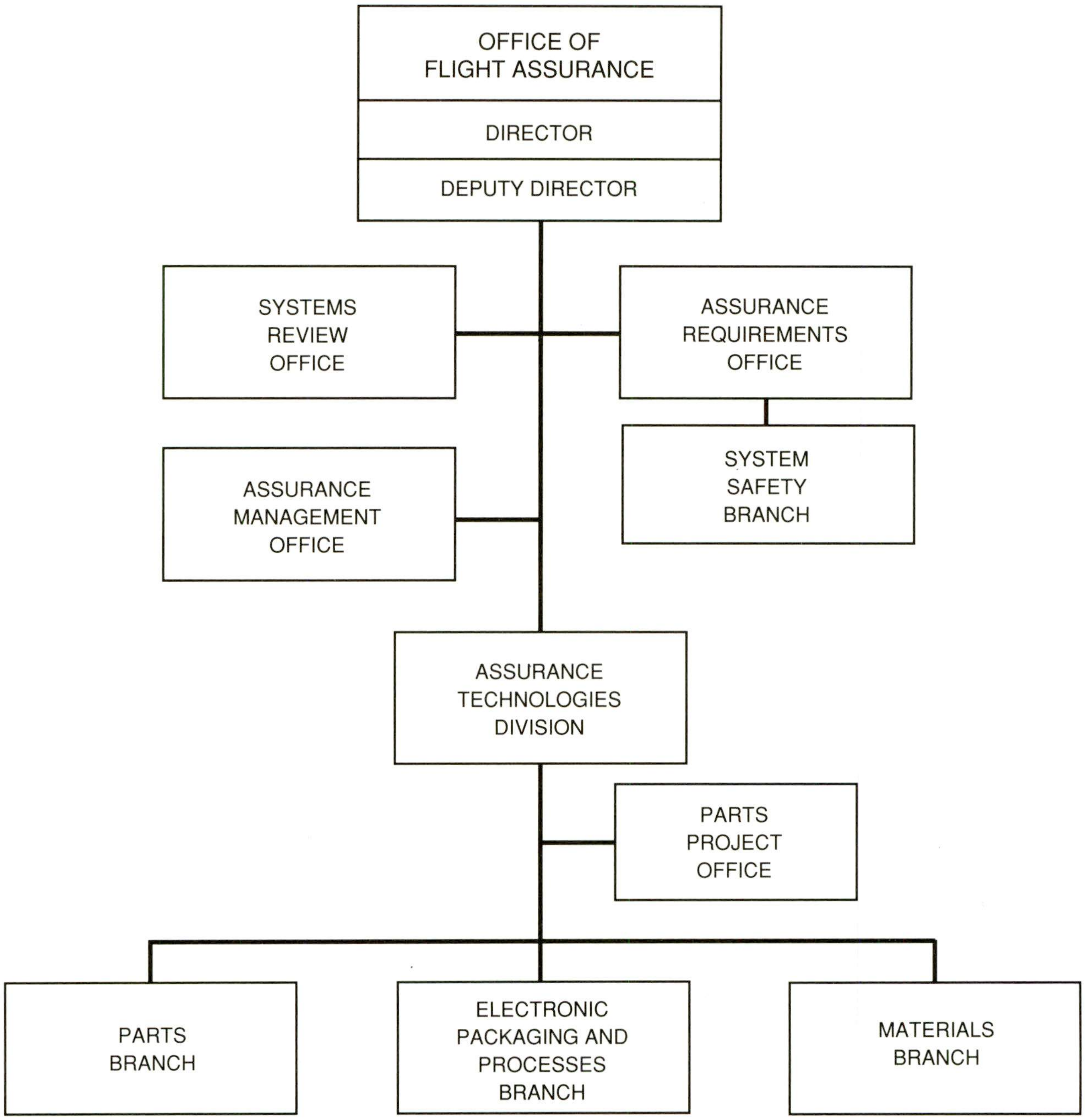
ABOVE LEFT: Polymer Section employees conducting a Fourier Transform Infrared analysis on organic material.

ABOVE: Training center for soldering of electrical connections.

Skill Needs

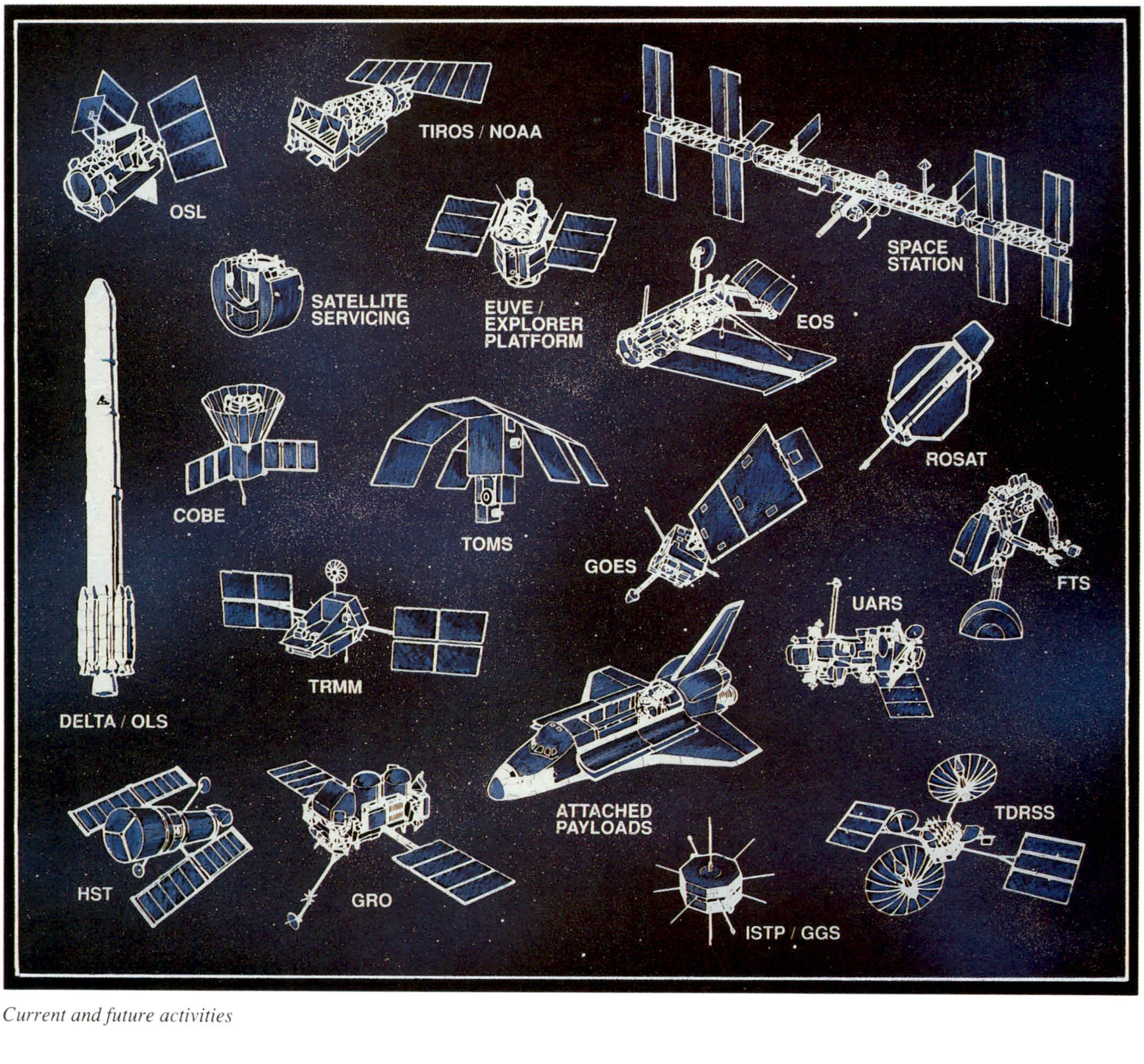
There are opportunities within the Flight Assurance Office in the following disciplines:

- Flight Assurance
- Product Assurance
- Systems Review
- Project Safety
- Parts Engineering
- Materials Engineering
- Metallurgy
- Ceramics
- Polymer Chemistry
- Chemistry
- Physics



Flight Projects Directorate

Many dynamic and interesting projects are managed by this Directorate. Goddard flight projects range in complexity from small explorer-class satellites and attached Shuttle payloads to large Earth-orbiting observatories; the Earth Observing System, which is the centerpiece of NASA's Mission to Planet Earth; international cooperative programs; and expendable launch vehicle development and services. The lifetime of the projects and the missions is up to 15 years. Because of this Directorate's expertise in on-orbit satellite refurbishment and servicing, the Hubble Space Telescope is expected to transmit valuable astronomical data for 15 years. We are responsible for the overall management, development, testing, and pre- and post-launch activities, including on-orbit checkout, of these important flight systems. Launches are scheduled aboard the Shuttle as well as on expendable launch vehicles. The Flight Projects Directorate manages an annual budget in excess of $1 billion.

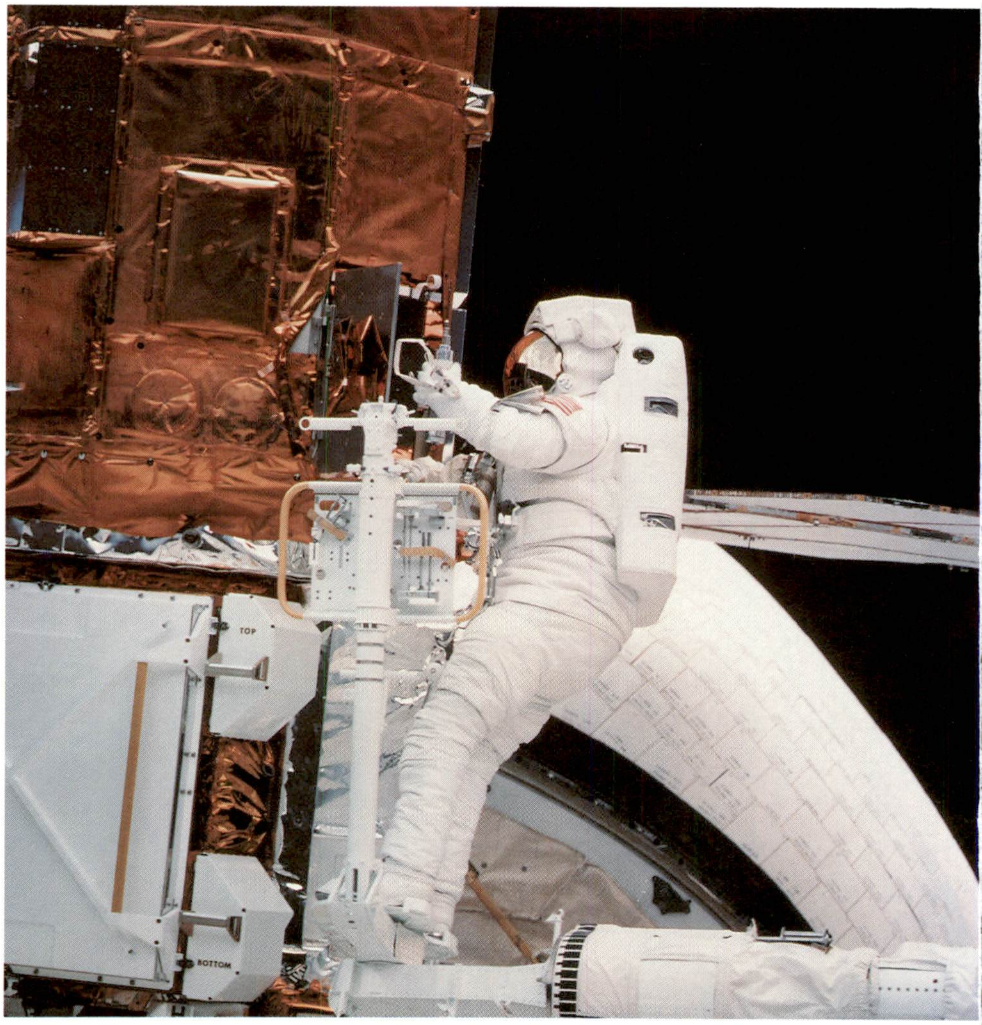


Current and future activities

Satellite Servicing Project
This project develops and produces the NASA multimission modular spacecraft and the explorer platform. It also conducts on-orbit servicing of Goddard spacecraft and develops serviceable spacecraft, airborne support equipment, and new extravehicular activity (EVA) support equipment.

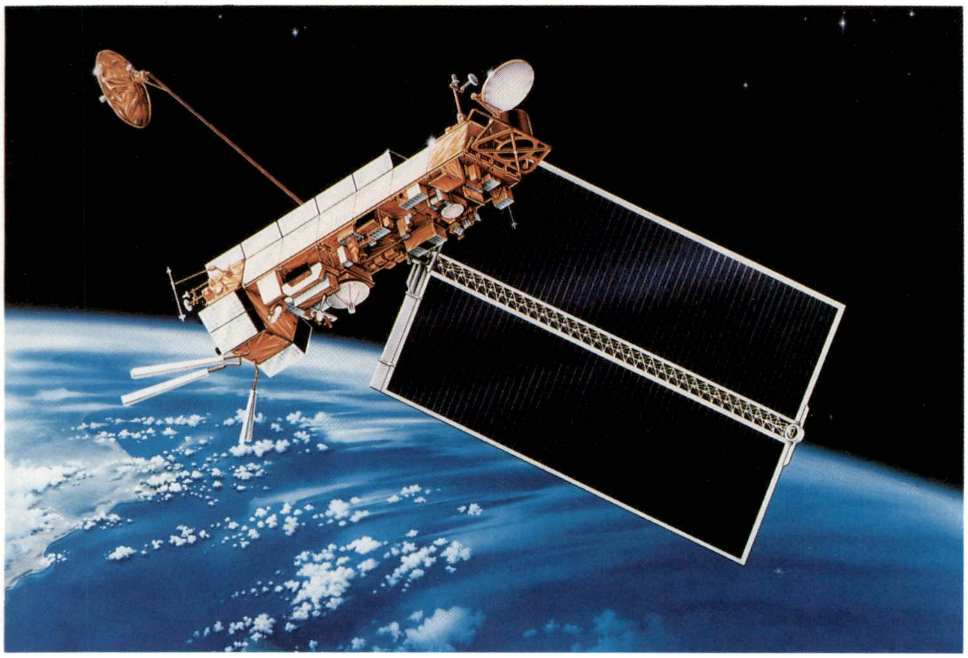
The project team plans, prepares, and conducts Shuttle-based satellite repair missions, such as the Solar Max Repair Mission and Hubble Space Telescope repair missions. The project team also is developing EVA-unique equipment and lightweight airborne support equipment to support combination deploy/retrieval missions.

Satellite servicing works on the principle that repair and refurbishment of satellites can benefit the entire space program by reducing spacecraft costs, allowing the recovery of scientific instruments, and using well-proven space engineering technology in the ever-changing and always demanding space field. We are always looking for fresh ideas and innovative engineers eager to work on the cutting edge of technology and looking to get more science for the dollar!



The Earth Observing System (EOS)
The goal of the EOS mission is to advance the understanding of the entire Earth system on a global scale by developing a deeper understanding of the components of that system, their interactions, and how the Earth system is changing. The EOS mission will create an integrated scientific observing system that will enable a multidisciplinary study of the Earth, including the atmosphere, oceans, land surfaces, polar regions, and solid earth. The Directorate manages and directs the mission; investigations will include developing and operating remote-sensing instruments. EOS is an international, coordinated effort that combines observational instruments with the scientific power to produce significant parts of the database needed for Mission to Planet Earth.

Within the EOS organization, there are three major projects: the EOS Platforms Project, which manages and develops the large orbiting "platforms" needed to carry instruments; the EOS Instruments Project, which manages the design and development of the flight facility and principal investigator instruments for flight; and the EOS Ground Systems and Operations



LEFT: Astronaut repairing Solar Maximum Satellite aboard Shuttle (STS-41C).

ABOVE: Artist's concept of the Earth Observing System (EOS) Polar Platform. The EOS, as a whole project, will be largest endeavor ever undertaken by Goddard.

Project, which designs and develops a comprehensive data system that includes observatory and instrument control, processing, storage, and efficient retrieval of EOS instrument data.

The EOS project is the largest ever undertaken by Goddard and will provide data for more than 20 years. EOS will be the most significant unifying effort of its time to understand the Earth as a planet.

The Hubble Space Telescope Project

The Hubble Space Telescope, launched in April of 1990, is a unique spaceborne observatory designed to conduct long-range astronomical research. This orbiting facility — a 2.4-meter-aperture telescope system with an initial complement of five scientific instruments — is supported by a combination of dedicated flight and ground systems.

The project team here at Goddard is dedicated to maintaining and operating the Hubble Telescope for approximately 15 years. This involves ground-systems operation and data analysis; the development, fabrication, and launch readiness of orbital replacement units and instruments; flight-systems performance analysis; maintenance mission planning and execution; and management of flight and support hardware.

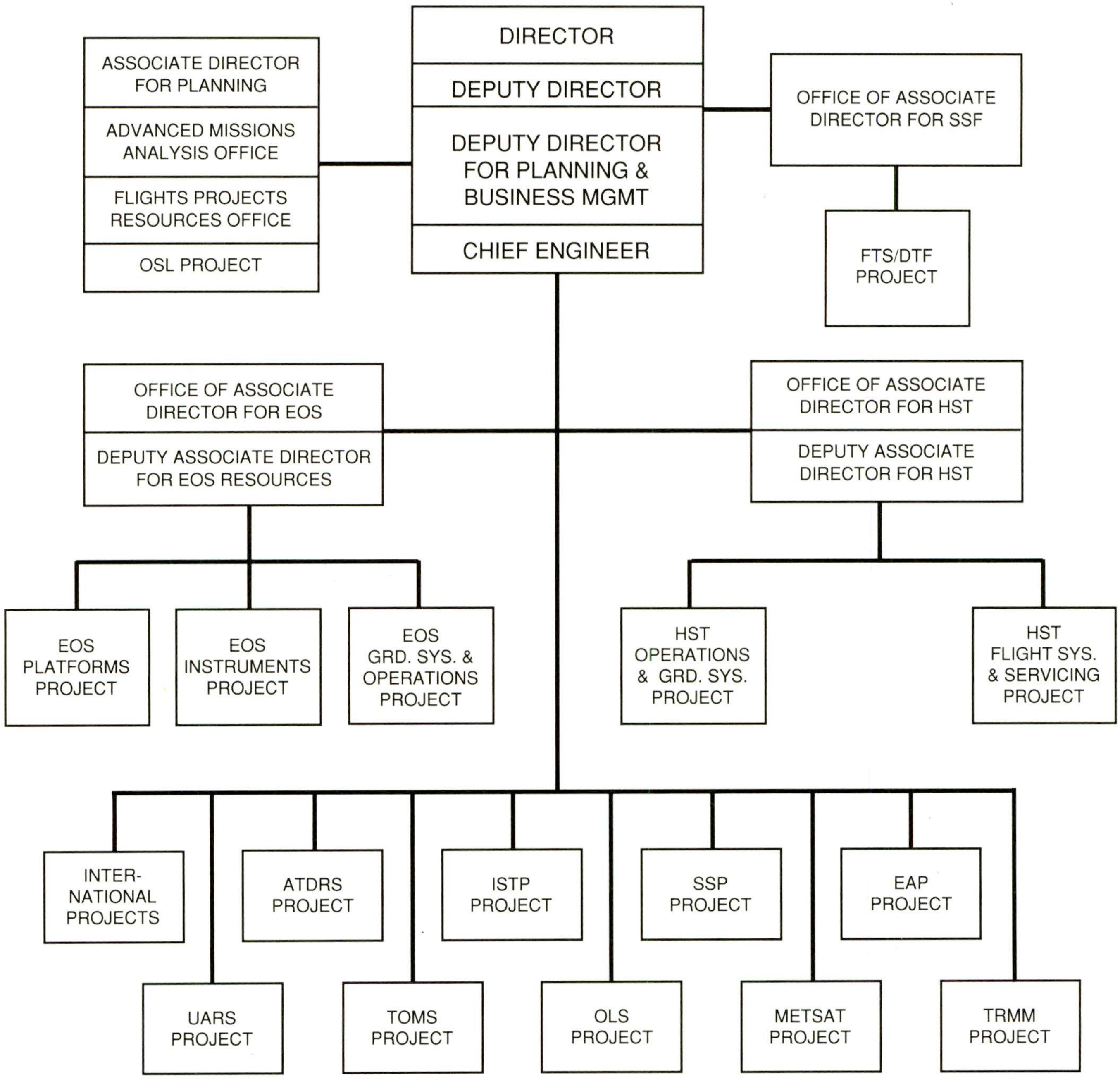
Resources Management staff organize, plan, and direct the business and financial operations of the Project. Flight Systems employees develop new, state-of-the-art spacecraft hardware and the scientific instruments to be used in upgrading the Telescope during servicing missions. Flight Operations personnel provide day-to-day operations capability to command, monitor spacecraft status, and provide science program planning, real-time target acquisition, acquisition of data, and standard processing of data. Mission Systems Engineering/Analysis staff provide observatory-level systems engineering and analysis in support of Flight Operations.

Hubble Space Telescope launched April 24, 1990, is scheduled for on-orbit servicing in approximately 3 years.

Skill Needs

There are opportunities within the Flight Projects Directorate in the following disciplines:

Project Management
Systems Management
Instrument Management
Ground Systems and Data-Processing Management
Software Management
Resource Analysis
Resource Management
Engineering
Mathematics
Accounting
Finance



Mission Operations and Data Systems Directorate

The goal of NASA's telecommunications and data processing systems is to make the link between scientists and their experiments appear as direct and transparent as possible. At the heart of these systems is the organization within the Goddard Space Flight Center chartered to provide advanced telecommunications and information systems technology: the Mission Operations and Data Systems Directorate (MO&DSD).

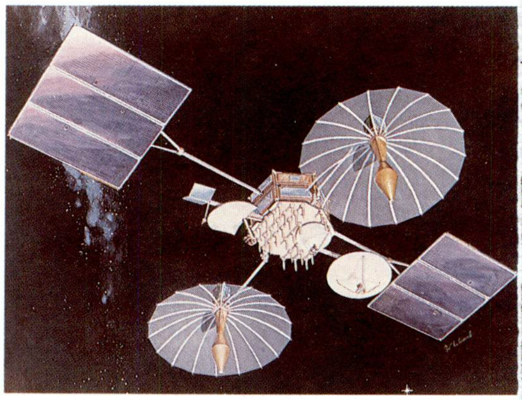
The great strength of the MO&DSD systems is that they provide a total end-to-end tracking, data, and communications service, an interactive network that transports commands to a satellite and returns the scientific data to the user. The major components of this two-way service, to be discussed on the following pages, are:

- Flight Dynamics
- Operations Control Centers
- Space and Ground Networks
- NASA Communications Network
- Data Processing
- Technology Applications

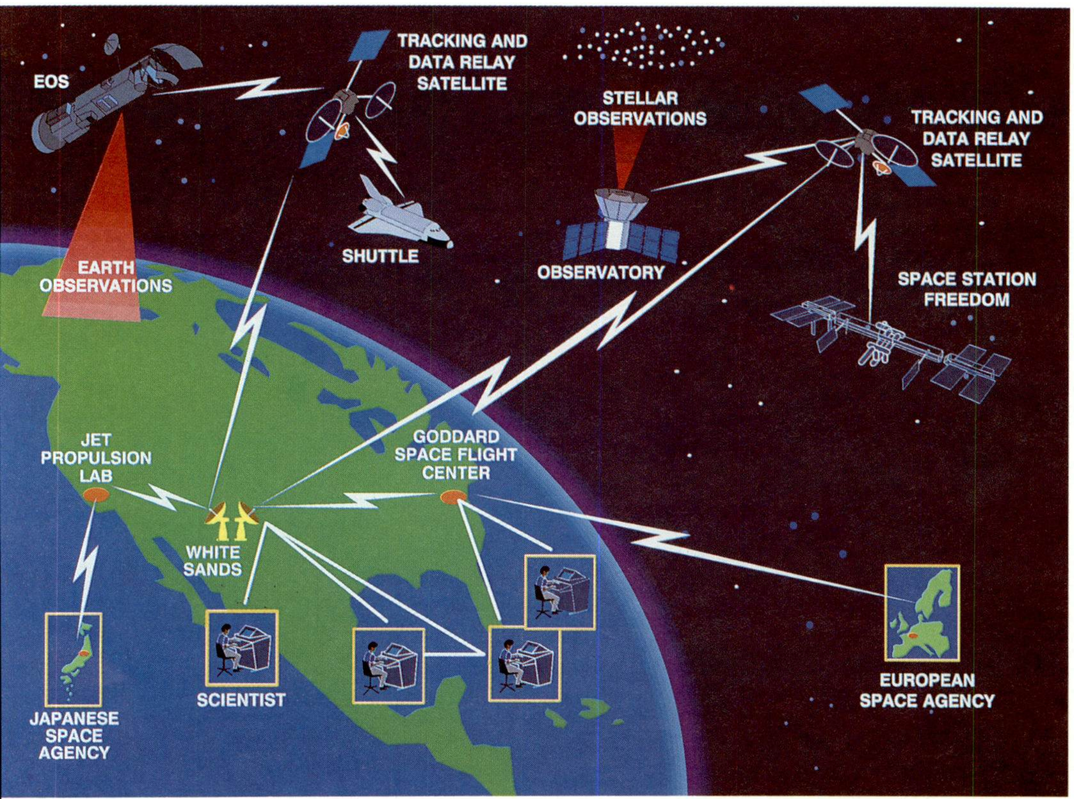
Flight Dynamics

The engineers responsible for the orbital and attitude dynamics of Goddard Space Flight Center missions begin their work years before a satellite is launched. Analyzing the science objectives of the mission, they determine the optimum orbit for fulfilling those objectives. They must decide on launch window, number and type of orbital maneuvers, how much fuel will be required, and when the satellite will reenter the Earth's atmosphere.

In addition to mission design, the flight dynamics function within MO&DSD provides ongoing orbit and attitude determination and control. The Flight Dynamics Facility, located at Goddard, analyzes real-time tracking and telemetry data to generate definitive and predictive orbits. Definitive orbits are used by experimenters in processing and interpreting scientific data. Predictive orbits are used to plan spacecraft operations and to produce acquisition data which indicate precisely where and when



tracking stations and tracking satellites must point their antennas to acquire a particular satellite. Spacecraft attitude is also determined and evaluated by flight engineers to control the pointing direction of the scientific satellite.



The MO&DSD provides end-to-end tracking and data system services to a broad range of customers, as shown in the picture above. Data rates of up to 300 megabits per second will allow tremendous volumes of data to be relayed between space-based scientific instruments— such as those aboard NASA's polar orbiting platforms of the Earth Observing System — and analysts at widely distributed locations on the ground. In the 1990s, MO&DSD will also support ongoing Shuttle operations, Space Station Freedom and numerous scientific missions, including the three "Great Observatories": Hubble Space Telescope, Gamma Ray Observatory and the Advanced X-Ray Astrophysics Facility. A major challenge in this decade will be the development of the data distribution and processing systems for programs such as Space Station Freedom and the Earth Observing System.

Operations Control Centers

The commands that keep a satellite on track and point or adjust its onboard instruments emanate from an operations control center. Control center personnel contribute significantly to mission planning and are responsible for on-line execution of the spacecraft operations plan. Depending on the category of spacecraft (for example, small explorer, Shuttle, large platforms), different types of control centers will be used. One of the largest and most sophisticated control centers ever developed is located at Goddard and supports the Hubble Space Telescope.

Space and Ground Networks

Transmissions to and from spacecraft in low-Earth orbit are controlled by NASA's Space and Ground Networks, both of which are managed by the MO&DSD's Network Control Center at Goddard. NASA's early tracking and data acquisition network, a worldwide system of ground stations, provided satellite contact limited by the Earth's horizon. Today's Tracking and Data Relay Satellite System (TDRSS) has —

LEFT: The Tracking and Data Relay Satellites (TDRSs) provide nearly full-orbit coverage to spacecraft in low-Earth orbit, relaying commands on the forward link and scientific data on the return link. The TDRSs are the centerpiece of NASA's Space Network and will be enhanced in the 1990s to meet the increased data requirements of the Space Station Freedom era.

figuratively speaking — deployed those ground stations in space at geosynchronous altitude, thereby achieving approximately 85-percent orbit coverage for spacecraft in low-Earth orbit.

Space Network

The TDRSS is the key element in NASA's Space Network. The TDRSS is composed of a space segment (the orbiting relay satellites) and a ground segment (principally, the ground terminals located at White Sands, New Mexico). The baseline space configuration consists of two operational relay satellites and a spare in geosynchronous orbit. The satellites provide a relay for signals between user spacecraft and the ground terminals. The Phase-B definition studies are underway for the Advanced TDRSS that will be developed for a first launch in late 1996.

Ground Network

The implementation of the TDRSS has allowed many ground tracking stations to be phased out. There remains a critical Shuttle support responsibility, however, at four Ground Network facilities. The stations at Merritt Island and Ponce de Leon, Florida and Cooper's Island, Bermuda, support Space Shuttle launches from the Kennedy Space Center. The facility at Dakar, Senegal functions as emergency backup for Shuttle orbital insertion communications. Free-flyer pre-launch and launch activities are also supported at these ground stations.

NASA Communications Network

After the Space and Ground Networks have acquired and returned the spacecraft data to Earth, the NASA Communications (Nascom) Network reenters the data system picture — Nascom was also responsible for transport services on the forward link. Once Nascom has assumed responsibility for data transport at the point of ground reception, the data is routed via satellite, through terrestrial or ocean cable links to the required destinations, which include project control centers, central data handling facilities, the Flight Dynamics Facility, and regional data handling/switching centers for further distribution.

The Nascom Network is a worldwide complex of communications services that include data, voice, teletype, and video systems. The network consists of approximately 850 satellite and terrestrial circuits, and provides data transport switching and control facilities which link approximately 140 domestic and foreign terminals. The primary switching center, which operates 24 hours a day, 7 days a week, is located at Goddard.

MO&DSD's Microelectronics Laboratory is equipped to develop systems in-house, from chip design to integration and test.

Data Processing

The last step for the telemetry information in the MO&DSD data system is data processing. This function captures the raw data from the spacecraft and processes them into usable products. These products can be near-real-time data sets for scientific investigators, long-term archived data stored for later research, or other products such as images and digital computer tapes distributed throughout the world. The MO&DSD develops and operates a number of central data handling facilities dedicated to specific missions as well as facilities that provide multi-mission support.

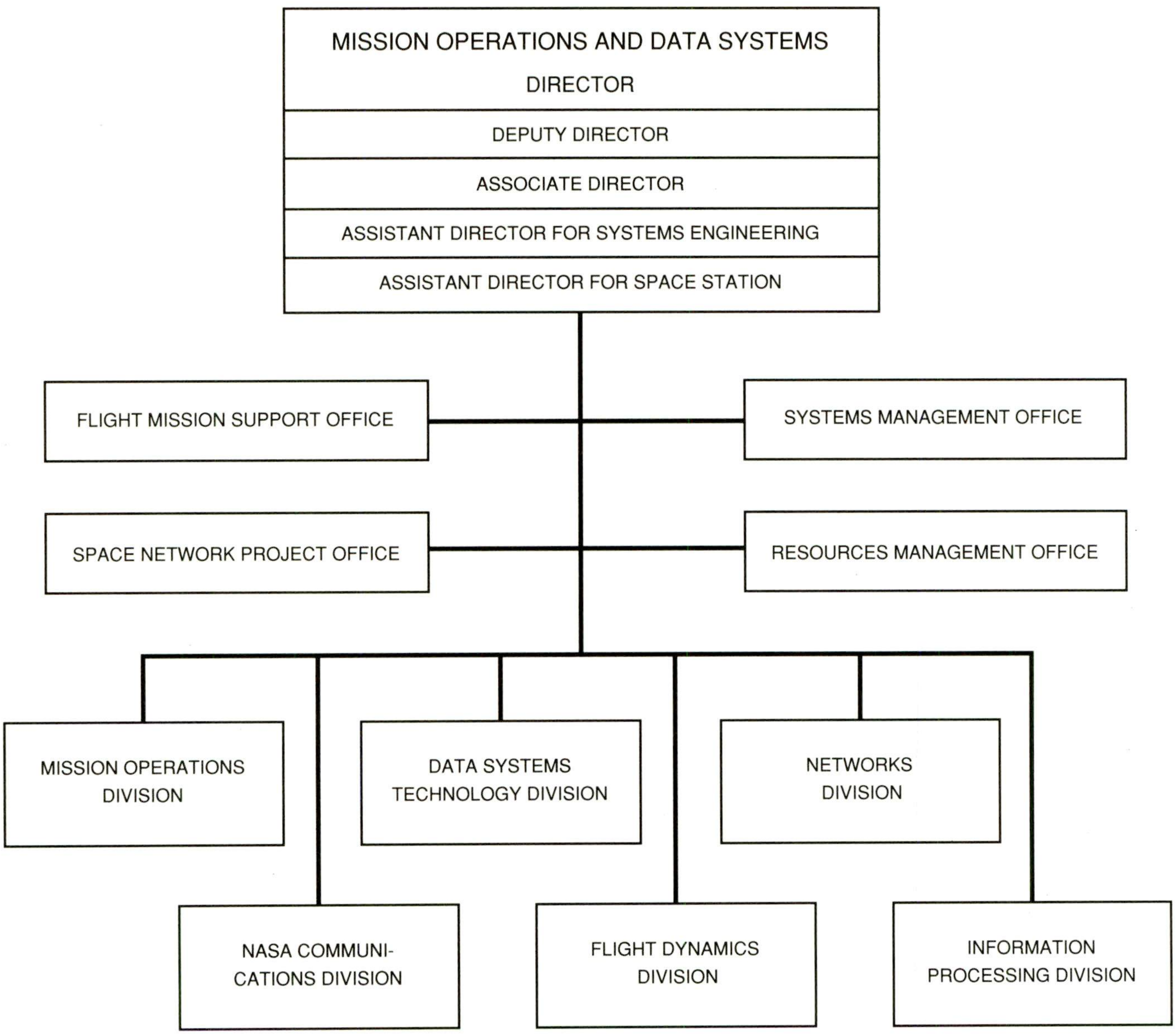
Technology Applications

Providing the essential control and data links between scientists and their instruments for increasingly complex missions requires a continuing effort to develop and apply information systems and communications technology throughout the space operations systems described above. Research in automation techniques, microelectronics, and system design and development are an integral part of the Directorate's contribution in preparing for future missions as mankind's quest for greater knowledge about the Universe grows.

Skill Needs

There are opportunities within the Mission Operations and Data Systems Directorate in the following disciplines:

Application Software	Digital Data Systems	Mission Operations Management
Data Base Management	Expert Systems	RF Communications
Data Systems Management	Flight Mechanics	Software Engineering
Digital Data Communications	Logic Design	Spacecraft Command and Control
Digital Data Processing	Mission Design	Systems Engineering



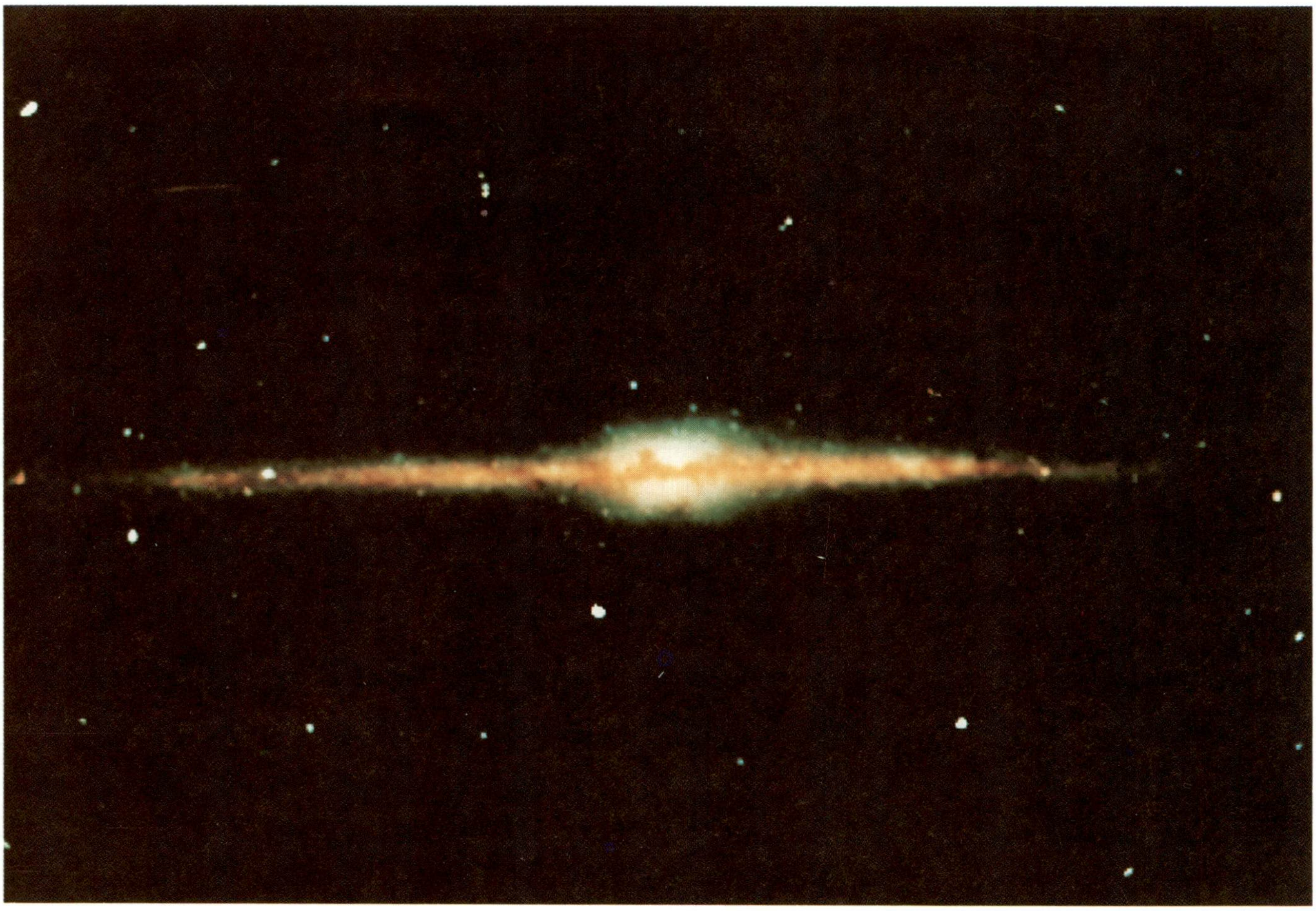
Space Sciences Directorate

The Space Sciences Directorate plays a leading role in conceiving and developing instruments and spacecraft for the scientific exploration of space through its three research organizations:

Laboratory for Astronomy and Solar Physics
Laboratory for Extraterrestrial Physics
Laboratory for High Energy Astrophysics

Also, through its Orbiting Satellites Project, the Directorate manages scientific spacecraft developed by Goddard.

The major strength of the Space Sciences Directorate is its people. The majority of the professional staff of the three laboratories are research scientists with doctoral degrees. Administrative, clerical, computer, engineering, and technical employees have the opportunity to participate in basic research while using cutting-edge technology and working directly with world-recognized scientists.

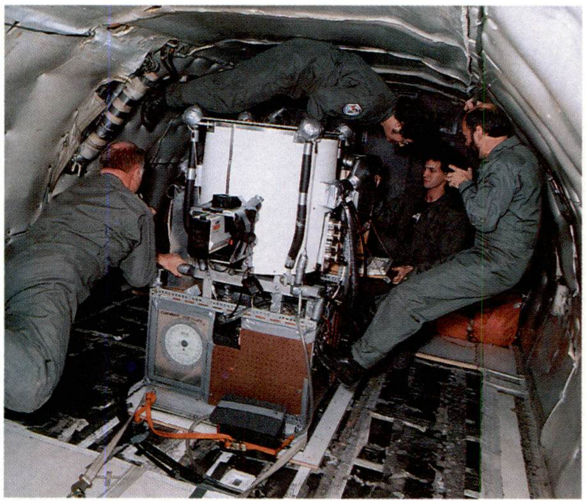


Our Milky Way galaxy, seen in infrared light from above the Earth's atmosphere. The image is based on data from an instrument built under the supervision of the Laboratory for Astronomy and Solar Physics and launched in November 1989, aboard NASA's Cosmic Background Explorer satellite.

Laboratory for Astronomy and Solar Physics (LASP)
LASP researches a wide range of subjects in astronomy, cosmology, and solar studies. Astronomical and cosmological studies are done primarily through observation of ultraviolet and infrared light. Solar research includes measurements of x rays, gamma rays, and radio waves, as well.

LASP members help design and operate apparatus launched on satellites, sounding rockets, aircraft, and balloons. They study data obtained from this equipment to gain new knowledge of the universe. They also develop computer systems and programs to aid in developing new instruments and to process and analyze data. Computer work is performed on a wide variety of systems ranging from personal workstations to supercomputers.

Laboratory for Extraterrestrial Physics (LEP)
LEP performs experimental and theoretical research on physical properties and dynamical processes of solar, planetary, and stellar objects, as well as the interstellar and interplanetary media. LEP scientists study the chemistry and physics of comets, planetary atmospheres, and solid objects in the Solar System, including meteorites, asteroids, and planets. They also pursue a vigorous program in astronomy, especially at infrared wavelengths.

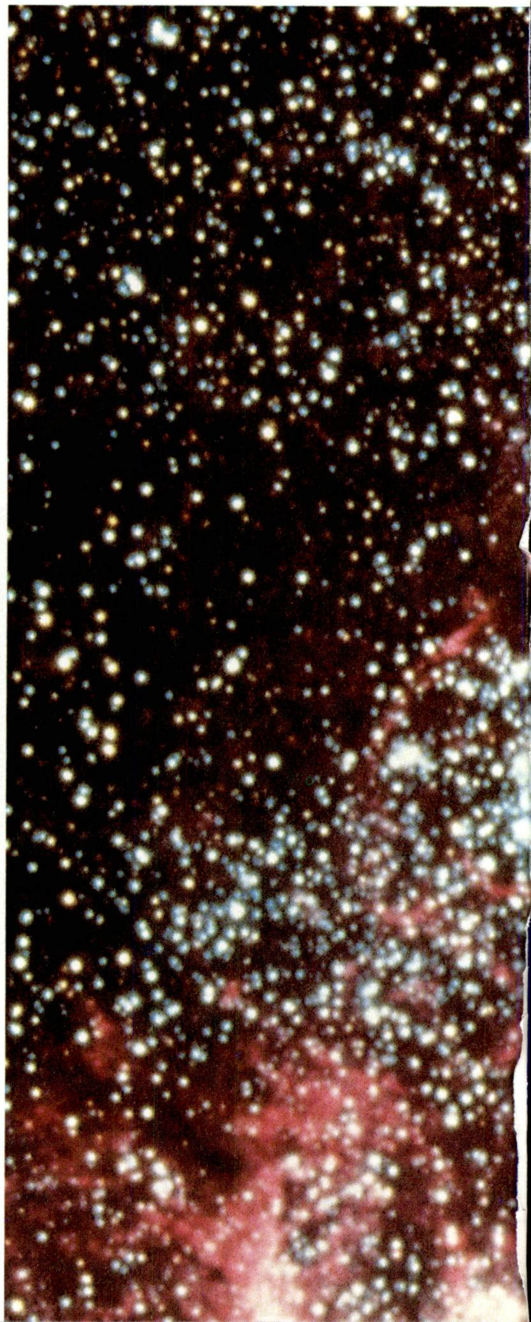


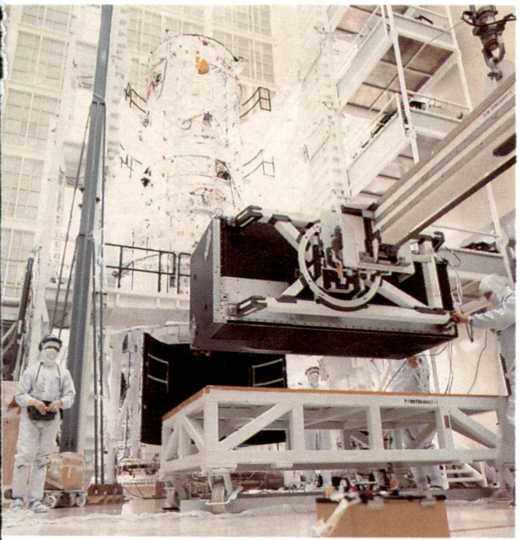
Chemistry in zero gravity. A high-temperature refractory nucleation experiment on board NASA's KC-135 Reduced Gravity Research Aircraft.

LEP conceives, develops, and builds experiments and integrates them into Earth-orbiting, planetary and interplanetary spacecraft, to measure magnetic and electric fields and space plasmas. The staff also develops spectrometers for observations of spectral lines and continua in the infrared and submillimeter spectral regions; these devices are flown on aircraft, balloons, and spacecraft, and are mounted on ground-based telescopes.

Laboratory for High Energy Astrophysics (LHEA)
LHEA explores the fundamental questions of astrophysics by gathering and interpreting the information carried by photons and subatomic particles with typical energies that are much higher than those found in the atmospheres of ordinary stars like the Sun. This field of research is called high energy astrophysics and the information collected constitutes the "signatures" of the most energetic processes in the universe.

With few exceptions, the radiation and particles studied by LHEA can only be collected above the Earth's atmosphere. The LHEA seeks, through space experiments and physical interpretation, to understand the origin and evolution of high-energy phenomena in the Sun and other ordinary stars; in collapsed stars, supernova remnants, and the interstellar and intergalactic media; in galaxies and their central cores; and in huge clusters of galaxies at great distances from the Milky Way.





LEFT: Goddard High Resolution Spectrograph (GHRS). Mounted on the Hubble Space Telescope, the GHRS was developed by the staff of LASP. It is the most accurate and powerful ultraviolet instrument ever flown in space.

RIGHT: Pegsat satellite chemical release experiment over Canada, April 1990. The whitish hemisphere is expanding, electrically neutral barium, while the magenta "tail" is barium ionized by sunlight and trapped in the Earth's magnetic field.

Current Activities in Space Sciences Directorate Laboratories

Laboratory for Astronomy and Solar Physics

Cosmic Background Explorer – *satellite operations and research on cosmology and the origin of galaxies*
Goddard High Resolution Spectrograph – *initial calibration and scientific operations on the Hubble Space Telescope (HST)*
Space Telescope Imaging Spectrograph – *advanced equipment to enormously increase the spectroscopic capabilities of the HST*

Laboratory for Extraterrestrial Physics

Voyager 1 and 2 – *research on the outer planets and the interplanetary medium with data from instruments developed in the Laboratory*
Mars Observer – *LEP hardware on this Mars-orbiting spacecraft will make the first comprehensive study of Mars' magnetic field*
International Solar Terrestrial Physics Project – *LEP has a leading role in this joint U.S. - Japan - European Space Agency program*

Laboratory for High Energy Astrophysics

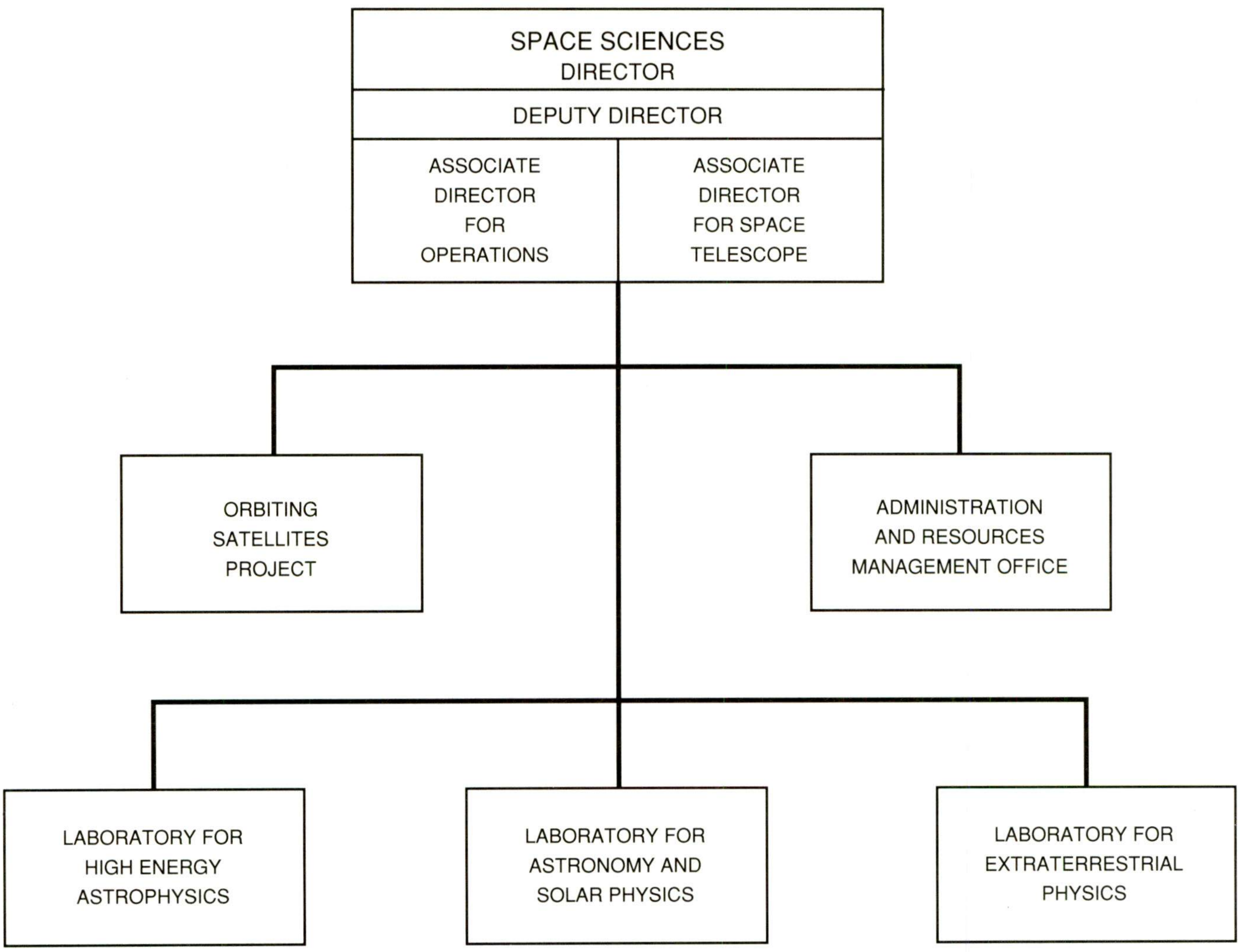
Broad Band X-Ray Telescope – *research on supernovae, binary stars, and galaxies on the Astro-1 mission of Space Shuttle Columbia*
Energetic Gamma Ray Experiment Telescope – *a major component of NASA's Gamma Ray Observatory satellite, launched in 1991*
Energetic Particle Acceleration, Composition, and Transport – *cosmic ray studies on the WIND satellite in interplanetary space*

Supernova 1987A. Gamma rays from nucleosynthesis in this cosmic explosion were observed by LHEA's Gamma Ray Imaging Spectrometer, on a balloon above Australia. LHEA instruments on the Astro mission, Gamma Ray Observatory, and Astromag will investigate x rays, gamma rays, and cosmic rays from supernovae (photo: European Southern Observatory).

Skill Needs

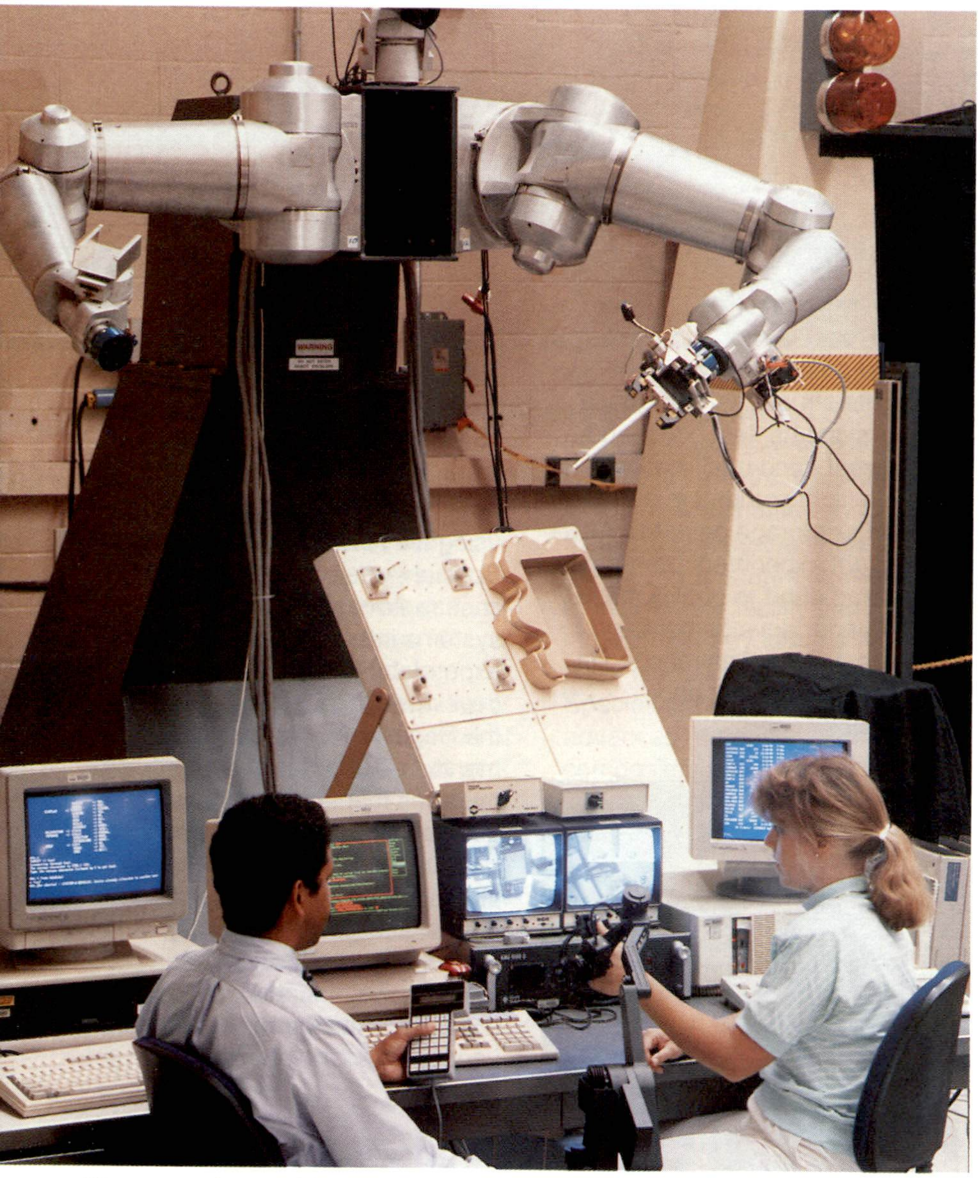
There are opportunities within the Space Sciences Directorate in the following disciplines:

- Astronomy
- Astrophysics
- Chemistry
- Computer Science (design, operation, programming, systems analysis)
- Aerospace Engineering
- Electrical Engineering
- Mechanical Engineering
- Magnetohydrodynamics
- Mathematics (applied and theoretical)
- Physics (atomic, engineering, high energy, nuclear plasma)
- Finance
- Business
- Public Administration
- Procurement
- Accounting



Engineering Directorate

The Engineering Directorate supports NASA space and Earth sciences and applications programs through technical research and development. Our enabling technology program increases knowledge and capabilities in areas necessary for the success of assigned NASA missions. We design, develop, and test components, subsystems, instruments, and spacecraft for multiple programs and projects. We oversee in-house development of flight hardware and software including instruments, Attached Shuttle Payloads and Small Explorer Spacecraft, and system and discipline engineering support for space- and Earth-science missions hardware such as the Hubble Space Telescope.



These seven-degree-of-freedom robotic arms are part of the engineering test bed supporting the development of robotic systems for space sciences and exploration.

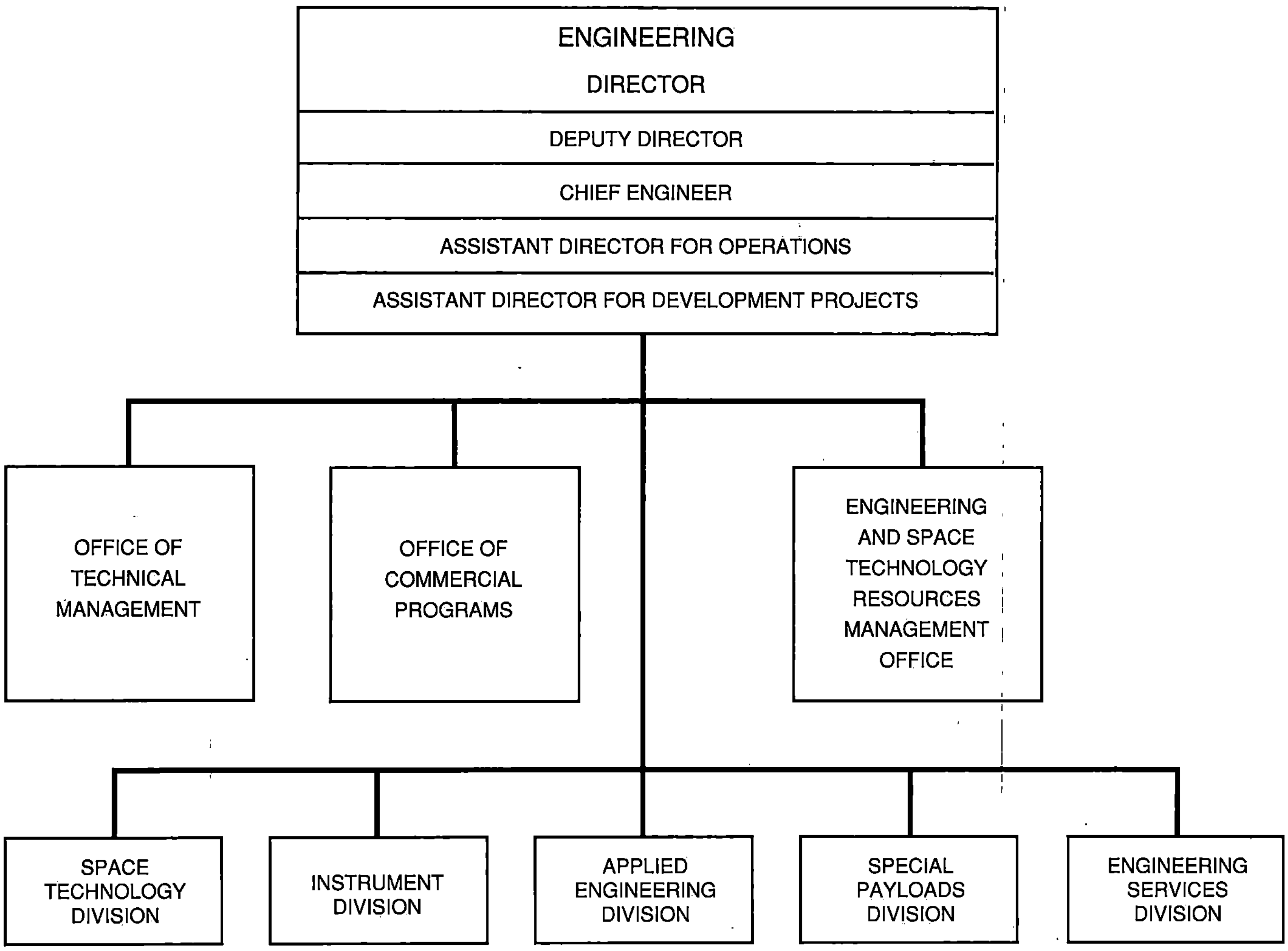
Directorate Activities Include:

- Technology research in laser communications and sensing, cryogenics, sensors, spaceborne data systems, and robotics.
- Small Explorer Satellite Program for frequent astrophysics missions.
- Instrument development for the Earth Observing System (EOS), the Advanced X-ray Astronomy Facility, the Space Infrared Telescope Facility, and the Mars Observer, among others.
- Development of payload modules and spacecraft for the Tropical Rainfall Measuring Mission and the X-ray Timing Explorer.
- On-Orbit Cryogen Transfer Flight Experiments.
- Development of the Payload Module flight hardware for the Extreme Ultraviolet Explorer.
- Development of advanced high-capacity spaceborne data systems.
- Application of new materials and manufacturing techniques.

Skill Needs

There are opportunities within the Engineering Directorate in the following disciplines:

- Space Power Systems
- Guidance and Control
- Cryogenics and Propulsion
- Mechanisms
- Optics
- Photonics
- Microelectronics and Detectors
- Microwave Instruments
- RF Communications
- Signal Processing
- Structures
- Thermal Engineering
- Contamination Control
- Electrical and Electronic Systems
- Flight Data Systems
- Spacecraft and Instrument Systems
- Spacecraft and Instrument Integration and Testing
- Experimental Fabrication
- Verification and Environmental Test Engineering



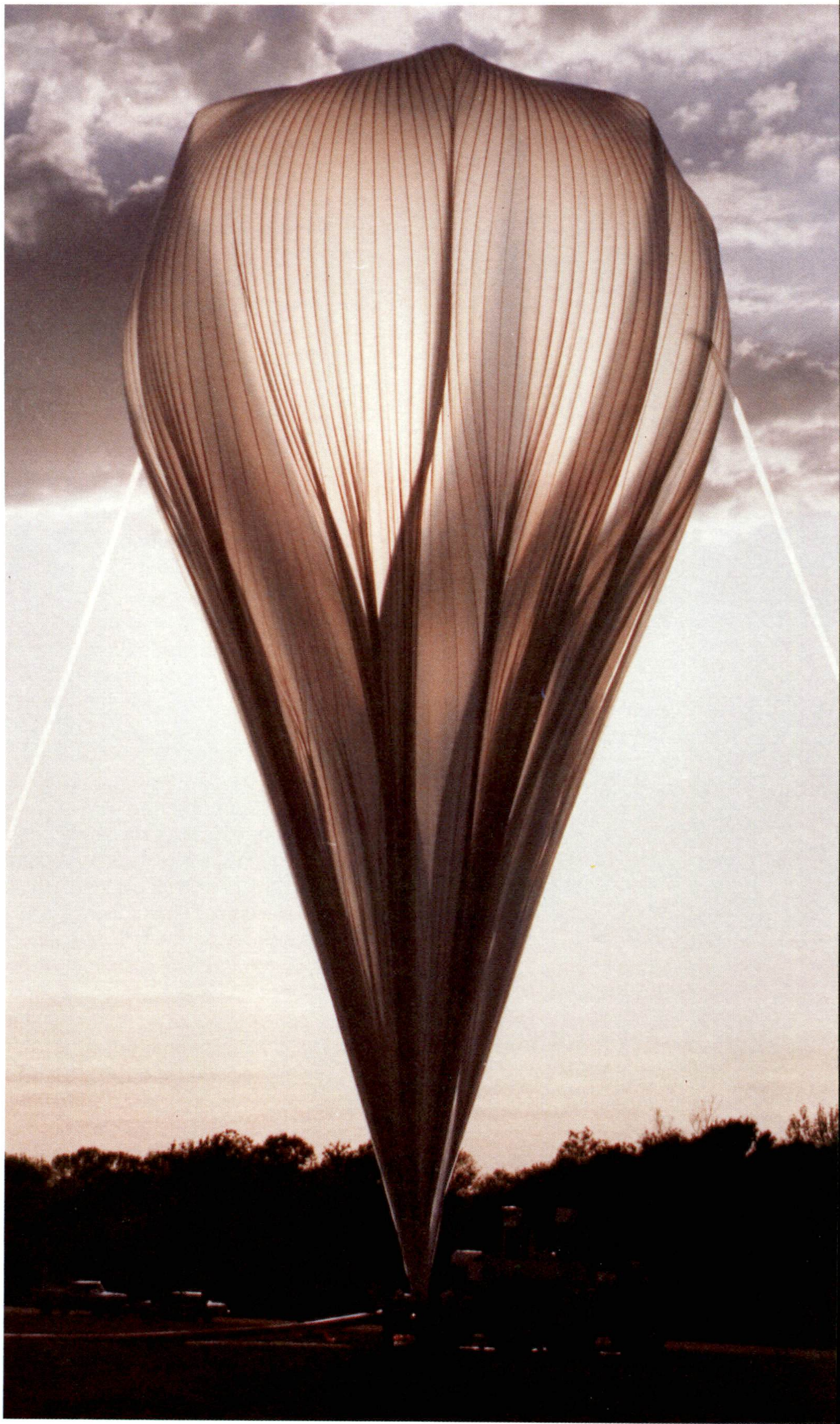
Suborbital Projects and Operations Directorate

Since 1945, work conducted at the Wallops Flight Facility, located in the coastal areas of Virginia, has undergone many changes. In the early years, the research focused on obtaining aerodynamic data at very high speeds as part of the effort to penetrate the sound barrier and to operate at supersonic speeds. The hallmark of the Wallops Flight Facility has been its suborbital research projects. This Directorate, the only one solely located at Wallops, manages NASA's suborbital programs, and supports the aeronautical programs. The sounding rockets, scientific balloons, and aircraft provide scientists with unique avenues for conducting science and research worldwide.

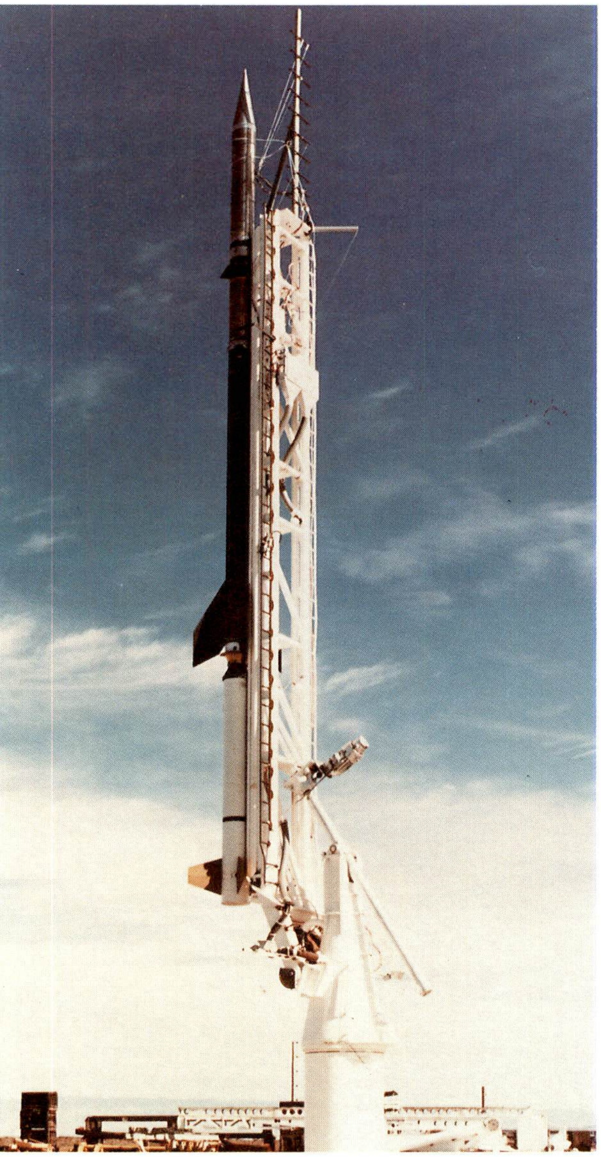
The sounding rocket program conducts an average of 35 missions each year. The sounding rocket fleet consists of 15 different vehicles, ranging from 10 to 64 feet in length. These 1- to 4-stage vehicles fly vertical trajectories carrying their payloads from 30 to 600 miles in altitude.

Throughout its history, the Suborbital Projects and Operations Directorate has adapted to the changing focus of the country's aerospace research endeavors and has maintained a dedication to applying inexpensive and innovative methods to scientific research.

Current activities include:
- Sounding Rocket Program
- Aeronautical Research Programs
- NASA-Owned Airport
- Aircraft Operations and Maintenance
- Project Management
- Engineering Support
- Flight and Ground Safety
- Computer Operations and Software Support
- Balloon Program
- Launch Range Operations
- Wallops Orbital Tracking Station
- Tracking and Data Acquisition
- National Scientific Balloon Facility
- Poker Flat Research Range
- Off-Range Expeditions



Scientific balloon is prepared for flight at the National Scientific Balloon Facility, Palestine, Texas.



Black Brant IX two-stage sounding rocket awaits launch from the pad at White Sands Missile Range, New Mexico.

Suborbital Resources Management Office

This Office develops budgetary plans and operating plan requirements; we monitor the actual progress of the plan throughout the year. Resources personnel assist technical managers with developing and executing plans using financial and personnel resources for institutional needs and Research & Development (R&D) programs under the cognizance of the Directorate.

Engineering Division

The Division plans, develops, fabricates, integrates, and tests both airborne and ground-based mechanical and instrument systems. This Division provides management and engineering support to the Office of Space Operations Tracking and Data Acquisition Program at Wallops, engineering and fabrication support for the Sounding Rocket Program, and software support for real-time operations and post-flight data processing, ground flight safety, and aeronautical research programs. We have four branches: Technical Support, Instrumentation Engineering, Electro-Mechanical Systems, and Safety and Quality Assurance. Our staff operate the mechanical and electronic fabrication shops; design, engineer, integrate, and test sounding rocket payloads; design and procure ground tracking, telemetry, and support systems; provide flight and ground safety analysis and support for rocket and balloon flights; and provide off-site launch range development.

Operations Division

The Operations Division plans, manages, and conducts aerospace and other project operations for Wallops personnel on-site, as well as at other locations. Radar and optical tracking, communications, acquisition of telemetry data, and computing support for range operations and data processing are as much a part of our work as are the preparation and launch of rockets and airplanes. The Division plans and directs Wallops' efforts in aeronautical research operations and airborne science support, as well as range operations and off-range expeditions. The most recent addition to operations is the Wallops Orbital Tracking Station that operates around the clock, every day of the week. Our staff operate and maintain the many facilities, instrument systems, and aircraft required to support the programs. Staff members travel

Wallops personnel monitor mission operations from the Range Control Center.

frequently on mission support and expeditions. They provide assistance and train foreign nationals. We have four branches: Aircraft Programs, Range Management, Data Acquisition, and Launch Vehicles.

Projects Division

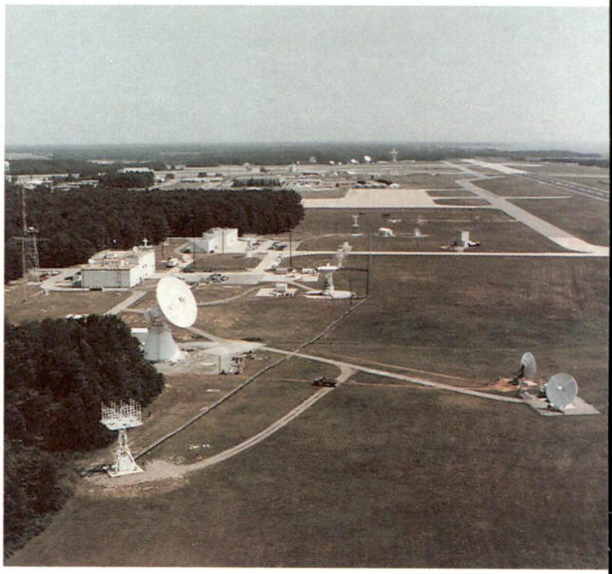
Since 1959, the NASA Sounding Rocket Program has conducted more than 2,400 launches with a vehicle success rate of 95 percent and a mission success rate of 86 percent. Balloons can travel up to 30 miles in altitude, and their flight lifetime ranges from several hours to several days. Since 1976, more than 400 balloons have been launched with an overall success rate of 85 percent.

The Division plans, manages, and conducts the NASA Sounding Rocket Program, other Lighter-Than-Air Program activities, and the NASA Balloon Program, including management of the National Scientific Balloon Facility at Palestine, Texas. The Division is composed of the Sounding Rocket Projects Branch and the Balloon Projects Branch. Sounding rockets fly near-vertical paths carrying scientific instruments to altitudes from 30 to approximately 600 miles (three to four times higher than the Space Shuttle). The experiment time above the Earth's atmosphere ranges up to 15 minutes.

Parachutes are used to recover the instruments for reuse, and special high-altitude parachutes sometimes are used for science purposes.

The Sounding Rocket and Balloon Programs provide low-cost, fast-response flight platforms and support basic scientific research. The combined programs support scientific organizations from domestic and foreign universities, international and commercial research institutions, and other government agencies, as well as various NASA field centers. The experiments provide a variety of information, such as density and temperature of particles in the upper atmosphere, properties and changes in the ionosphere, the natural radiation surrounding the Earth, and many other phenomena. Approximately 40 sounding rockets and 45 balloons are launched each year from various locations around the world. Financial support for university investigators is provided by the Sounding Rocket and Balloon Programs, and many graduate students have earned degrees based on participation.

Final preparations for a spin balance test are conducted on a Black Brant IX sounding rocket payload section.

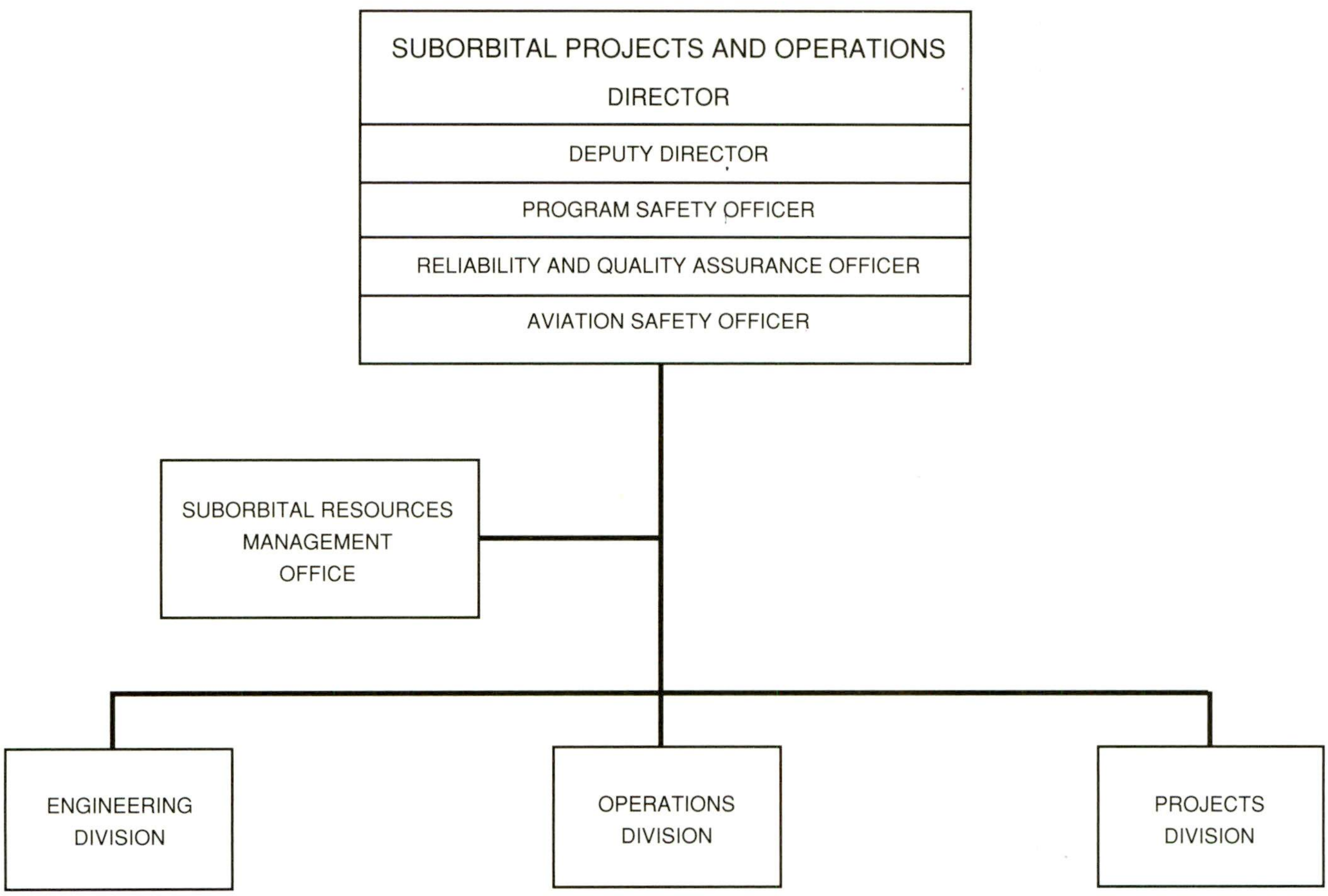


Wallops Orbital Tracking Station supports such satellite programs as COBE, IUE, and Nimbus-7.

Skill Needs

There are opportunities within the Suborbital Projects and Operations Directorate in the following disciplines:

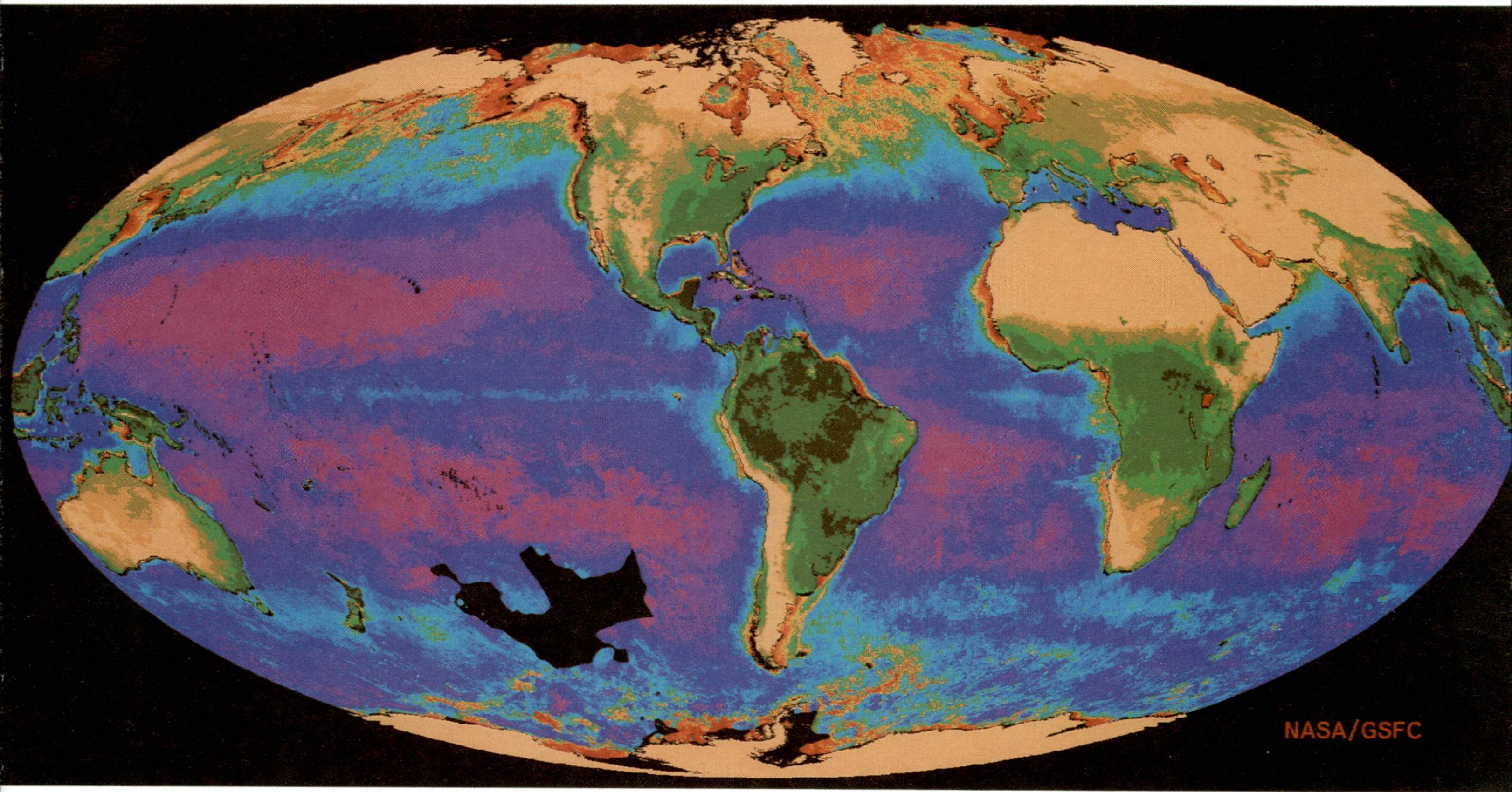
- Aerospace Engineering
- Electrical Engineering
- Electronics Engineering
- Mechanical Engineering
- Mathematics
- Physical Sciences
- Computer Programming
- Aircraft Piloting
- Scientific and Technical Photography
- Resources Analysis and Management



Earth Sciences Directorate

Our goal is to develop a better understanding of processes affecting global change and the distribution of natural resources through research, development, and application of advanced space technologies. The program ranges from basic research, including modeling and data analysis, to the development of sensor systems for ground-based, airborne, and spaceflight observing activities. The Directorate is evidence that Goddard is a center-of-excellence in research and a major location and resource for Earth observation activities.

Related aspects of oceanography, hydrology, and climate research in areas such as global physical system modeling, interactive process studies, and solar-terrestrial relationships are research topics.



Directorate activities, ongoing and future, include:

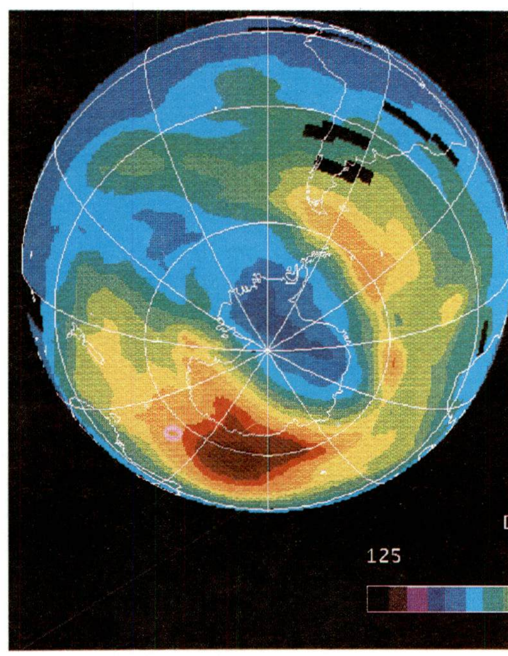
- Develop an understanding of solar, anthropogenic, and natural influences on the atmosphere and related systems that affect the habitability of the Earth.
- Study long-term global climate change.
- Conduct oceans research, including development of remote-sensing algorithms and analysis and interpretation of data.
- Acquire and analyze data on plate tectonics, continental and regional crustal deformation, and local earthquake hazards.
- Develop, test, apply, and evaluate algorithms for processing satellite image and non-image data.

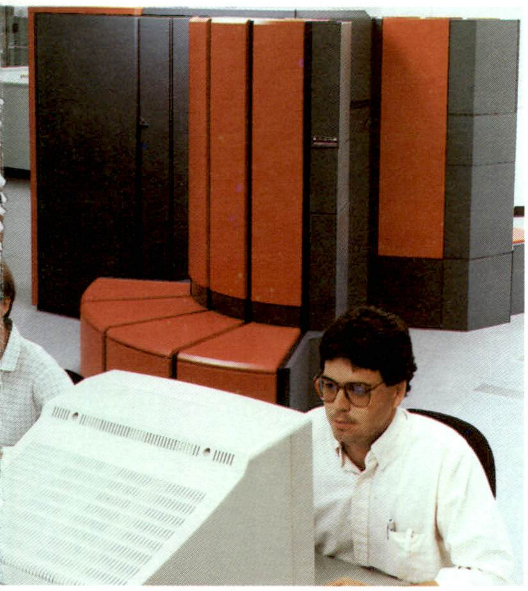
Representation of global biomass in the oceans and on land as retrieved from the Coastal Zone Color Scanner (CZCS) and the Advanced Very High Resolution Radiometer (AVHRR).

The Laboratory for Atmospheres
Our staff plan, manage, and execute a comprehensive theoretical and experimental research program dedicated to advancing our knowledge and understanding of the atmospheres of the Earth and other planets. A large portion of the research program is aimed specifically at advancing our ability to predict the weather and climate of Earth. The Laboratory also identifies requirements for observations of atmospheric processes by satellite or other techniques; conceives, designs, develops, and analyzes electronic, electromagnetic and mechanical sensors operating in the ultraviolet, infrared, optical, and radio portions of the EM spectrum for remote and in-situ exploration and examination of terrestrial and planetary atmospheres; and provides for analysis and interpretation of data to further our knowledge of atmospheric phenomena.

The Laboratory for Terrestrial Physics
This Laboratory researches applications of remote sensing and other space technology to advance the state of knowledge in the Earth sciences and to aid in the improved management of the resources of the Earth. Most of the effort is focused in specific research areas, such as investigation of the Earth's geoid, gravity, and magnetic fields for application to crustal and ocean dynamics, Earth structure, and earthquake mechanisms; understanding motions and mechanics associated with plate tectonics; studies of the spatial and temporal dynamics of land features; and soils and soil moisture. Instruments and data systems are developed; new, one-of-a-kind ocean, atmosphere, and terrestrial remote-sensing instruments, covering the visible and infrared spectra, are designed, fabricated, calibrated, and tested by our staff.

The Goddard Institute for Space Studies (GISS)
Located on the campus of Columbia University in New York City, GISS conducts a broad program of research in space and Earth sciences for current and future Goddard programs. Current research emphasizes a broad study of global change, an inter-disciplinary research initiative addressing natural and man-made changes in our environment that occur on time scales of decades and affect the habitability of our planet. A key objective is prediction of atmospheric and climate changes. The research combines analysis of comprehensive global data sets, derived mainly from spacecraft observations, with global models of atmospheric, land surface, and oceanic processes. The research approach includes study of past changes on Earth such as paleoclimate changes and study of other planets as an aid to prediction of future evolution of the Earth on a planetary scale.

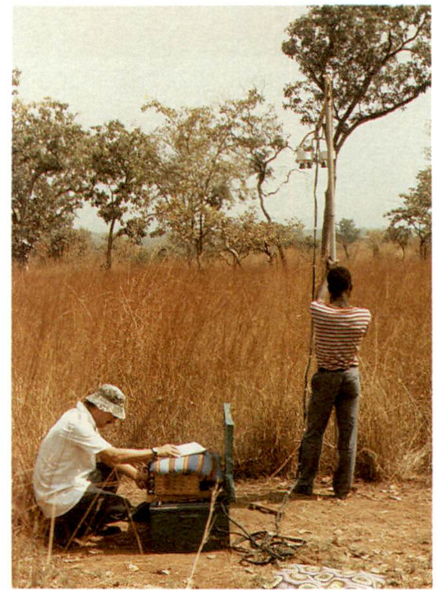




FAR LEFT: Researcher setting up instrumentation on the Black Rapids Glacier in Alaska.

LEFT: The CRAY YMP is a supercomputer used to support NASA-funded researchers in space and Earth sciences.

RIGHT: Scientists on an African field trip measure plant spectral reflectance for later comparison with satellite data.



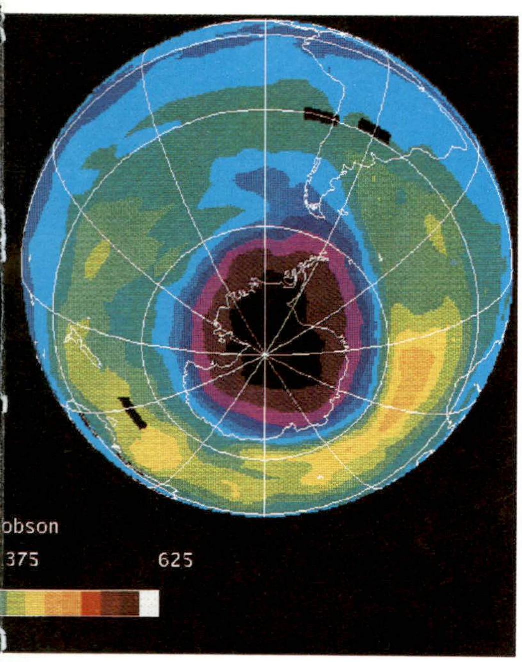
systems and techniques associated with remote and in-situ sensing. The uses of remote sensing in research on the Earth environment, global habitability, global biogeochemical cycles, and global change are demonstrated through flight programs and analyses.

The Laboratory for Hydrospheric Processes

Our staff perform theoretical and experimental research on various components of the hydrological cycle and its role in the Earth system. The program observes, understands, and models the global oceans and ice, surface hydrology, and mesoscale atmospheric processes. The Laboratory researches Earth observational

The Crustal Dynamics Project

Project staff develop and apply space geodetic techniques to study the dynamic motions of the Earth. An extensive measurement program is using both Very Long Baseline Interferometry (VLBI) and Satellite Laser Ranging (SLR). The Crustal Dynamics Project's developments of SLR and VLBI technology result in very accurate geodetic measurements of plate motion, plate deformation, regional deformation, and polar motion.



The appearance of the ozone hole as shown by the Nimbus-7 Total Ozone Mapping Spectrometer (TOMS). TOMS measures the total column of ozone using back-scattered sunlight. Dobson units represent the number of ozone molecules in the atmospheric column. One thousand Dobson units is equivalent to a 1-cm-thick layer of pure ozone at standard pressures and temperatures. Nimbus 7 was launched in November 1978, and TOMS has been taking data for 12 years. The data from TOMS are analyzed at Goddard.

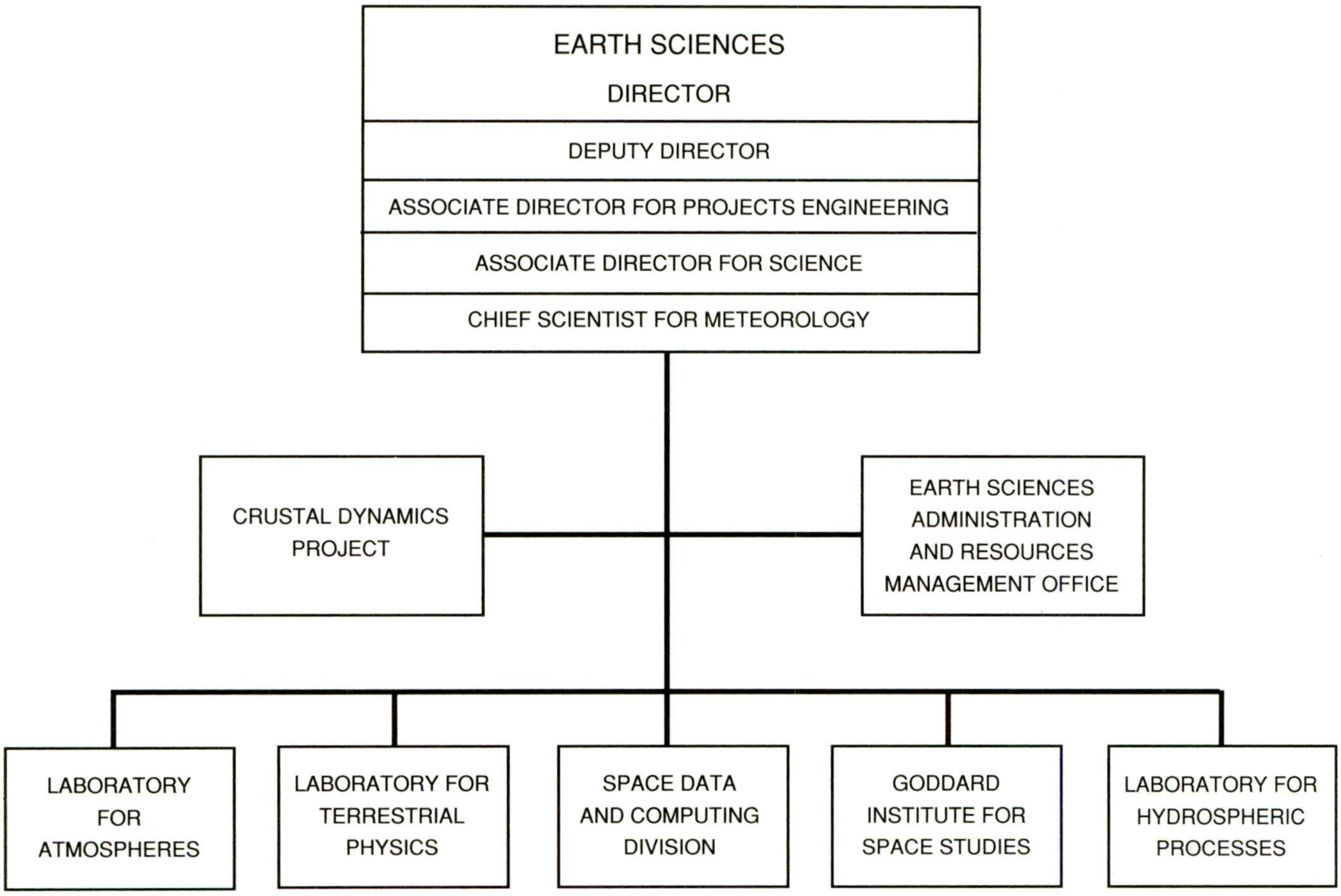
The Space Data and Computing Division

This Division makes data from satellites and other sources accessible and useful to an international, multidisciplinary research community. The Division operates three computational facilities for analyzing data, simulating complex processes, and storing and distributing data. The NASA Center for Computational Sciences enables research in a full range of space and Earth science disciplines. The National Space Science Data Center staff develop state-of-the-art data management systems, data visualization techniques, distributed data bases, and new technologies for mass storage. The Science Information Systems Center researches advanced data-systems architectures and satellite information-processing techniques.

Skill Needs

There are opportunities within the Earth Sciences Directorate in the following disciplines:

- Sensor/Instrument Engineering
- Mathematics
- Meteorology/Climatology
- Atmospheric Physics
- Computer Sciences
- Data System Analysis/Data System Engineering
- Geography
- Oceanography
- Geophysics/Geodynamics/Geology
- Hydrology
- Botany/Biology/Forestry/Agronomy
- Glaciology
- Resource Analysis
- Administrative Operation Analysis



Benefits

The Goddard Space Flight Center recognizes that its employees are its greatest asset and is committed to fostering an environment that provides career development, training, attractive benefits, services, and facilities.

Developmental Opportunities
The Center considers employee training and development to be essential to its mission.

Center goals are to:
- keep employees abreast of knowledge and new developments in their respective fields of specialization;
- provide employees with the necessary skills and knowledge to deal effectively with current and changing programs, procedures, technology, and mission requirements;
- meet future leadership requirements through the systematic identification, selection, and development of supervisors and managers.

Each year, the Center sponsors on-site, 150-200 courses in science, engineering, administration, management, and computing. A Learning Center with over 160 different courses, provides further opportunity for independent learning through video and computer-based training.

Goddard's training programs include:

Professional Intern Program (PIP)
The PIP Program is a developmental program for entry-level scientists, engineers and professional administrative employees. This program is designed to acquaint employees with NASA and Center missions and operations, integrate employees into the workforce, and prepare employees for complex duties and increased responsibility.

Program activities include:
- preparation of an Individual Development Plan (IDP) by each intern with the assistance of the supervisor;
- the establishment of a mentoring relationship with a senior staff member;
- participation in various orientation activities;
- formal on-the-job training; and
- the completion of a PIP project and presentation of results to a panel along with a final written report.

Part-Time Graduate Study Program (PTGSP)
The PTGSP allows employees to pursue graduate studies at local colleges and universities in areas relevant to their work and the mission of the Center. Participants may use a specific amount of work hours for academic studies while the remaining work week is spent on regularly assigned duties. The Center funds tuition, books, and related laboratory and equipment fees.

Masters of Science Program
The Masters of Science program is a cooperative endeavor between George Washington University's School of Engineering and Applied Science and the Goddard Space

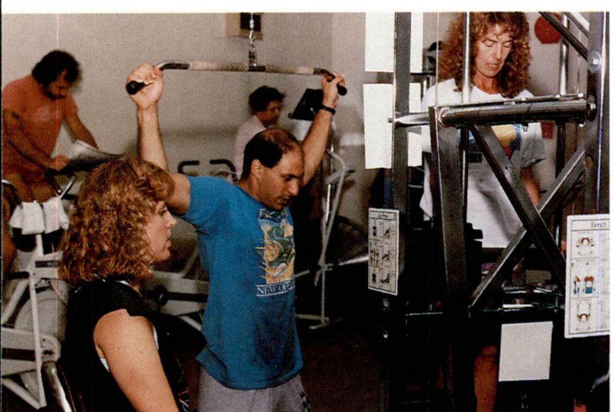
Flight Center. The program gives qualified employees a chance to increase their technical knowledge and skills in areas relevant to the work being performed at the Center. Courses are held on-site at Goddard after normal working hours.

Masters of Engineering Management (MEM)
The MEM is conducted on-site at the Goddard Space Flight Center by George Washington University. The program provides an opportunity for qualified employees to further develop their skills to meet Center skill needs in technical administration and management of Goddard's programs and projects. Tuition costs for the program are Center-funded. Courses are held on-site at Goddard after normal working hours.

Federal Employment Benefits

Paid Moving Expenses
Concerned about the cost of relocation? You may be eligible for reimbursement of certain travel expenses and the shipment of household goods.

Flexible Work Schedule
Employees work a basic 40-hour work week, 8 1/2-hour workday, with 1/2 hour for lunch.



The Fitness Lab offers an array of exercise equipment.

The Learning Center provides employees the opportunity for independent study.

Flexitour provides employees the opportunity to establish start time between 6:30 and 9:00 a.m. Your work schedule will be determined by yourself and your immediate supervisor, based on your preferences and your work unit needs.

Leave
Beginning your first day on the job, you earn 13 days of annual leave each year. This is personal time off that you schedule with the approval of your immediate supervisor. You earn 20 days of leave after three years of employment; and a maximum of 26 days of leave after 15 years of service. You also earn 13 days of sick leave each year. This leave may be used for illness, doctor appointments, or for maternity. Unused sick leave is accumulated indefinitely and thus provides continuation of pay should an employee have a long illness. Other types of leave are available for specific situations (e.g., jury duty or military service).

Paid Holidays
Federal holidays are observed with pay:

- New Years' Day
- Martin Luther King's Birthday
- Inauguration Day
- Washington's Birthday
- Memorial Day
- Independence Day
- Labor Day
- Columbus Day
- Veteran's Day
- Thanksgiving
- Christmas

Health Care
You can enroll in one of several comprehensive health insurance plans, with approximately 75 percent of the cost paid by the Center. There are two major types of plans:

- Fee-for-Service Plans
  You may choose your own physician, hospital, and other health care providers. These plans reimburse you or the health care provider for covered services.

- Prepaid Plans
  These are the Comprehensive Medical Plans/Health Maintenance Organizations that provide or arrange for health care by designated plan physicians, hospitals, and other providers in particular locations.

Life Insurance
In addition, you may elect low-cost life insurance. You are eligible to enroll in two group life insurance plans:

- Federal Employee Group Life Insurance (FEGLI) available to all Federal employees.
- NASA Employees Benefit Association (NEBA) available to NASA employees.

The amount of coverage you elect depends on your basic annual salary. Additional life insurance is also available.

Awards and Recognition
Goddard's success is due to the creativity, innovation, and performance of its employees. The Center's awards program acknowledges and rewards employee contributions. Employees are eligible to receive cash and honorary awards for superior work that contributes to the productivity, economy, or effectiveness of NASA or Goddard programs. Awards can be for either individual or group performance. An Employee Suggestion Program also acknowledges and rewards employees for their ideas.

Retirement
As a new employee to the Federal government, you are automatically covered by the Federal Employees Retirement System (FERS). FERS is a three-tiered Retirement Plan consisting of:
- Social Security
- Basic Benefits
- Thrift Savings Plan

Once you retire, after meeting basic eligibility requirements, you will receive a retirement pension in the form of a paid monthly annuity for the rest of your life.

Advancement

Salary Increases
All employees receive annual cost-of-living increases, designed to keep salaries in pace with private-industry salaries. In addition, you are eligible to receive periodic salary increases.

Accelerated Promotion
Entry-level (GS-7) Engineers and Scientists are eligible for promotion to the GS-9 level in six months.

Career Promotion Eligibility
The career ladder is as follows:

To GS-9	6 months*
To GS-11	1 year*
To GS-12	1 year*
To GS-13	1 year*

*Basic eligibility. Actual promotion may vary at each grade level depending on performance.

You and your supervisor will jointly develop performance standards that define your job requirements. Your performance will be evaluated against these standards at least twice each year. Informal performance discussions with your supervisor are encouraged at any time. This formal and informal feedback gives you a sense of your achievements and career development.

Services and Facilities

GEWA
The Goddard Employees Welfare Association (GEWA) offers activities that foster and promote social, athletic, educational, cultural, and welfare interests for the entire Center workforce.

Specific facilities and activities maintained and sponsored by GEWA include:

A Recreation Center available to all GEWA members for on-site organization functions such as picnics, dinners, award ceremonies, and parties.

An Exchange Store which offers all employees and their families discounted tickets to theaters, sporting events, and local area attractions. Items and mementos are also available at reduced costs.

A Souvenir/Gift Shop located at the Visitor Center offers reduced prices on merchandise through GEWA special discount privileges.

Club Activities
A few of the over 50 clubs on Center sponsored by GEWA include: Aerobics, Music and Drama, Photo, Softball, Toastmasters, and Travel.

Other Facilities

The Center also houses two cafeterias, a credit union, a child care center, a full-service library, and a travel office for both official and personal travel.

The Center's child care facility offers creative play and development to chidren ages 2 through kindergarten.

The Goddard Health Unit provides a wide range of physical programs and counseling services.

The Goddard Fitness Lab offers individual exercise programs, monitoring of employees' blood pressure, body-fat evaluations, and special programs. The Lab features a variety of physical fitness equipment.

The Washington Mall

The Air and Space Museum

The Washington D.C. metropolitan area offers diverse cultural and recreational activities to suit any lifestyle.

The Baltimore Inner Harbor

An Employee Assistance Program is also available to you to help you deal with stress, financial, marital, and other personal problems.

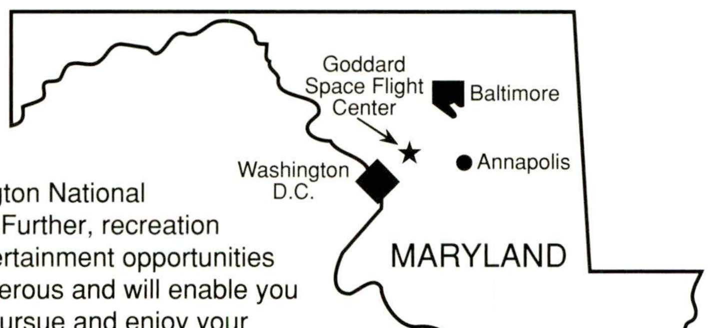
Employees are also offered free annual physical examinations.

Employee Services Area
The Center's Office of Human Resources' Employee Services Area houses brochures, pamphlets, publications, and videos about a wide range of personnel information. Such information includes job opportunities, health and life insurance, retirement, career development and training, housing and relocation services, and other items of interest to employees and the public.

Goddard's Communication
The Center emphasizes communication to its workforce. The communication network consists of daily bulletins, newsletters and frequent announcements that keep you informed of current and future activities.

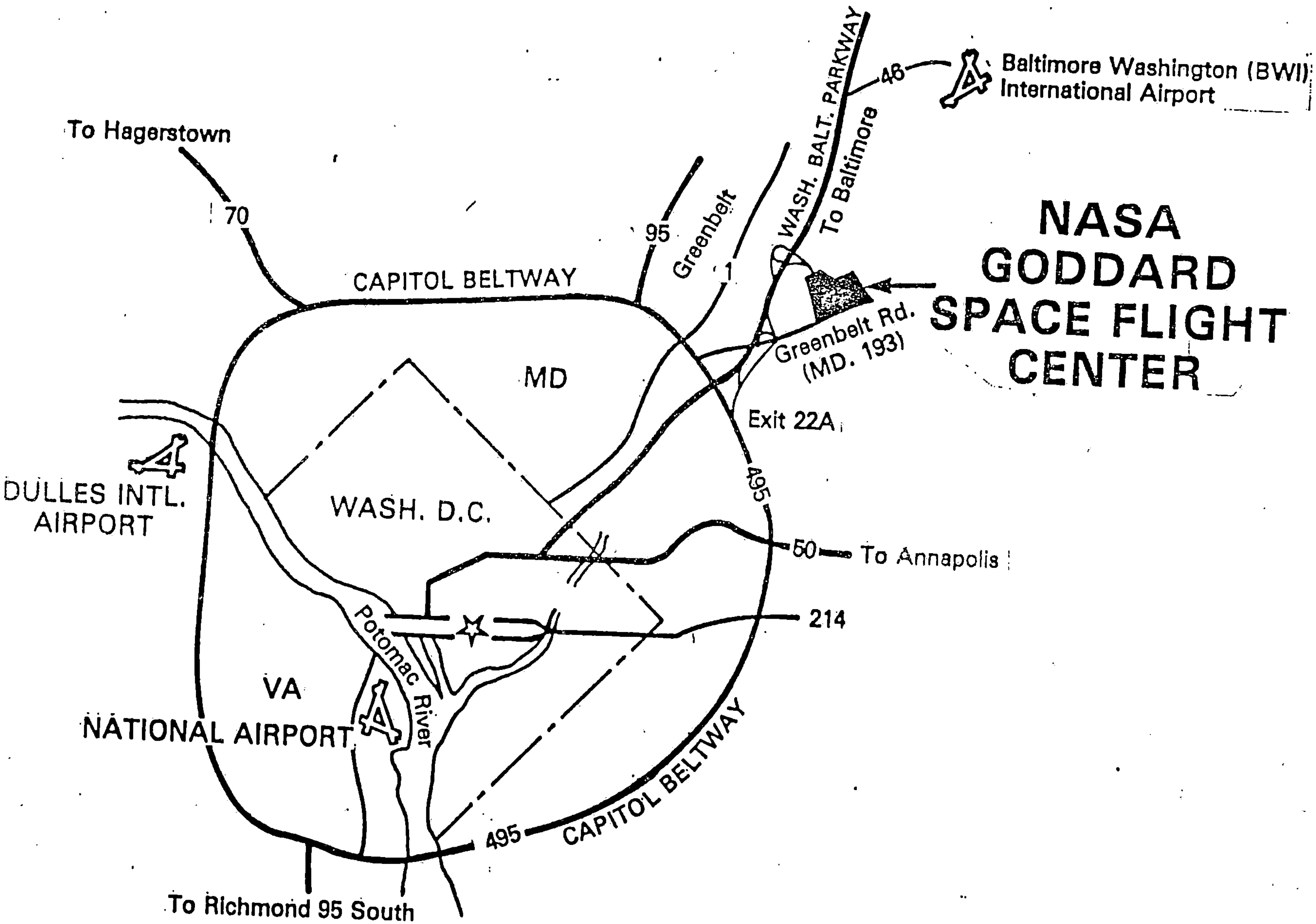
The Surrounding Area
Goddard is ideally located between Washington, D.C. and Baltimore, Maryland. We are surrounded by outstanding cultural, recreational, and historical points of interest. The Washington, D.C. metropolitan area offers a lifestyle for everyone.

Getting around the area is easier than one expects. There are five Metrorail stations that link the county with the Nation's Capital and several others are under construction. We have the historic Union Station located near The U.S. Capitol, the Amtrak Metroliner, the Maryland Rail Commuter Line, and Ride Sharers Matching services. In addition, we are serviced by three major airports: Baltimore-Washington International Airport, Dulles Airport and the Washington National Airport. Further, recreation and entertainment opportunities are numerous and will enable you to fully pursue and enjoy your personal interests.

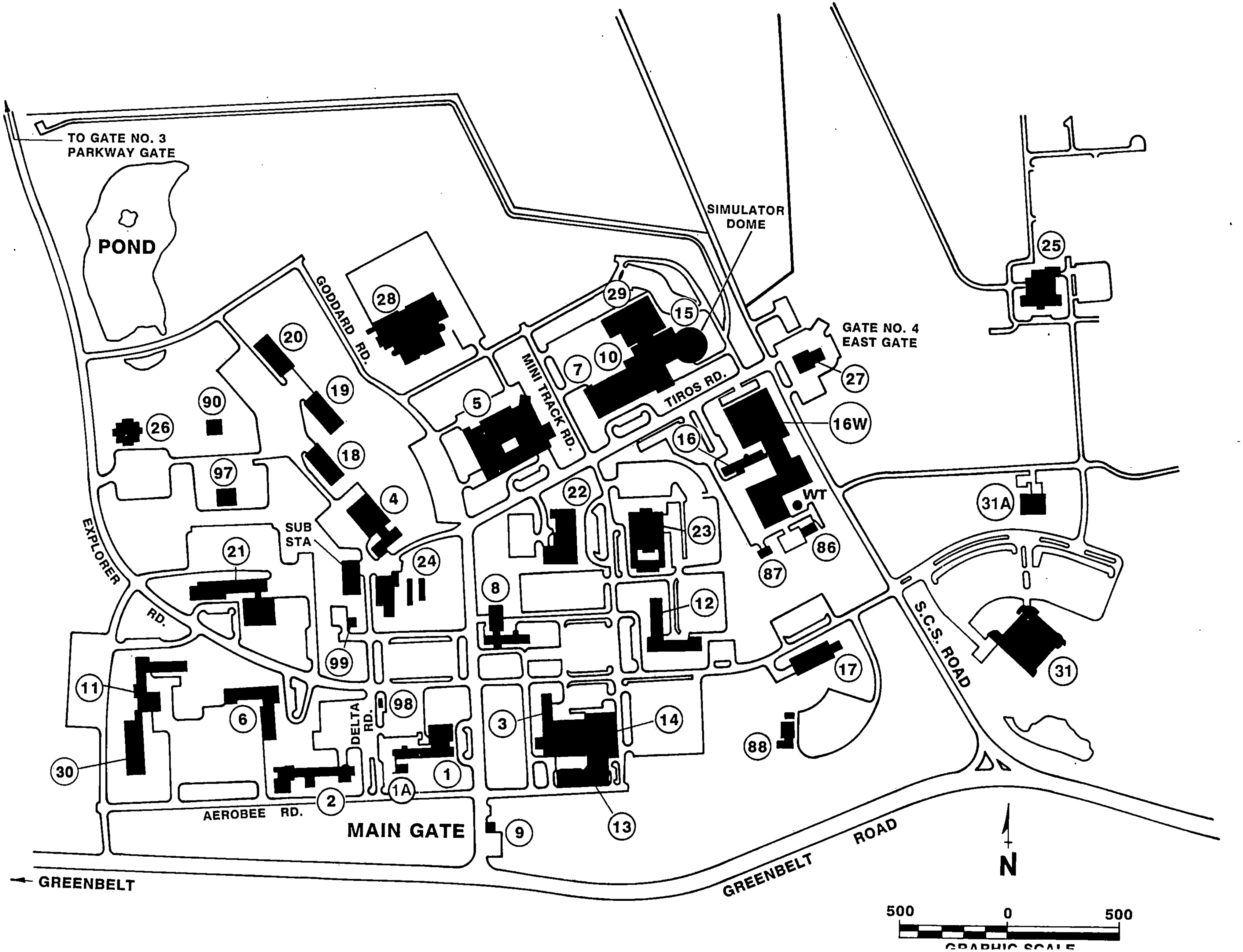


As for education, colleges and universities in the commuting area offer undergraduate and graduate courses of study.
They include:

American University
The Catholic University of America
George Washington University
Howard University
The Johns Hopkins University
Mary Washington College
University of Maryland



The Goddard Space Flight Center (GSFC) is located on MD. 193 (Greenbelt Road) in Greenbelt, Maryland. To reach GSFC from Maryland or the Tysons Corner area, take the Beltway (Interstate 495) to exit 22A the Baltimore-Washington (B-W) Parkway, North, and MD. 193 Greenbelt Road east to NASA. If you are coming from Washington, DC or other parts of Virginia, take Interstate 395 to New York Avenue to the B-W Parkway. The first exit after the Beltway is Greenbelt Road (MD. 193). Take MD. 193 Greenbelt Road east and follow the signs to NASA/GSFC.

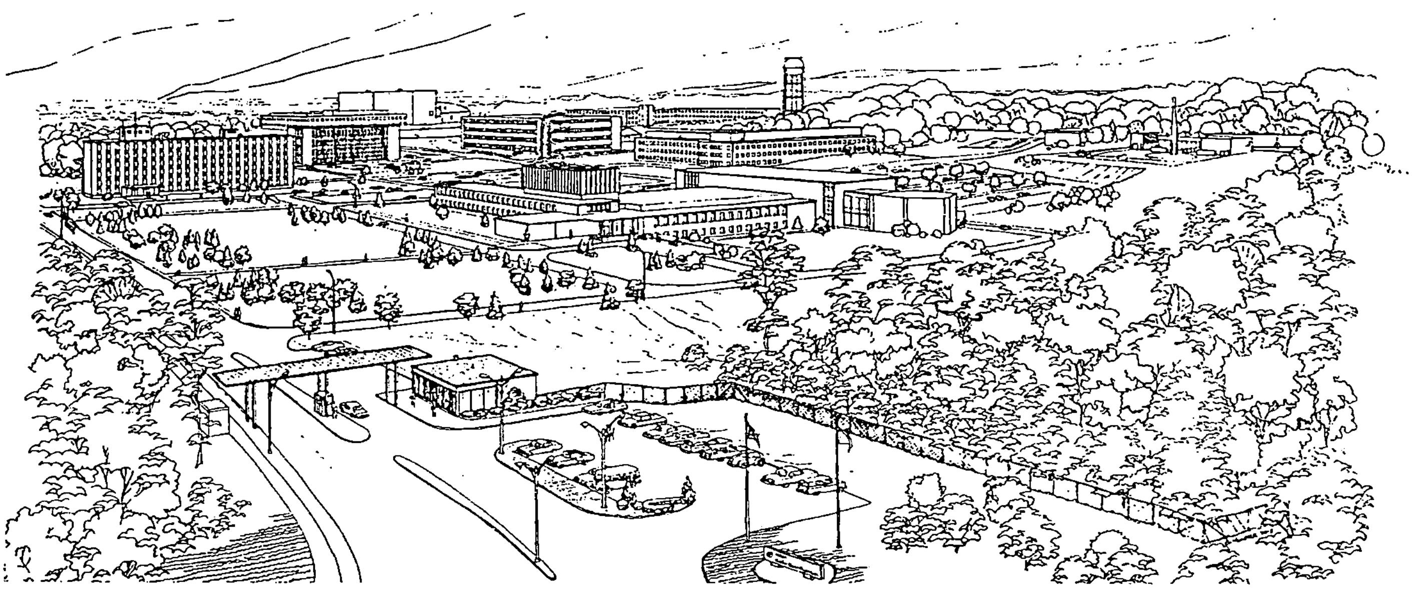

TO GATE NO. 3
PARKWAY GATE
POND
GODDARD RD.
MINI TRACK RD.
TIROS RD.
SIMULATOR
DOME
GATE NO. 4
EAST GATE
SUB
STA
EXPLORER
RD.
DELTA
RD.
AEROBEE RD.
MAIN GATE
S.C.S. ROAD
GREENBELT ROAD
GREENBELT
WT
N
500
0
500
1
1A
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
16W
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
31A
86
87
88
90
97
98
99

NASA Facts

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771
AC 301 286-8955

Goddard Space Flight Center



Goddard Space Flight Center, Greenbelt, Maryland

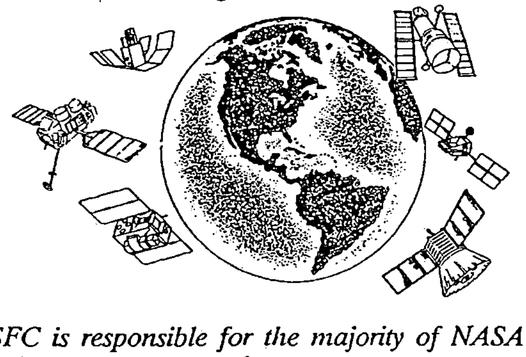
History

On January 15, 1959, by action of the National Aeronautics and Space Administration (NASA) Administrator, four divisions (Construction Division, Space Science Division, Theoretical Division and the Vanguard Division) of NASA were designated as the new Beltsville Space Center on land which was originally part of the Beltsville Agricultural Research Center, Beltsville, Maryland. Later that year, the Center was formally renamed the Goddard Space Flight Center (GSFC) "in commemoration of Dr. Robert H. Goddard, American pioneer in rocket research."

GSFC has played a major role in space progress almost from its opening. Its first employees were the 157 people of the Vanguard project who were transferred to Goddard from the Naval Research Laboratory. The first satellite under the project control of Goddard was Explorer VI, launched in August 1959, and it provided the world its first image of Earth from space. This was only the beginning of Goddard's long history in the Nation's space program.

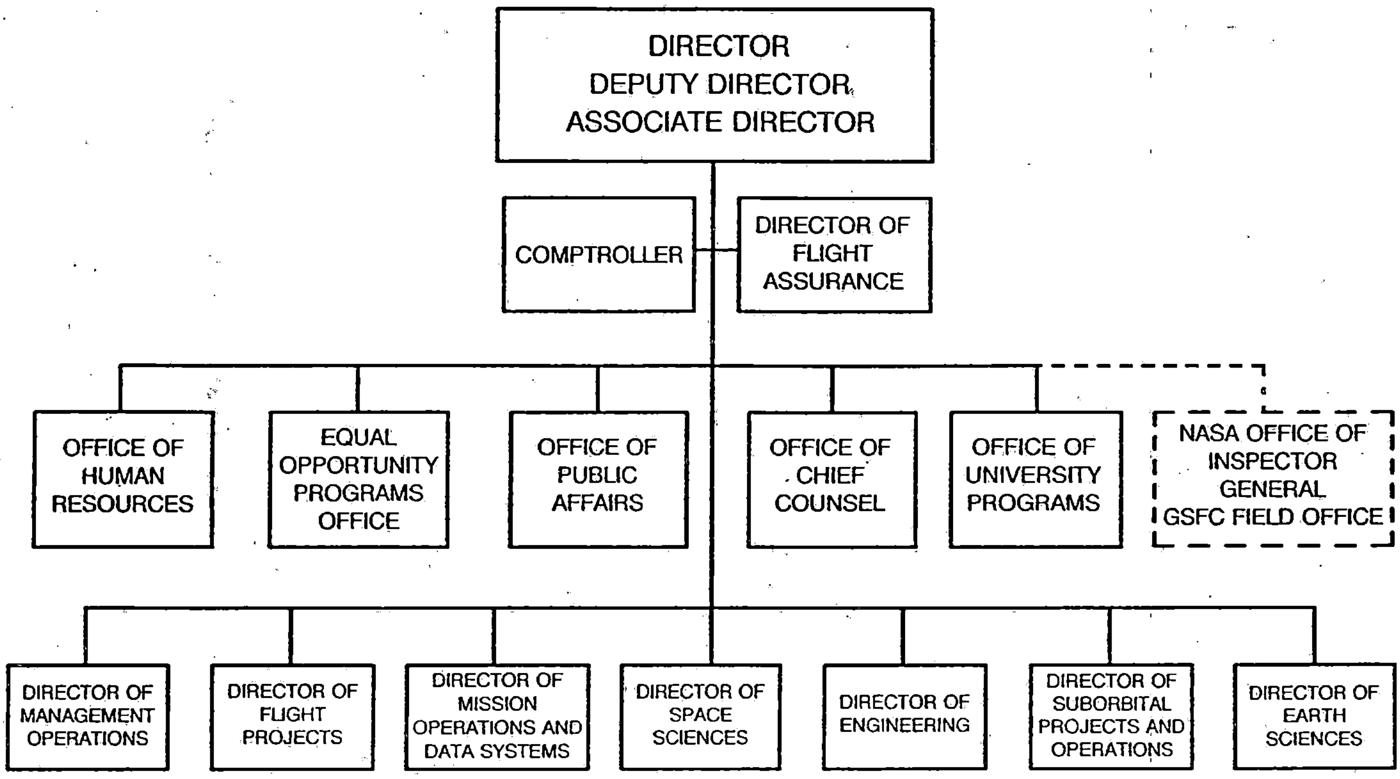
Our Mission

The mission of Goddard Space Flight Center is to expand knowledge of the Earth and its environment, the solar system and the universe through observations from space. To assure that the Nation maintains leadership in this endeavor, the Center is committed to excellence in scientific investigation, in the development and operation of space systems and in the advancement of essential technologies.



GSFC is responsible for the majority of NASA's near Earth-orbiting spacecraft.

Organization



Under the leadership of its Director, Dr. John M. Klineberg, the Center is managed by a system of directorates. The directorates and their functions are:

- Office of the Director (Code 100) - Provides overall management and coordinates control over the diversified activities of the Center.
- Management Operations (Code 200) - Provides business and institutional support and services necessary for the successful accomplishment of the Center's scientific and technical missions. Sharon C. Foster is the Director.
- Office of Flight Assurance (Code 300) - Responsible for safety, reliability and quality assurance programs to ensure flight mission success. This includes the control of electronic parts, materials and processes. The office also is responsible for independent design reviews of technical and flight safety aspects of spacecraft and instruments. Robert C. Baumann is the Director.
- Flight Projects (Code 400) - Plans, organizes and directs the management of the Center's major flight projects, new start studies, international projects, and the small and medium class expendable launch vehicles. Vernon J. Weyers is the Director.
- Mission Operations and Data Systems (Code 500) - Plans, designs, develops and operates spaceflight tracking and communications networks and provides data systems support for near-Earth spaceflight missions. Dale L. Fahnestock is the Director.
- Space Sciences (Code 600) - Carries out research in space sciences and provides scientific counsel to other directorates that are working on space science projects. Dr. Stephen S. Holt is the Director.
- Engineering (Code 700) - Provides engineering expertise and support for the design, development, and testing of components, subsystems, systems and spacecraft for a variety of projects. In addition, Goddard's engineers consult with other NASA centers, other agencies, industry, and other countries in the area of automated space systems and related technology. Thomas E. Huber is the Director.
- Suborbital Projects and Operations (Code 800) - Responsible for the overall management, operation and support of NASA's sounding rocket and balloon programs and the conduct of aeronautical research. This function is located at the Wallops Flight Facility, Wallops Island, Virginia. Joseph T. McGoogan is the Director.
- Earth Sciences (Code 900) - Conducts scientific studies in the Earth sciences leading to a better understanding of processes affecting global change and the distribution of natural resources through research, development, and application of space technologies. Dr. Vincent V. Salomonson is the Director.

Workforce

Almost 13,500 persons work at the Goddard Space Flight Center at all of its sites. This number includes more than 4,000 civil servants and approximately 9,500 contract personnel (Greenbelt, Maryland - 3,722 civil servants and 8,654 contract personnel; Wallops Island, Virginia - 372 civil servants and 822 contract personnel; Goddard Institute for Space Studies in New York, New York - 23 civil servants and 43 contract personnel). Of this number, more than 3,600 civil servants and 7,500 contract personnel live in the State of Maryland (1,695 civil servants and 3,061 contract personnel in Prince George's County).

Total GSFC Workforce

	Civil Servants	Contract Personnel
Clerical/typist	494	376
Professional/ administrative	825	1,949
Scientist/engineer	2,264	4,519
Technician	489	1,836
Wage Grade	74	829

Major Contractors at Goddard, Greenbelt, Maryland

The following is a listing of those contractors performing work at the Goddard Space Flight Center, Greenbelt, Maryland, which employ more than 50 employees.

Advanced Computer Systems Inc.
Associate University for Research and Astronomy
Bendix Field Engineering Corp.
Centennial Contractors Inc.
Computer Sciences Corp.
City Wide Security Services
Eagle Maintenance Service Inc.
E.L. Hamm and Associates Inc.
Engineering and Economic Research Systems
Fairchild Space and Defense
Jackson and Tull Inc.
Kenrob and Associates
Lockheed Missiles and Space Corp.
McDonnell Douglas Space Systems
NSI Technology Services Corp.
NYMA Inc.
Ogden Logistics Services
Raytheon Service Co.
Science Systems Applications Inc.
Swales and Associates Inc.
ST Systems Corp.
Unisys
Universities Space Research Associates

Facilities

There are 30 major buildings, providing approximately 2,500,000 square feet of space, located at the Greenbelt, Maryland, site of the Goddard Space Flight Center, situated on approximately 1,200 acres.

Goddard's acreage includes four additional nearby facilities. Of these four facilities, Goddard owns the Propulsion Research Facility and the Magnetic Test Facility. The Optical Research Facility and the Antenna Range are held under revocable permit from the Beltsville Agricultural Research Center (BARC). Soil Conservation Service Road, which divides the space center's East Campus and West Campus, is owned by Goddard Space Flight Center and BARC.

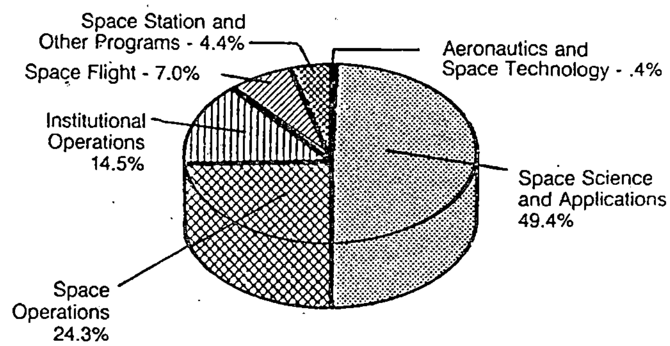
In the near future, Goddard plans the addition of three major facilities to the Greenbelt campus. These include the Quality Assurance and Detector Development Laboratory (QUADDL) which will house approximately 40 civil servants and contract personnel in 58,800 square feet of space. This building is scheduled for completion in 1993 and will provide office and laboratory space for the Materials Branch and a state-of-the-art Class 100 clean room laboratory for the Electron Device Development Section.

Another facility is the Earth Observing System Data Information System (EOSDIS), which will house up to 900 civil servants and contract personnel working on a five-shift, 24-hours-a-day, 365-days-a-year basis. EOSDIS will provide approximately 200,000 square feet of office and data processing and archiving space. Occupancy is scheduled for 1994, with a full complement on board by 1997. This facility will serve as a key node in the Earth Observing System (EOS) communications system as well as a distribution center for Earth data from numerous sources such as the Total Ozone Mapping Spectrometer (TOMS) and Tropical Rainfall Measuring Mission (TRMM). The facility will house systems necessary for overall management of the EOS ground system and the largest of seven nationwide Distributed Active Archive Centers necessary for archiving a significant portion of the EOS observational data. It also will house the Mission Operations and instrument control center functions needed to monitor and control the EOS space platforms and their suite of instruments while in Earth orbit.

The third facility is the proposed Earth Systems Science Building (ESSB) which will house approximately 1,000 day shift civil servant and contractor personnel. The building will include 385,000 square feet of space and will house the present complement of Goddard Earth Science Directorate Laboratories, including the Laboratory for Atmospheres, the Laboratory for Terrestrial Physics, the Laboratory for Hydrospheric Processes, and the Crustal Dynamics Project, all of which are at present scattered across the Center in seven different buildings. In addition, the ESSB will provide accommodations for guest investigators associated with the EOS program.

Budget

As illustrated in the pie chart below, the Goddard budget was approximately $2.5 billion for fiscal year 1991.



Direct Funds

Total Research & Development/Space Flight, Control & Data Communications	$1893.4M
Total Research & Program Management/Construction of Facilities	$339.6M
Total Reimbursable Funds (Est.)	$250.0M
Total	$2483.0M

Goddard Launches 1991 - 1993

Gamma Ray Observatory

The second of NASA's "Great Observatories" the Gamma Ray Observatory (GRO) collects a broader range and higher quality gamma-ray data than ever before possible, providing information about the distribution and nature of gamma radiation throughout the Universe.

Tracking and Data Relay Satellite

The Tracking and Data Relay Satellite System (TDRSS) permits movement of large volumes of data from near-Earth satellites with great speed. Consisting of four satellites in geostationary orbit (22,300 miles altitude) and ground facilities at White Sands, New Mexico, the TDRS spacecraft acquire data from other orbiting user-satellites and relay that data to the ground station.

TOMS

The Total Ozone Mapping Spectrometer (TOMS), identical to the instruments flown on the Nimbus-7 spacecraft launched in 1978, was launched aboard the Soviet spacecraft Meteor-3 in an international effort to gain more data on the depleting ozone layer.

Upper Atmospheric Research Satellite

Ten scientific instruments aboard the Upper Atmosphere Research Satellite (UARS) will collect data to help scientists better understand the mechanism controlling the upper atmospheric structure and its response to natural and man-made variations.

Extreme Ultraviolet Explorer

A group of four telescopes comprising the Extreme Ultraviolet Explorer (EUVE) are designed to produce a highly-sensitive survey of the sky. The spacecraft will look at bright extreme ultraviolet sources and be used to study stellar evolution and the local stellar population.

NOAA

Goddard Space Flight Center designs and builds weather satellites for the National Oceanic and Atmospheric Administration. NOAA weather satellites track storms, pinpoint temperature differences in the oceans, and warn of early freezes and melting snow and ice from low-Earth orbit.

Diffuse X-Ray Spectrometer

Measuring the spectral distribution of near-by stars, the Diffuse X-Ray Spectrometer (DXS) will help confirm or disprove theories on how the present state of our galaxy came to be and how galaxies evolve.

Geotail

Geotail will use lunar-swingby orbit adjustment to place it in the region of Earth magnetotail, an extended region of the Earth magnetic field on the side of Earth opposite the Sun. Here the spacecraft will study charged particles and plasma characteristic resulting from Solar activity.

LAGEOS-II

The Laser Geodynamic Satellite II (LAGEOS-II) will promote research in Earth Sciences by providing very precise satellite geodetic measurements.

GOES

Acting as NOAA's agent under 1973 agreement, Goddard procures spacecraft and instruments for the National Oceanic and Atmospheric Agency (NOAA). The Geostationary Operational Environmental Satellite (GOES) series provide observations of cloud cover, atmospheric temperature and moisture profiles, as well as severe storm warnings and Search and Rescue Operations.

GGS Wind

The Wind Mission of the Global Geospace Science (GGS) Program is designed to determine solar wind input properties including plasma waves, energetic particles, and electric and magnetic fields for magnetospheric and ionospheric studies.

Advanced TDRS

Using state-of-the-art space technology, the Advanced Tracking and Data Relay Satellites will provide additional satellites to the Space Network for tracking and communication relay for near-Earth orbiting satellites.

ASTRO-D

In this cooperative mission with Japan, Goddard will provide four mirrors for a shuttle-carried payload designed to perform astronomical X-ray spectroscopy.

GGS Polar

The Polar Mission of the Global Geospace Science (GGS) Program will study the polar ionospheric region looking at energy input with a full range of plasma physics fields and particles "in situ" and remote sensing instruments.

Hubble Space Telescope Servicing

The instruments on the Hubble telescope are modular, designed for quick and simple replacement, much like changing tapes in a video cassette recorder. Because replacing Hubble's mirror in space or bringing the telescope back to Earth are not practical, scientists plan to compensate for the mirror's imperfection with the "second generation" scientific instruments, replaced on orbit.

RELEASE: 92-64

EUVE SATELLITE TO EXPLORE NEWLY OPENED WINDOW

The extreme ultraviolet is one of the least-studied portions of the electromagnetic spectrum. Now, with the launch of NASA's Extreme Ultraviolet Explorer (EUVE) satellite, this new window on the universe will be opened to detailed study.

EUVE, NASA's 67th Explorer mission, will be the first satellite to make both spectroscopic and wide-band observations over the entire extreme ultraviolet (EUV) region. It is scheduled for launch aboard a McDonnell Douglas Delta II expendable launch vehicle from Cape Canaveral Air Force Station, Fla., on June 4, 1992. EUVE is designed to operate for at least 18 months from a 340-mile Earth orbit and will orbit the Earth every 96 minutes.

This unique satellite consists of four telescopes -- the most powerful set of EUV telescopes ever flown. Three instruments will map the entire sky to determine the existence, direction, brightness and temperature of sources of extreme ultraviolet radiation. The fourth instrument is designed to make spectroscopic observations to determine the composition and temperature of the EUV sources discovered during the sky mapping. Some of the objects EUVE is likely to detect and study are white dwarf stars, binary star systems and the hot outer atmospheres (coronae) of stars similar to the sun.

From the many objects of astronomical interest discovered during the EUVE all-sky survey and other objects already thought to be observable in the extreme ultraviolet, guest observers will propose to study targets using the spacecraft's fourth instrument, the extreme ultraviolet spectrometer.

The EUVE is one of a long line of relatively low-cost, small-to-moderately sized missions that make up the Explorer program. Since the Explorer Program began in 1958, these missions have given scientists worldwide a new understanding of astronomy and astrophysics, providing them an opportunity to probe nearly every region of the electromagnetic spectrum from infrared radiation to gamma rays.

Goddard Space Flight Center, Greenbelt, Md., is responsible for the design, construction, integration, checkout and operation of EUVE. The spacecraft's science instrumentation was designed, constructed and calibrated by the Space Science Laboratories of the University of California, Berkeley. The EUVE is managed by Goddard for NASA's Office of Space Science and Applications.

- end -

Ocean Topography Experiment (TOPEX/POSEIDON)

Objective

The Ocean Topography Experiment (TOPEX/POSEIDON) is designed to: 1) gather information about the global oceans' general circulation and their relationship to climate change using precise measurements of ocean surface topography; 2) increase knowledge of the interaction between atmosphere and ocean, including the exchange of heat and momentum; and 3) make detailed maps of currents, eddies and other features of ocean circulation.

Description

TOPEX/POSEIDON is a joint NASA and French Space Agency (CNES) project that includes two French and three NASA instruments. Using satellite radar altimetry, the mission will make substantial contributions to the understanding of global ocean dynamics. TOPEX/POSEIDON is a vital contribution to two major international ocean/atmosphere research programs: the World Ocean Circulation Experiment (WOCE) and the Tropical Ocean Global Atmospheric (TOGA) program, both of which are components of the World Climate Research Program.

Launch Date:	July 1992
Payload:	5 instruments
Orbit:	66 degree inclination; 1,336 km (721 nm) altitude, nominally circular
Design Life:	3 years; expendables for 5 years total
Length:	5.5 m (18 ft)
Weight:	2,700 kg (5,940 lbs)
Diameter:	3.5 m (11 ft)
Launch Vehicle:	Ariane IV
International Participation:	France

Instruments/Investigations/Principal Investigators

NASA Altimeter (ALT) - (Johns Hopkins University Applied Physics Laboratory)
Solid State Altimeter (SSALT) - (Toulouse Space Center - France)
TOPEX Microwave Radiometer (TMR) - (Jet Propulsion Laboratory)
Determination d'Orbite et Radiopositionement Integre par Satellite (DORIS) - (Toulouse Space Center - France)
Global Positioning System Demonstration Receiver (GPSDR) Experiment - (Jet Propulsion Laboratory)

Mission Events

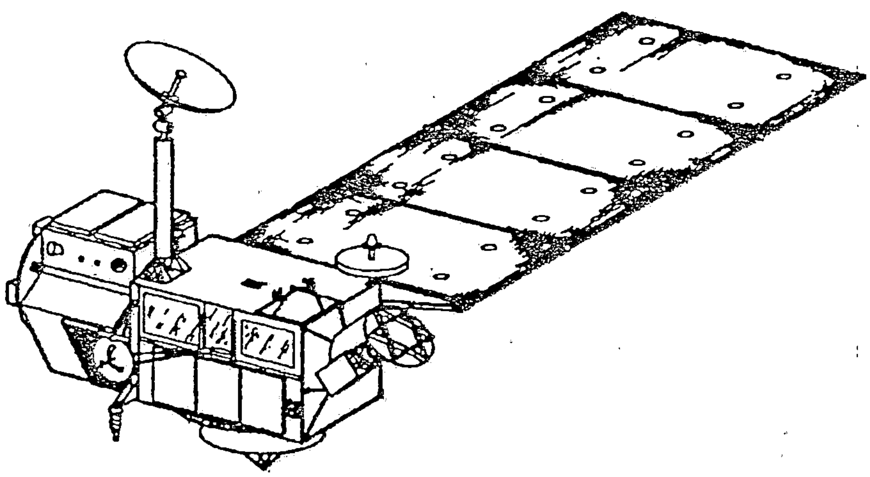
Program start: October 1986
Satellite contract award: June 1987
Preliminary Design Review: October 1988
Critical Design Review: May 1989
Start sensor integration: May 1991
Satellite delivery: April 1992

Management

NASA Headquarters
L. Jones, Program Manager
W. Patzert, Program Scientist
Jet Propulsion Laboratory
C. Yamarone, Project Manager
L. Fu, Project Scientist
French Space Agency (CNES)
J. Fellous, Program Manager
A. Ratier, Program Scientist
M. Dorrer, Project Manager
M. Lefebukè, Project Scientist
Major Contractor
Fairchild Space Company

Status

A Memorandum of Understanding between NASA and CNES was signed March 1987. A contract was awarded to Fairchild for satellite development. Significant progress was made in the manufacture of the satellite subsystems and sensors during 1990. Flight hardware fabrication was completed in early 1991. Integration of the spacecraft bus, instrument module and instruments began in September 1991 and is expected to be completed by April 1992. The spacecraft will then undergo performance and environmental acceptance testing to support a May 1992 delivery of the satellite to the Kourou launch site in French Guiana for integration with the Ariane IV launch vehicle. Launch of TOPEX/POSEIDON is scheduled for July 1992.



Ocean Topography Experiment

Small-Class Explorers (SMEX)

Objective

The objectives of the Small-Class Explorers (SMEX) are to enable new areas of exploration and special topic investigations in space astrophysics, and atmospheric and space plasma physics; and to provide a quick reaction research capability, through small sized missions and frequent launch opportunities.

Description

SMEX payloads are modest size, modest capability payloads, up to 500 pounds, which make major contributions a number of NASA's space science and applications disciplines.

The Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX) will be a Zenith-pointing satellite in near-polar orbit which will carry a payload of four particle detectors, each of which addresses a subset of the required measurements. The instruments can measure the electron and ion composition of energetic particle populations from approximately 0.4 million electron Volts (MeV)/nucleon to hundreds of MeV/nucleon using a coordinated set of detectors of excellent charge and mass resolution, and with higher sensitivity than previously flown instruments. SAMPEX will: 1) provide measurements on how some ions from partially ionized plasmas such as the solar corona and the very local interstellar medium are energized to nearly the speed of light by shocks or other means and reach the Earth; and, 2) monitor fluxes of fast electrons which come from space onto the Earth's atmosphere and are important in the chain of chemical reactions leading to the formation and depletion of ozone.

The Fast Auroral Snapshot Explorer (FAST) will collect measurements of electrical and magnetic fields and simultaneously correlate these with their effects on the electron and ions at altitudes of 350 to 4,200 kilometers with very high time resolution. These observations will be complemented by data from other spacecraft at higher altitudes, which will be observing fields and particles and photographing the aurora from above, thus placing FAST observations in global context. At the same time, auroral observatories and geomagnetic stations on the ground will provide measurements on how energetic processes that FAST observes affect the Earth.

The Submillimeter Wave Astronomy Satellite (SWAS) will be a three-axis stabilized, stellar-pointing spacecraft launched into a 38 degree, 600 kilometer, circular orbit. It will have a 71 centimeter off-axis Cassegrain antenna, state-of-the-art heterodyne receivers cooled to 150 degrees Kelvin (K) by passive radiators, and the highest quality Acousto-Optical Spectrometer (AOS) to be provided by the Federal Republic of Germany (FRG). In less than 20 minutes of integration, SWAS will be able to measure the full range of predicted H_2O, O_2, C, $_{13}CO$, and $H_2{}_{18}O$ abundances in any giant molecular cloud core within 1 kiloparsec. Of particular importance, the AOS will permit simultaneous observation of four of these lines at any one time, thus maximizing the observing efficiency and substantially increasing confidence in the spatial coincidence of maps made in the various lines. Local clouds (diameter less than 1 kiloparsec), such as Orion, Taurus, Ophiuchi, and Perseus, will be mapped in each of the four lines. A survey of galactic Giant Molecular Clouds will be performed, and a number of gas rich extra-galactic sources, such as the Magellanic Clouds, will be observed.

Small-Class Explorers (SMEX) (Continued)

Description (Continued)

	SAMPEX	FAST	SWAS
Launch Date:	June 1992	September 1994	June 1995
Payload:	4 particle detectors	4 instruments	telescope & receivers
Orbit:	82 degree inclination; 550 x 657 km (297 x 355 nm) altitude, circular	83 degree inclination; 350 x 4,200 km (189 x 2,268 nm), altitude, non-Sun synchronous	38 degree inclination; 600 km (324 nm) altitude
Design Life:	3 years	1 year	3 years
Length:	1.5 m (5 ft) (stowed)	0.86 m (3 ft) (stowed)	1.65 m (5 ft)
Weight:	158 kg (348 lbs)	162 kg (356 lbs)	218.6 kg (482 lbs)
Diameter:	0.86 m (3 ft) (stowed)	1.17 (stowed)	.97 m (3 ft)
Launch Vehicle:	SCOUT	Enhanced Pegasus	Pegasus
International Participation:	FRG	None	FRG

Instruments/Investigations/Principal Investigator

SAMPEX

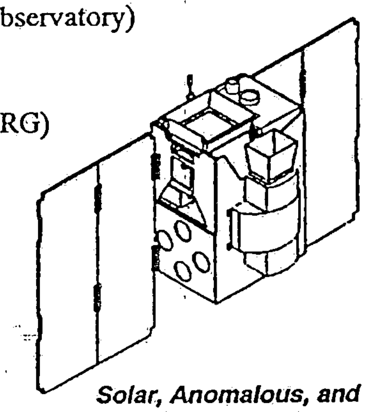
Principal Investigator - G. Mason (University of Maryland)
Low Energy Ion Composition Analyzer (LEICA) - (University of Maryland)
Heavy Ion Large Telescope (HILT) - (Max Planck Institute for Extraterrestrial Physics - FRG)
Mass Spectrometer Telescope (MAST) - (California Institute of Technology)
Proton-Electron Telescope (PET) - (California Institute of Technology)

FAST

Principal Investigator - C. Carlson (University of California-Berkeley)
Electric Field Plasma Experiment - (University of California-Berkeley)
Quadrispherical Electrostatic Electron Analyzer - (University of California-Berkeley)
Time-of-flight Energy Angle Mass Spectrograph - (University of New Hampshire and Lockheed Palo Alto Research Laboratory)
Magnetometer - (University of California-Los Angeles)

SWAS

Principal Investigator - G. Melnick (Smithsonian Astrophysical Observatory)
Antenna, Star Tracker, Instrument Integration - (Ball Aerospace)
Submillimeter Heterodyne Receiver (SHR) - (Millitech)
Acousto-Optical Spectrometer (AOS) - (University of Cologne - FRG)

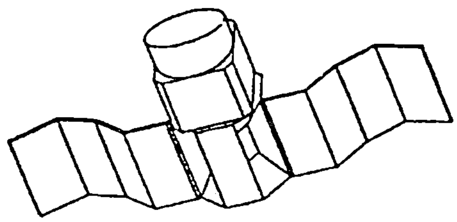


Solar, Anomalous, and Magnetospheric Particle Explorer

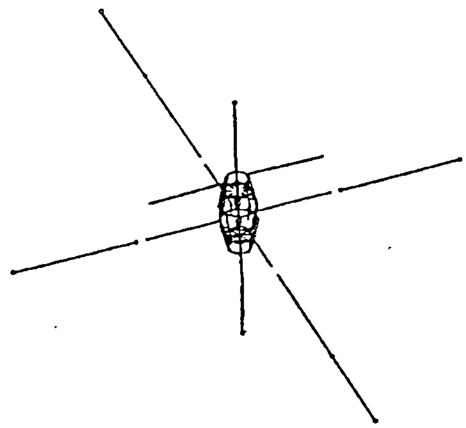
Small-Class Explorers (SMEX) (Continued)

Management

NASA Headquarters
D. Gilman, Program Manager
V. Jones, SAMPEX Program Scientist
L. Caroff, SWAS Program Scientist
E. Whipple, FAST Program Scientist
Goddard Space Flight Center
O. Figueroa, Project Manager
D. Baker, Project Scientist
G. Colon, SAMPEX Mission Manager
D. Betz, SWAS Mission Manager
G. Chin, SWAS Mission Scientist
T. Gehringer, FAST Mission Manager
Major Contractors
University of Maryland (SAMPEX)
California Institute of Technology (SAMPEX)
Max Planck Institute (SAMPEX)
Aerospace Corporation (SAMPEX)
Smithsonian Astrophysical Observatory (SWAS)
Ball Aerospace (SWAS)
University of Cologne (SWAS)
Millitech (SWAS)
University of California-Berkeley (FAST)
Lockheed Palo Alto Research Laboratory (FAST)
University of New Hampshire (FAST)



Submillimeter Wave Astronomy Satellite



Fast Auroral Snapshot Explorer

Status

SAMPEX
Critical Design Review (CDR) was completed in June 1990. Instrument integration began in September 1991. Currently in flight integration for a June 1992 launch.

FAST
Preliminary Review completed in November 1991. Currently being developed and built for a 1994 launch.

SWAS
Concept Review was completed during June 1990. The instruments and spacecraft began development in December 1991 for a 1995 launch.

NASA Facts

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771
AC 301 286-8955

NASA'S OZONE STUDIES

Barely half a decade ago, stratospheric ozone depletion was mainly of interest to atmospheric scientists. Today it is a worldwide environmental concern that has been addressed by several international accords. Ozone depletion epitomizes the environmental problems humans face today: it is global; it is the direct but unintended result of human industry; and remedying it will have direct and indirect economic consequences. Since the mid-1970s, NASA has been in the forefront of research into why and how the ozone layer in the stratosphere, or upper atmosphere, undergoes regular dramatic changes.

Ozone, a molecule made up of three oxygen atoms, shields life on Earth from the harmful effects of the ultraviolet radiation of the Sun. The increased amounts of ultraviolet radiation that would reach the Earth's surface because of ozone depletion could increase the incidence of skin cancer and cataracts in humans and may harm crops and interfere with marine life.

Because the risks of ultraviolet radiation are so serious, scientists all over the world are working to determine how much of the ozone-related change in the atmosphere is caused by humans and how much is attributable to natural processes, such as the shift in atmospheric dynamics, volcanic activity or the solar cycle.

Studies have shown that ozone depletion is caused by complex, coupled chemical reactions. Recent data has indicated that man-made chlorofluorocarbons (CFCs), used in refrigeration, electronics and other industries, are capable of altering the levels of atmospheric ozone. Continued build-up of CFCs is expected to lead to additional ozone loss worldwide. Ongoing studies are essential to provide the necessary understanding of the causes of ozone depletion.

For decades, NASA has pioneered the study of the atmosphere in order to improve life on Earth. The agency's commitment to environmental research is continuing with Mission to Planet

Earth, a coordinated series of ground-based, airborne and space-based programs designed to study the Earth as a single, global environmental system. By analyzing and collecting data from a variety of experiments, missions and satellites, NASA scientists hope to contribute to humanity's better understanding its influences on the atmosphere and the rest of the environment. Within Mission to Planet Earth, NASA's on-going commitment to ozone studies includes current and future missions. Five of the projects are detailed below.

TOMS

Since its launch aboard NASA's Nimbus-7 polar-orbiting satellite in 1978, the Total Ozone Mapping Spectrometer (TOMS) has provided reliable, high-resolution mapping of global total ozone on a daily basis. TOMS, managed by NASA's Goddard Space Flight Center (GSFC), Greenbelt, Md., is the primary source of high-resolution global maps about the total ozone content of the atmosphere.

Analyses of TOMS data have traced in detail the annual development of the Antarctic "ozone hole," a large area of intense ozone depletion that occurs between late August and early October. The ozone hole was discovered through British ground-based observations in the mid-1980s, but analysis of TOMS data indicates it has existed since at least 1979.

Recent studies by Goddard scientists using more than 11 years of TOMS data have revealed that the reductions in ozone over the mid-northern latitudes are approximately twice as severe as previously believed. The possibility that increased ultraviolet radiation could reach the Earth's surface during the beginning of the growing season raises questions of significant economic, environmental and health effects.

A long-term, consistent record of ozone levels is essential to understanding and predicting ozone depletion. To ensure that ozone data will be available throughout the next decade, NASA will continue the TOMS program using U.S. and foreign launches. On Aug. 15, 1991, the Soviet Union launched a Meteor-3 satellite carrying a TOMS instrument. A third TOMS will be launched aboard a Pegasus booster in 1993, and the Japanese Advanced Earth Observations Satellite (ADEOS) will carry a fourth TOMS when it launches in 1995.

UARS

Launched Sept. 12, 1991, the Upper Atmosphere Research Satellite (UARS) will help scientist better understand the energy input, chemistry and dynamics of the upper atmosphere and the coupling between the upper and lower atmosphere. UARS, the first satellite dedicated to studying stratospheric science, will focus on the processes that lead to ozone depletion, complementing and amplifying the measurements of total ozone made by TOMS.

Ten UARS instruments will provide the most complete data on upper atmospheric energy inputs, winds, and chemical composition ever gathered. Taken together these observations constitute a highly integrated investigation of the nature of the upper atmosphere. In its first two weeks of operation, UARS data confirmed existing ozone-depletion theories by providing three-dimensional maps of ozone and chlorine monoxide near the South Pole during development of the 1991 ozone hole. UARS, developed and managed by GSFC, ultimately will provide information that nations around the world can use to make decisions on environmental policies.

ATLAS

The Atmospheric Laboratory for Applications and Science (ATLAS), a series of Space Shuttle-Spacelab missions, will carry two instruments to measure ozone and other chemicals in the upper atmosphere, complementing and expanding measurements made by UARS. ATLAS will investigate how Earth's atmosphere and climate are affected by the Sun and by the products of industrial complexes and agricultural activities. Scientists from six countries will conduct 12 investigations in atmospheric science, solar physics, space plasma physics and astronomy.

ATLAS-1, scheduled to be launched aboard Space Shuttle Atlantis in early 1992, will be the first in an 11-year series of missions to study long-term interactions between the atmosphere and the Sun. Later missions dedicated to Earth science are planned at about one-year intervals. The series of flights will return data from very highly calibrated instruments that will help scientists study trends in the atmosphere and complement long-term satellite measurements. The ATLAS missions are managed by Marshall Space Flight Center, Huntsville, Ala.

AIRBORNE RESEARCH

Not all of NASA's ozone research is conducted from space. Periodic expeditions that fly instruments through the atmosphere aboard research aircraft have greatly expanded our understanding of ozone depletion. Airborne expeditions over both the Arctic and Antarctic have led scientist to conclude that chemical reactions involving human-produced chlorine are the main cause of ozone depletion in the upper atmosphere.

NASA, in conjunction with the National Oceanic and Atmospheric Administration, the National Science Foundation and industry, has conducted two airborne campaigns: over the Antarctic (1987) and Arctic (1989). The second Airborne Arctic

Stratospheric Expedition began in October 1991, with ER-2 flights over the North Pole from Fairbanks, Alaska. It will continue through March 1992 with ER-2 flight out of Bangor, Maine, and DC-8 flight from the Ames Research Center, Mountain View, Calif. Ames in the managing center for NASA's airborne research programs.

SSBUV

The Shuttle Solar Backscatter Experiment (SSBUV), a highly calibrated instrument developed at Goddard for periodic flights aboard the Space Shuttle, determines ozone levels by measuring reflected ultraviolet light. SSBUV measures the total amount and height distribution of ozone in the upper atmosphere and collects data to calibrate ozone-measuring instruments on other satellites. Scientists directly compare the SSBUV and satellite-instrument data as the two pass over the same Earth location within an hour. These orbital coincidences can occur 17 times a day.

SSBUV has flown three times: on STS-34 (October 1989), STS-41 (October 1990) and STS-4333 (August 1991). The next planned mission is ATLAS-1/STS-45 (early 1992) and regular flights are scheduled through the 1990s.

SAGE

The Stratospheric Aerosol and Gas Experiment (SAGE), was first launched in 1979 aboard the Applications Explorer Mission B spacecraft and provided ozone measurements using the solar occultation technique until 1981. The application of this technique represented the first global, high vertical resolution data set for stratospheric ozone. It is the vertical measurement orientation and self-calibrating feature which distinguishes SAGE measurements from those of other space instruments.

SAGE II began operation with the Earth Radiation Budget Satellite in 1984 and is still healthy today, making important contributions to studies of the Antarctic ozone hole with high resolution scrutiny of ozone, water vapor and polar stratospheric clouds. Most recently, SAGE observed large changes in lower stratospheric ozone in the northern polar region caused by energetic protons released from the Sun during intense solar flares.

The most important result of SAGE measurement has been the combination of data from both missions, along with the data from the SAM II experiment on Nimbus-7, which monitors long-term changes in ozone.

SAGE is managed by Langley Research Center, Hampton, VA.

The Future--Mission to Planet Earth

These five complementary projects are important to understanding the dynamic processes that can lead to ozone depletion. As part of NASA's Mission to Planet Earth, the agency's ozone depletion studies are designed to observe the Earth of a global scale.

Mission to Planet Earth is NASA's contribution to the multi-agency U.S. Global Change Research Program. The centerpiece to Mission to Planet Earth is the Earth Observing System (EOS), a series of environmental research satellites planned to begin launches in 1998. The EOS program will continue and integrate the measurement by TOMS, ATLAS, UARS and SSBUV, and will provide the first coordinated, simultaneous measurements of the interactions of the atmosphere, oceans, land surfaces and biosphere. Early versions of the EOS Data and Information System will incorporate existing ozone data for the widest possible distribution to international researchers.

####

January 1992

NASA Facts

National Aeronautics and
Space Administration

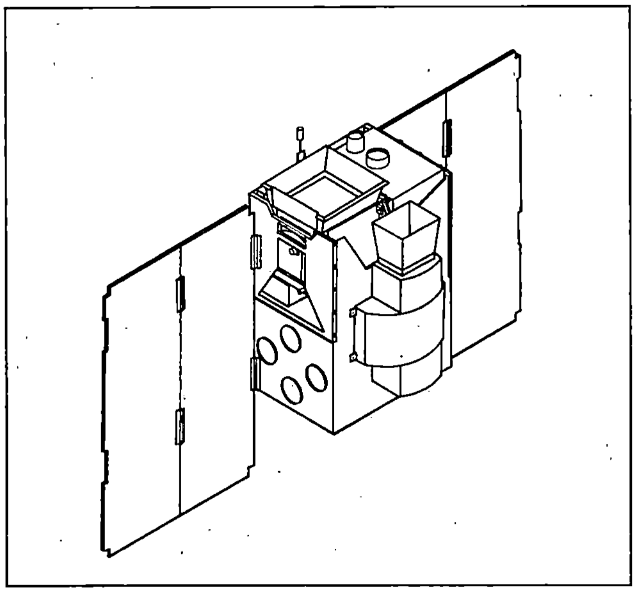
Goddard Space Flight Center
Greenbelt, Maryland 20771
AC 301 286-8955

Small Explorer (SMEX) Program

The Small Explorer Project (SMEX) is a NASA initiative to provide frequent flight opportunities for relatively inexpensive space missions. This international program involves spacecraft which weigh approximately 400 pounds (180 kg) each and can be launched into Earth orbit by Scout and Pegasus launch vehicles.

In spite of their small size, SMEX missions will investigate some of the most important questions raised in astrophysics and space physics. The program will conduct focused investigations which probe conditions in unique parts of space, complement major missions, prove new scientific concepts or make significant contributions to space science in other ways.

Capitalizing on availability of mature or developed instrumentation to carry out scientific investigations allows SMEX missions to be accomplished quickly and frequently. It is a goal of the SMEX Program to bring each mission to launch readiness within three years after the start of detailed design activities.



SAMPEX

By having a short development time and small size, the SMEX missions allow critical training opportunities for the next generation of scientists and engineers.

The SMEX program is managed by the Engineering Directorate of Goddard Space Flight Center in Greenbelt, MD, for NASA's Office of Space Science and Applications. The project manager for SMEX is Orlando Figueroa. Project scientist is Dr. Daniel N. Baker. The Program Manager at NASA Headquarters is Dr. David A. Gilman.

Background

The Small Explorers are part of NASA's Explorer Program which since 1958 has launched small and moderate-sized science mission payloads into space. Explorer missions have served both to pioneer new fields of space science and to investigate in detail one particular aspect of science.

With the launch of the Japanese Solar-A mission in August 1991, 68 U.S. and cooperative-international scientific space missions have been part of the Explorer Program

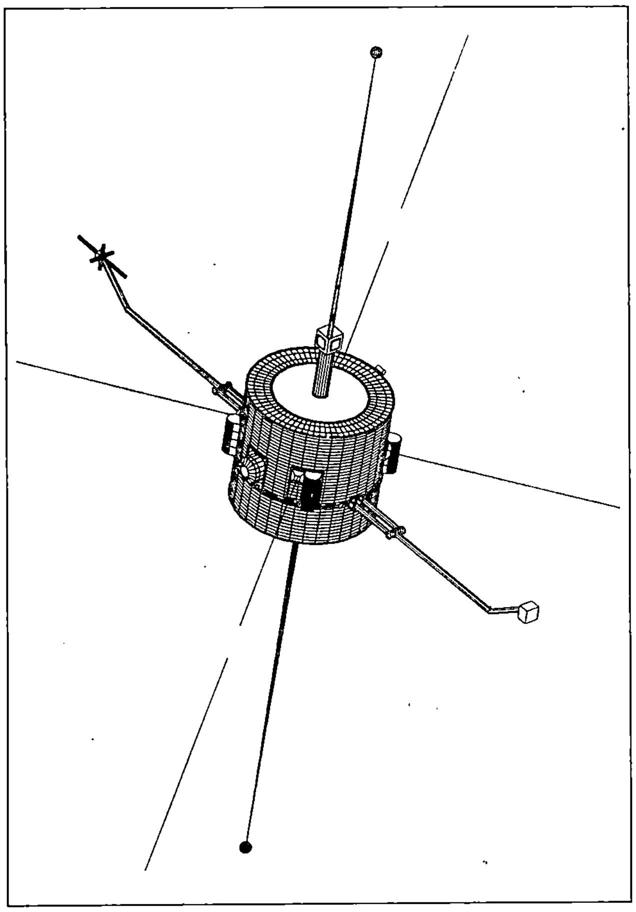
For example, the Goddard-managed International Ultraviolet Explorer (IUE), continues to operate after more than 13 years in Earth orbit. The Cosmic Background Explorer (COBE), which is making dramatic contributions towards the scientific understanding of the origins of the universe, is another example of an Explorer mission managed by Goddard.

The Missions

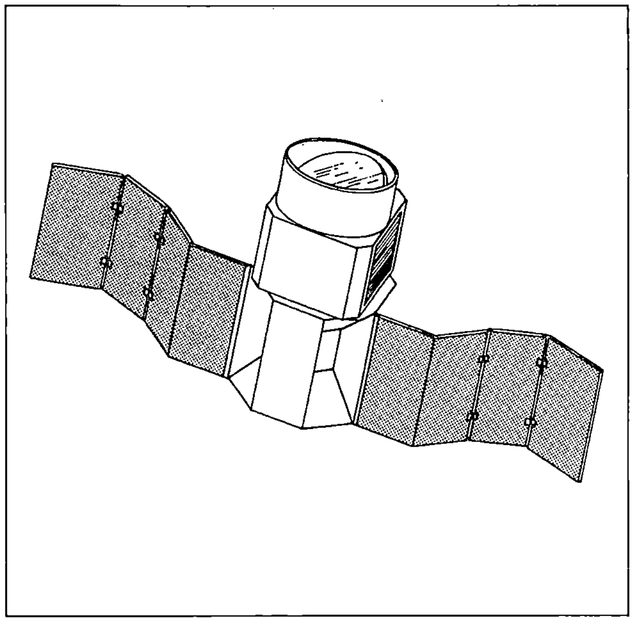
Three SMEX missions are currently approved. They are as follows:

- **SAMPEX** – The Solar Anomalous Magnetospheric Particle Explorer, scheduled for launch in June 1992, will collect data from unique parts of the Earth's magnetic field in order to study solar energetic particles, anomalous cosmic rays, galactic cosmic rays and magnetospheric electrons. Of the four instruments on SAMPEX, two were flown previously as Get Away Special (GAS) experiments on the space shuttle. Dr. Glenn M. Mason, University of Maryland, College Park, is principal investigator and there are 10 Co-Investigators from American and German institutions. The mission manager for SAMPEX is Gilberto Colon.

• **FAST** – The Fast Auroral Snapshot Explorer will investigate the processes thought to be responsible for producing the Earth's aurora. In studying these processes, FAST will complement investigations carried out simultaneously by missions of the International Solar Terrestrial Physics (ISTP) Program. FAST is scheduled for launch in September 1994. There are five instruments on FAST, four of which are similar to instruments that will be carried to other parts of space by the ISTP missions. Dr. Charles W. Carlson, University of California, Berkeley, is the principal investigator for FAST. There are four Co-Investigators from U.S. institutions. Mission manager for FAST is Timothy Gehringer.



FAST



SWAS

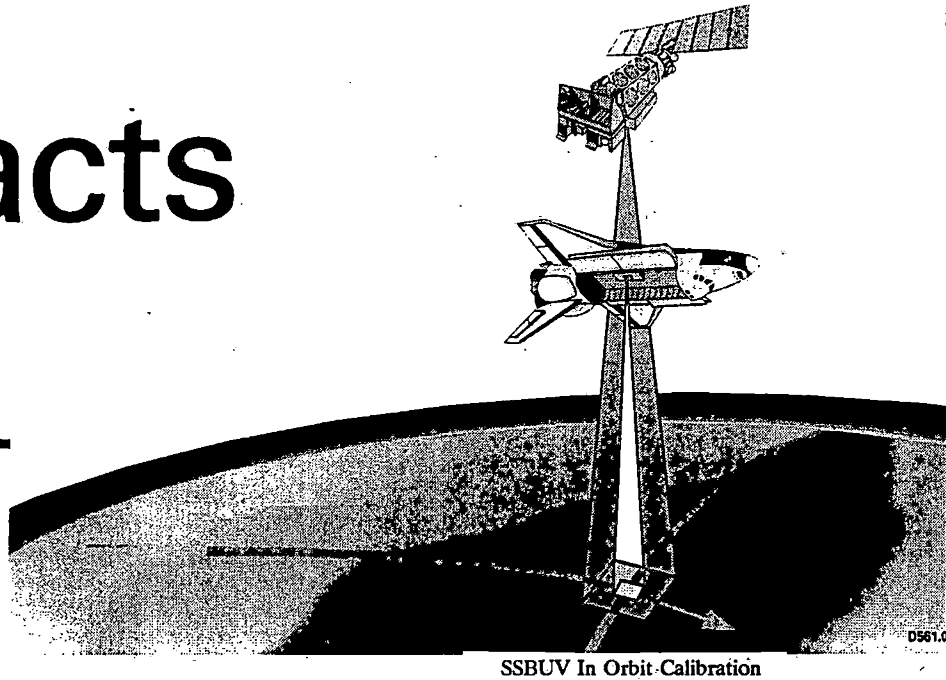
• **SWAS** – The Submillimeter Wave Astronomy Satellite is scheduled for launch in 1995. It will investigate the physical conditions, chemical composition, and energy release of immense, interstellar clouds of molecules and will relate these results to the formation of stars and planetary systems. SWAS will prove a new scientific concept by pioneering the investigation of these clouds at important radio frequencies that can only be seen from space. The principal investigator is Dr. Gary J. Melnick, of the Harvard-Smithsonian Center for Astrophysics, Cambridge, MA. Dr. Melnick will head a team of 11 Co-Investigators from institutions across the U.S. and Cologne, Germany. Both instruments on SWAS are similar to instruments used in ground observatories. The mission manager for SWAS is David Betz.

An Announcement of Opportunity for future Small Explorer missions is expected to be released in the first half of 1992.

NASA Facts

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771
AC 301 286-8955



SSBUV In Orbit Calibration

SHUTTLE SOLAR BACKSCATTER ULTRAVIOLET (SSBUV) INSTRUMENT

The Shuttle Solar Backscatter Ultraviolet (SSBUV) instrument was developed by NASA's Goddard Space Flight Center to compare the observations of several ozone measuring instruments aboard the National Oceanic and Atmospheric Administration's NOAA-9 and NOAA-11 satellites and the NIMBUS-7 satellite. The SSBUV data are used to calibrate these instruments to ensure the most accurate readings possible for the detection of atmospheric ozone trends.

The SSBUV will help scientists solve the problem of data accuracy caused by calibration drift of Solar Backscatter Ultraviolet (SBUV) instruments on these satellites. The SSBUV uses the Space Shuttle's orbital flight path to assess instrument performance by directly comparing data from identical instruments aboard the NOAA spacecraft and the NIMBUS-7 as the space shuttle and the satellite pass over the same Earth location within an hour.

These orbital coincidences can occur 17 times a day.

The satellite-based SBUV instruments estimate the amount and height distribution of ozone in the upper atmosphere by measuring the incident solar ultraviolet radiation and ultraviolet radiation backscattered from the Earth's atmosphere. The SBUV measures these parameters in 12 discrete wavelength channels in the ultraviolet. Because ozone absorbs in the ultraviolet wavelengths, an ozone measurement can be derived by comparing the amount of incoming solar radiation to the amount backscattered by the atmosphere.

Working with Other Instruments

For STS-45, SSBUV is co-manifested with the ATLAS-1 payload which carries a compliment of Earth and Space science experiments. Currently, SSBUV is co-manifested with ATLAS on its next four flights scheduled through 1996.

Among other measurements, several Upper Atmosphere Research Satellite (UARS) instruments also will measure ozone. Simultaneous measurements by SSBUV and ATLAS with the UARS instruments will be a unique opportunity to tie in the detailed observations of the physics and chemistry of the stratosphere being made by UARS with the regular on-going SBUV ozone observations. These data sets can then be used as a baseline for detecting long-term changes in the stratosphere.

SSBUV's value lies in its ability to provide precisely calibrated, or verified, ozone measurements. The instrument is calibrated to a laboratory standard before flight, then is recalibrated during and after flight to ensure its accuracy. These laboratory standards are routinely calibrated at the National

Institute of Standards and Technology. The rigorous calibration provides a highly reliable standard to which data from the SBUV instruments can be compared.

Previous Flights

The three previous SSBUV flights occurred on STS-34 in October 1989, STS-41 in October 1990 and STS-43 in August 1991. NASA's goal is to fly SSBUV missions approximately once a year between 1989 and 2000 to provide precise calibration measurements across a full 11-year solar cycle.

After SSBUV's flight last August, the instrument was checked out at Kennedy Space Center, to make certain everything was working. The tape recorders then had their information removed and the data was sent to GSFC for processing. The payload was sent back to Goddard where the instrument was checked out and recalibrated. Then the payload was refurbished with new avionics, which interfaces with the orbiter power, data and command systems. Other repairs and hardware enhancement were made, SSBUV was reassembled, requalified and sent back to Kennedy Space Center. All of this happened in only four months. At the same time, data from previous flights are being reprocessed. All of this is accomplished with a team of only 12.

SSBUV's impact on our ability to accurately detect ozone trends was expected after approximately four flights. Data from the first flight has already been used to estimate ozone trends in the upper stratosphere since 1980. These results show a depletion of about 8 percent over 10 years, which is consistent with predictions of ozone depletion.

The SSBUV instrument and its flight support electronics, power, data and command systems are mounted in the space shuttle's payload bay in two flight canisters, that together weigh 900 pounds (410 kilograms). The Instrument Canister holds the SSBUV instrument, its aspect sensors and in-flight calibration system. Once in orbit, a motorized door assembly opens the canister to allow the SSBUV to view the Sun and Earth and closes to provide contamination protection and to perform in-flight calibrations. The Support Canister contains the avionics which includes the power, data, and command systems.

SSBUV will now obtain power from the space shuttle and will receive real-time ground commands and data acquisition which overcomes many operational limitations SSBUV was under on previous flights. This will allow enhanced SSBUV data gathering capabilities and an ability to coordinate measurements with the ATLAS and UARS instrument compliments. SSBUV commands will be sent from a Payload Operations Control Center (POCC) at Johnson Space Center, Houston, TX. SSBUV data will be received at Johnson and the Marshall Space Flight Center, Huntsville, AL. Marshall is responsible for managing the ATLAS payload and for integrating SSBUV science requirements into the mission timeline.

Ernest Hilsenrath of GSFC is the Principal Investigator, Don Williams is the Mission Manager. SSBUV is managed by GSFC for NASA's Office of Space Science and Applications.

#####

February 1992

NASA Status Report

National Aeronautics and
Space Administration

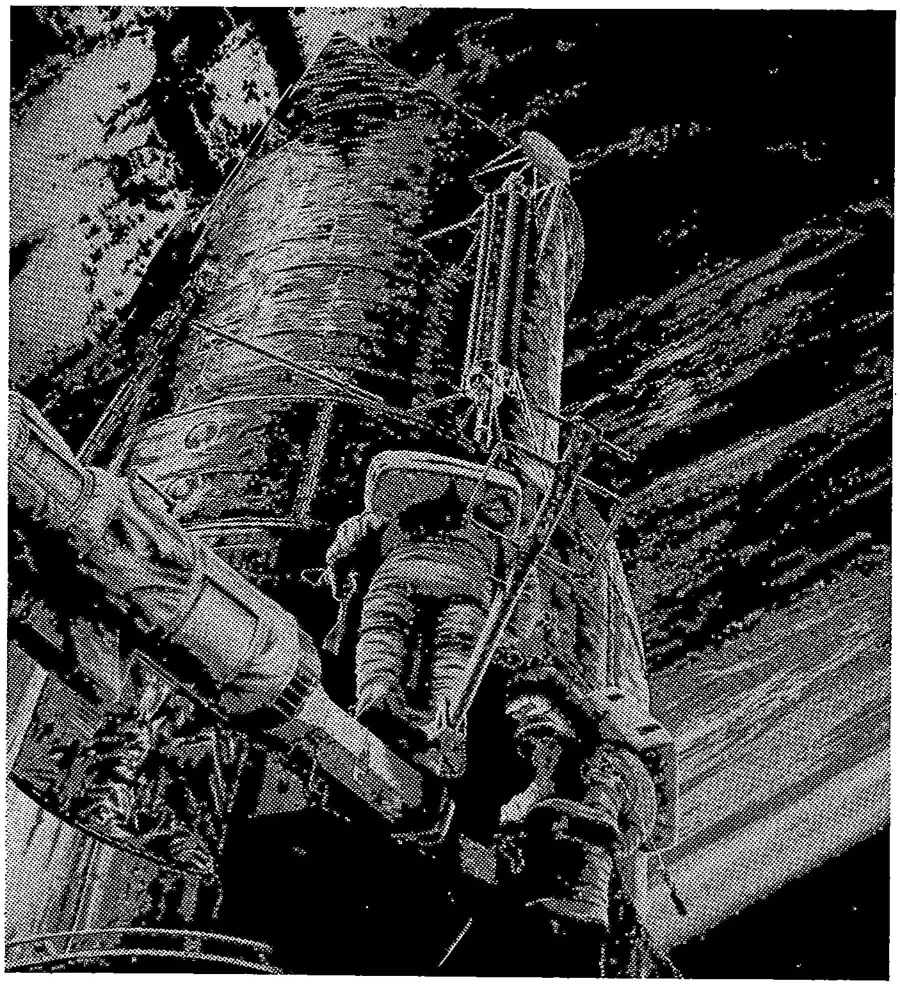
NASA Headquarters
Washington, DC

March 1992

The Hubble Space Telescope:
Report on Plans for the HST Servicing Mission

Background

The Hubble Space Telescope (HST) was launched on April 24,1990. By June 1990, two problems were discovered: spherical aberration of the primary mirror and jitter caused by the solar arrays. Image processing and spacecraft control software have compensated somewhat for both of these problems, but servicing is necessary to fix them. HST was designed for on-orbit servicing, to repair and refurbish the observatory and to upgrade its capabilities by installing advanced instruments. On-orbit servicing will permit correction of the spherical aberration and the solar array jitter.



Conceptual illustration of astronauts replacing instruments during the Hubble Space Telescope servicing mission.

(Ball Aerospace Systems Group, artist, Scott Kahler)

Mission Goals and Planning

The primary objective of the first HST servicing mission is to correct for spherical aberration in HST's primary mirror and replace faulty solar arrays.

The major constraint on NASA's ability to service HST on this mission is the amount of work that can be completed during the planned Space Shuttle flight. The current plan provides for 3 days of extravehicular activity (EVA) servicing, a day to redeploy HST and another day to assure the safe return of the Space Shuttle (for example, by manually closing the cargo bay doors if necessary). This amount of on-orbit work time provides for two optical fixes—the Wide Field/ Planetary Camera II (WF/PC II) and the Corrective Optics Space Telescope Axial Replacement (COSTAR); replacement of the solar arrays, two pairs of gyros and one gyro electronics box; and enough additional time to replace another subsystem that will be identified at a later date.

During the ongoing mission preparation, NASA is investigating methods to improve the efficiency of the work, so that any extra EVA time would provide a margin to assure the critical work required to restore essential HST capabilities is completed.

Mission Overview

Currently scheduled for launch in late 1993-early 1994, the orbiter will rendezvous with HST on the third day of the flight. HST will then be captured and secured in an upright position in the cargo bay for servicing. Working in pairs, on alternating days, the four EVA crewmembers will be spending three 6-hour work days performing the repairs.

Development has begun on astronaut simulations of on-orbit servicing operations to rehearse and optimize EVA repair work at Johnson Space Center's Weightless Environment Training Facility and Marshall Space Flight Center's Neutral Buoyancy Simulator (these large water tanks simulate the weightless environment of space). Early EVA training on individual components began this March. Other key events that will affect planning for the mission include the selection of a flight crew and a Shuttle cargo integration review in late 1992. Meanwhile, planning teams, including representatives of NASA Headquarters, Goddard Space Flight Center, Johnson Space Center, and Kennedy Space Center, will continue working on detailed and comprehensive procedures and time lines for this challenging mission.

Mission Cargo

Wide Field/Planetary Camera II

The Jet Propulsion Laboratory team that built HST's Wide Field/Planetary Camera (WF/PC) began developing a spare instrument in 1985. When the Hubble's mirror was found to be flawed, NASA and the WF/PC science team immediately began working on an optical correction that could be built into WF/PC II. The new design incorporates an optical correction by the refiguring of relay mirrors already in the optical train of the cameras. Each relay mirror is polished to a new "prescription" that will compensate for the incorrect figure on HST's primary mirror. Small actuators will fine-tune the positioning of these mirrors on orbit, ensuring the very precise alignment that is required.

Through a servicing bay door built into the side of HST, astronauts will slide out the 610-pound, wedge-shaped WF/PC I, as they would a giant drawer, and replace it with WF/PC II. The new instrument will have three wide field cameras and one planetary camera instead of the original eight. The WF/ PC II team chose to reduce the number of cameras to four in order to develop a system to align the corrective relay mirrors on-orbit remaining on schedule and within budget. Improved Charged Coupled Devices (CCDs) that were not available when the first WF/PC was built will be incorporated in WF/ PC II to improve its sensitivity, particularly in the ultraviolet.

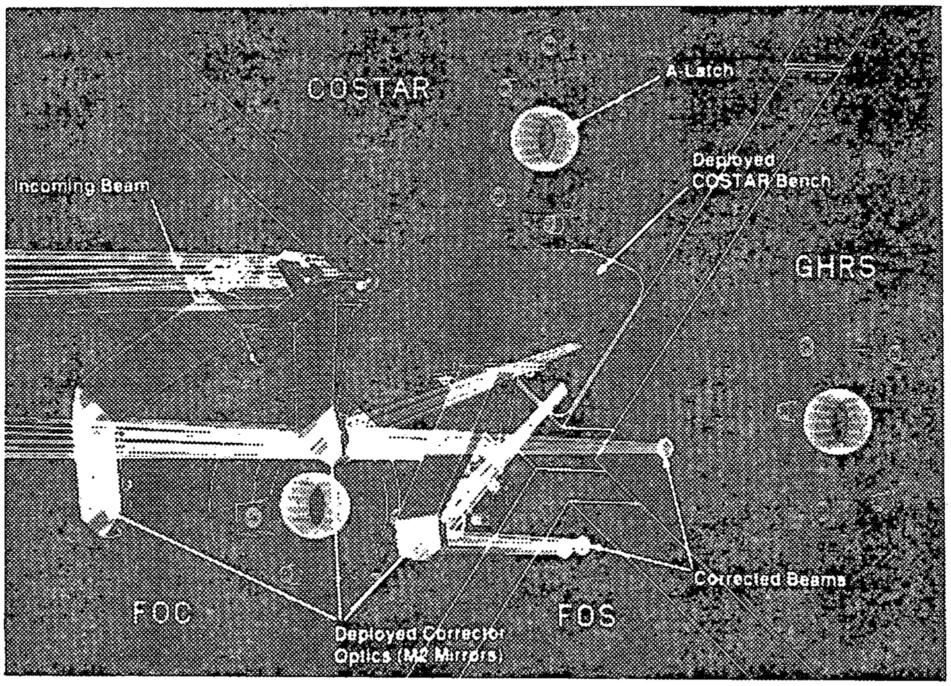
WF/PC II is proceeding within its budget and, despite the complexity of the task, is on schedule to be delivered from the Jet Propulsion Laboratory to NASA's Goddard Space Flight Center in the spring of 1993. WF/PC II will be tested with spacecraft and ground system simulators there before being sent to Kennedy Space Center to be integrated with the Space Shuttle.

Corrective Optics Space Telescope Axial Replacement (COSTAR)

COSTAR was invented by the Hubble Space Telescope Strategy Panel, a group of scientists and engineers brought together at the Space Telescope Science Institute in the fall of 1990 to consider how to fix HST. Being built by Ball Aerospace under contract to

Functional illustration of the Corrective Optics Space Telescope Axial Replacement (COSTAR). It will use precisely shaped mirrors to correct for the spherical aberration.

(Ball Aerospace Systems Group)



NASA, COSTAR has no detectors or cameras. It will use precisely shaped mirrors to correct for the spherical aberration.

Through a servicing bay door, astronauts will pull out the 487-pound, phone-booth-sized High Speed Photometer (HSP) and install in its place the identically sized COSTAR. Once in place, COSTAR will deploy a set of mechanical arms, no longer than a human hand, that will place corrective mirrors in front of the openings that admit light into three of HST's observing instruments (the Faint Object Camera, Faint Object Spectrograph, and Goddard High Resolution Spectrograph).

COSTAR's corrective mirrors will refocus light relayed by HST's primary mirror before it enters these instruments. COSTAR will restore the optical performance of these instruments very close to the original expectations.

The HST team decided that COSTAR would displace the High Speed Photometer because the photometer does proportionately less science than any one of HST's other four instruments.

Less than a year after beginning development, COSTAR passed a major milestone—the critical design review. The project remains within budget and on schedule, with no major technical problems.

Solar Arrays

HST's deployable solar arrays, provided by the European Space Agency (ESA), create a jitter problem that interferes with spacecraft stability. The arrays were designed to accommodate the expansion and contraction caused by heating and cooling as the Hubble moves in and out of daylight in its 90-minute orbits. However, a compensation device that allows for the expansion and contraction of the solar array blankets does not expand and contract as smoothly as expected. ESA has redesigned a set of spare solar arrays to reduce the jitter to an acceptable level. A critical design review took place during January 1992. All participants in the HST program were pleased with the redesign, and ESA is fully committed to its role as a partner in the program.

Gyros

Three gyros are required to point and track HST; three more gyros are on board as backups. One of HST's six gyros failed in December 1990, and a second one failed in June 1991. Two of the four gyros contain components that are suspected of causing the failures. While these failures have not affected HST's performance, replacing the failed hardware will increase system reliability. If time permits on the servicing mission, astronauts will remove and replace two Rate Sensor Units (RSU) and an Electronic Control Unit (ECU)—each housing a pair of gyros. The replacement units are flight-qualified spares that are being

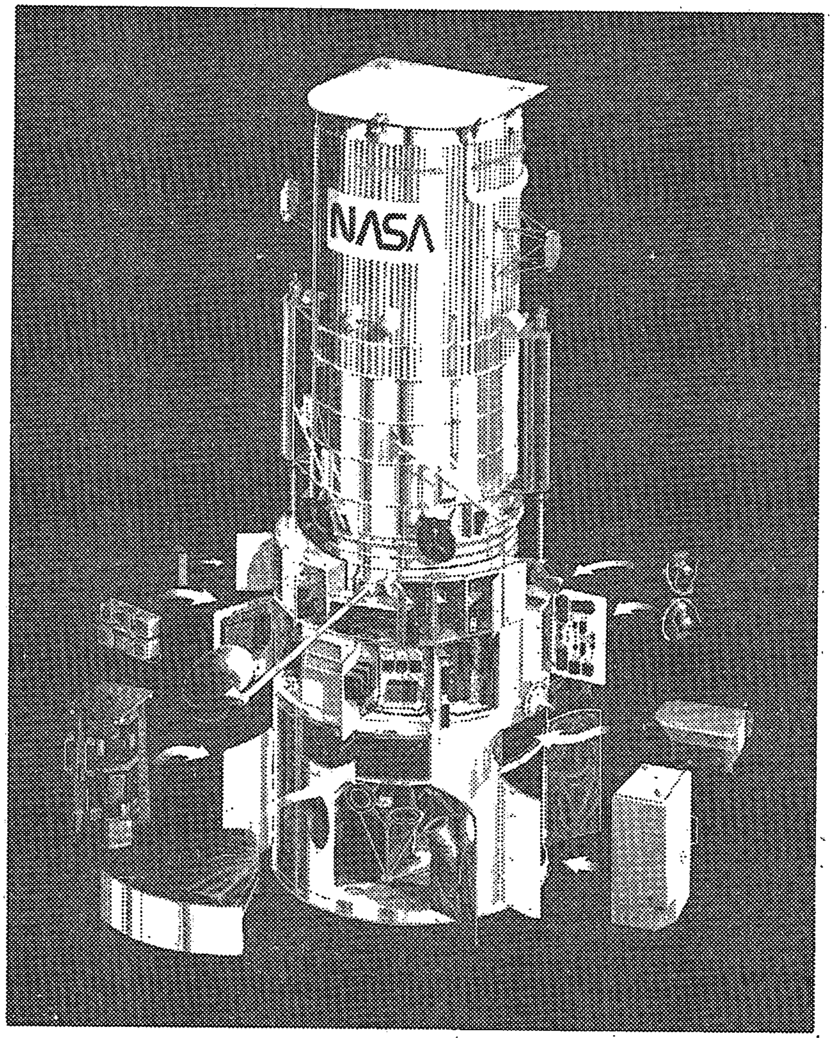
rebuilt to replace the suspected point of failure (a hybrid circuit). The first RSU and ECU are scheduled to be delivered to Goddard Space Flight Center in the summer of 1992; the second RSU is to be delivered in the spring of 1993.

Servicing/Support Equipment

From the very beginning, HST was designed for servicing in space, and many of its subsystems were designed to be modular, standardized, and accessible. HST has 49 different modular subsystems designed for servicing, ranging from small fuses to scientific instruments. HST also features 225 feet of handrails and 31 footholds to aid EVA crews in servicing tasks. More than 80 tools, ranging from screwdrivers to special hardware designed specifically for HST servicing, are available for use on this mission.

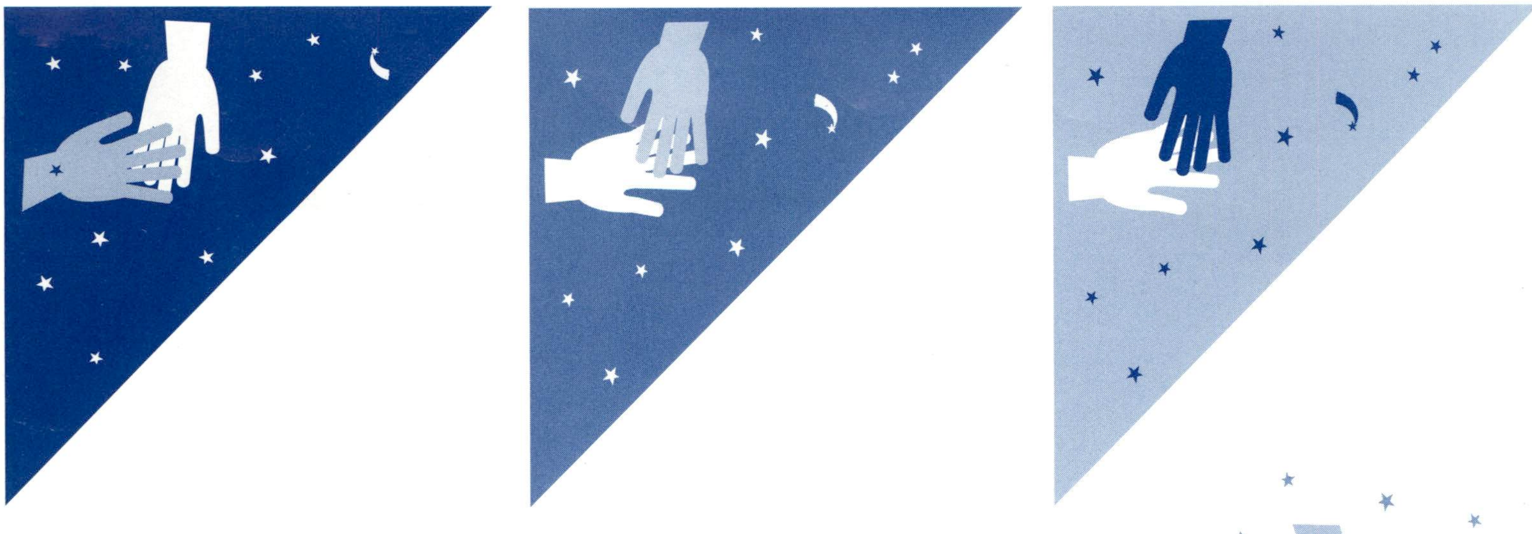
Conclusion

The Hubble Space Telescope servicing mission is a challenging and complex endeavor, but all elements of mission planning are on schedule, and EVA simulations will begin in March 1992. The Astrophysics Division will continue to report on the evolution of plans for the HST servicing mission.



Instruments, batteries, computers, and other essential components in the equipments bays are accessible through doors for easy removal and replacement. These items, called Orbital Replacement Units, are designed for servicing in space.

(Gordan Raney, artist, Lockheed)



GLOBAL YOUTH FORUM '92
CASE STUDIES

MAY 14 - 15, 1992, UNITED NATIONS, NEW YORK CITY


PEOPLE WORKING FOR A BETTER WORLD™
Corporate Patron
SC Johnson wax
S.C. Johnson & Son, Inc.


OUTH FORUM '92
1992, UNITED NATIONS, NEW YORK CITY

Secondary School
40 Students, aged 11-16, and 17 others

BARROUALLIE SECONDARY SCHOOL
Barrouallie Post Office
Barrouallie, St. Vincent and the Grenadines

A WASTE MANAGEMENT AND ENVIRONMENTAL PRESERVATION PROGRAM – Beach Protection

Issue: Waste discarded on the beach and in the town; excessive exploitation of the beach's sand and stones for use in building construction.

Action: A march and a rally were held to heighten public awareness and a clean-up campaign was organized. A sponsored island-wide competition was also held.

Outcome: An increased public awareness of the need to protect the beach. A cleaner beach. A greater awareness that involvement of youth in such an activity can create a great impact.

Youth Movement/
250 Participants aged 15 and over

EARTH SAVERS MOVEMENT
Ninoy Aquino Hall
Ninoy Aquino Park
Quezon Avenue
Quezon City, Philippines

A THEATER PRODUCTION WITH AN ECOLOGICAL MESSAGE – Dreams ("Development and Rehabilitation of the Environment Through Arts, Media and Science")

Issue: Global warming, recycling, pollution, waste management.

Action: Young ecologically concerned volunteer artists trained youth including "street kids" and disabled/disadvantaged children to participate in theater productions, e.g. "The Legend of the Mango Tree," for international performance.

Outcome: Messages urging everyone to help save the planet and regarding environmental problems were dramatically conveyed to international audiences, helping them to internalize ecological issues.

Other Earth Savers Movement Projects include a rehabilitation program that the Baguio earthquake, ballets, conferences and "The Ten Commandments for Sustainable Development." Their motto: "Sweep Clean, Keep Green."

Youth Movement
BARBADOS
15 Youth, aged 16-28

YOUTH TO YOUTH
Foul Bay
St. Phillip, Barbados

A SOCIAL AND PHYSICAL ENVIRONMENT CARE PROGRAM

Issue: The damaging effect of social problems on the environment.

Action: Organized hikes and nature walks; enrolled young people in environmental awareness workshops and seminars.

Outcome: Youth were made aware of the link between social and physical environments; they became more concerned for personal health; there was greater realization of the damaging effects of drug abuse on the personal and physical environment.

First year
Medicine Students

ANTARJATIK BESHAMARIK
SHEBA SANGSTHA
c/o Chowdhury Anwar Husain
'Zohura Mansion' Rm. 18
27/1 Mymensingh Rd.
Dhaka-1000, Bangladesh

A SAFE DRINKING WATER PROGRAM

Issue: Contaminated water sources, water diseases, inadequate knowledge of hygiene requirements.

Action: Environmental fair and cultural shows, public speeches, local council cooperation, training in the use of simple methods of water purification.

Outcome: Distribution and planting of tree saplings; managing of nursery beds for summer; increased public awareness.


Global Youth Forum
United Nations Environment Programme

Youth Movement

THE BOY SCOUT AND GIRL GUIDE ASSOCIATION OF JORDAN
Amman, Jordan

TREE PLANTING AND WASTE MANAGEMENT PROGRAMS – The Greater Jordan Campaign and the Plastic Bag Campaign

Issue: The need for more trees in a mostly desert country; improper waste disposal.

Action:

1. All Guides and Scouts nationwide have each planted one tree every year since 1988. Trees are often planted in the desert land which covers 75% of Jordan's surface area.

2. Dead Sea and Red Sea shores have been cleaned, as have national parks. A flower is given to passersby with a card requesting them to dispose of their litter properly. A booklet has been published showing how plastic bags harm animals, are an eyesore and may take years to decompose.

Outcome: Hundreds of thousands of trees have been planted all over the country. Over one million plastic bags have been picked up and much other litter. Environmental awareness has been raised.

Future Plans: Both campaigns will continue until the year 2000. Other projects are also underway e.g. a paper recycling project in which paper is collected from embassies and large corporations. In cooperation with the Ministry of Water and Irrigation, a water preservation project has also commenced.

Environmental Christian Stewardship Group
50 "inner city" children, aged 10-12

THE DOLPHIN DEFENDERS
812 No. Union Blvd.
St. Louis, MO 63108 USA

A GLOBAL WARMING PROGRAM – Operation Chill Out

Issue: Global warming as a result of the excessive release of carbon dioxide.

Action: Reducing energy consumption through use of low watt compact fluorescent and "energy pincher" light bulbs to replace existing bulbs. Recycling aluminum cans (recycling one can per day keeps 140 lbs. of carbon dioxide out of the atmosphere each year), glass bottles and newspapers. Letter writing campaign to Senators supporting legislation regarding car mileage per gallon and signing of global warming petition. Creation of wildlife habitats and bush and tree planting. Newsletter. Reducing energy consumption by keeping air conditioners at 80 degrees F. Walking to destinations up to 5 miles away. Campaign to stop the destruction of ancient forests in northwestern USA.

Outcome: Over 87,000 lbs. of carbon dioxide were kept out of the atmosphere. Awareness raised through media coverage, newsletter and contact with adults.

Future Plans: Developing more inner city wildlife habitats. Maintaining a focus on recycling and the use of compact fluorescent bulbs to save energy. Completing a global warming exhibition display.

School
11 Participants, aged 14-17

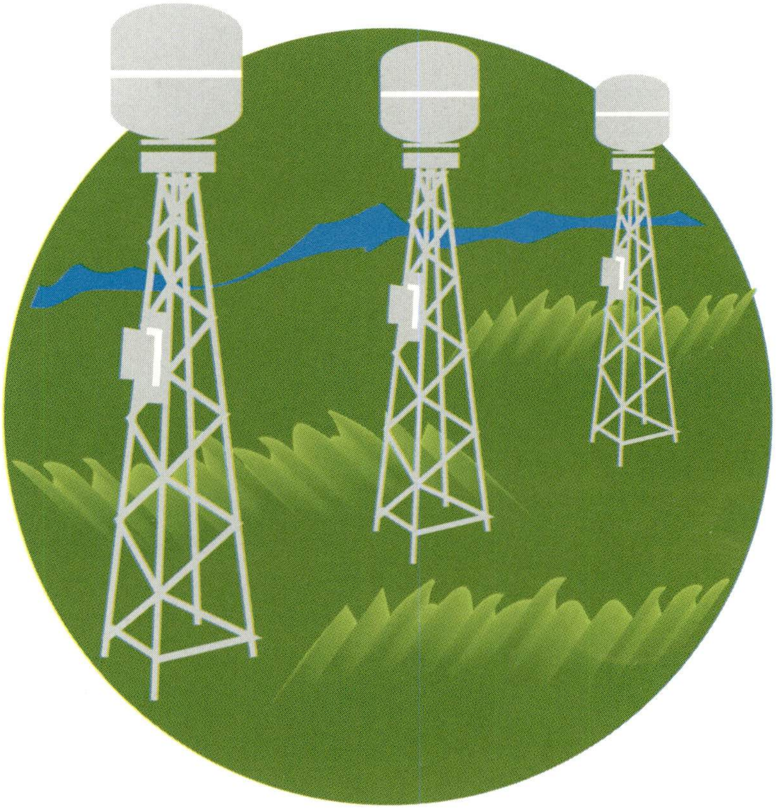
SUNDIAL SCHOOL
Chapeles Voges Street, No. 14
Phillipsburg, St. Maarten
Netherlands, Antilles

A TREE PLANTING PROGAM – Greening of School Premises

Issue: Soil erosion, over-development of land and deforestation.

Action: Planting trees; lectures; group activities and excursions to different locations on the island; media exposure.

Outcome: A number of trees have been planted; the surroundings are more beautiful and attractive; there is more shade.



YOUTH DECLARATIO

It is well-kno

ongoing destruction

has affected children and youth

Like casualties in a war, we are often c

when the water disappears, the first to go

suffer when nature turns her fury on our comm

generation has had a new burden added to the alrea

Politicians and leaders have begun to tell us tha

future, is on our shoulders, that we are the ones who will h

on your part, it is also a frightening burden that we must carr

many more have been frightened into not caring, because carin

ridicule and to the despair that grows out of our nightmare vision

efforts cannot possibly save the planet. As hard as we try, you ca

enthusiasm, but we do not have the tools to carry out our vision.

This fear that we may be defeated before we even begin affects

extinction. We are having to ask ourselves terrifying questions, like "Will th

Will there be a world left to live in?"

Above all, we are afraid of not being heard. If you really believe that

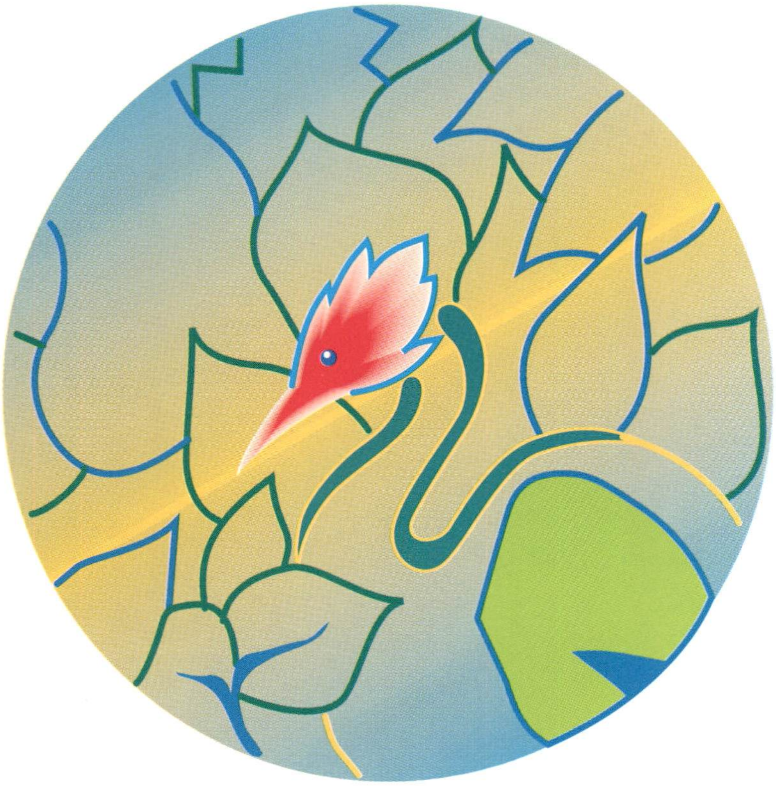
you must take to help us. The United Nations and all its member agencies mus

1. Give youth greater access to the decision-making processes at all levels. If

where we can make that difference. If you are leaving the future to us, then

2. Learn to understand youth. Governments always talk about the vision, th

us. But we're also frightened, confused and very disappointed. Looking arou



N TO EARTH SUMMIT

wn that the
of our environment
more than any other group.
n the frontlines - the first to go thirsty
hungry when famine strikes, the first to
unities. All this is certainly true, but today our
dy heavy load.
t the task of saving the environment, of protecting the
ave to make a difference. Not only is this a delaying tactic
. Many of us are both ready and willing to do our part, but
ng makes us vulnerable. It makes us vulnerable to criticism, to
ns of tomorrow. As long as you control the reins of power, our
nnot expect us to do it alone. We have the energy, we have the

us deeply. Where previous generations feared war or disease, we fear
ere be rainforests around in 20 years? Will there be clean water to drink?

we are the ones who must act to save our future, then there are steps that
t resolve to assist us in the following ways.

f we are really going to make a difference, you must allow us into positions
please leave us the present as well. We can't build one without the other.

e enthusiasm and commitment of youth. And these things are true about
nd the world, most of us do not face a bright future.

YOUTH ORGANIZATION
30 Members, aged 6-15

KIDS FOR SAVING EARTH
213-8 Pushkinskaya St.
Rostov-on-Don 344022
Russia

A WASTE MANAGEMENT PROGRAM – The Dustbin Project

Issue: The struggle for clean city streets.

Action: Raising awareness by contacting TV stations, two newspapers and city administration officials. School children drew pictures and wrote slogans on dustbins (trash cans) around the city.

Outcome: Major city streets become cleaner.

High School SCHOOL
Aged 12 and over

LAUREL SPRINGS HIGH
P.O. Box 1440
Ojai, California 93024
USA

AN ENVIRONMENT EDUCATION AND AWARENESS-RAISING PROGRAM – Laurel Springs Environmental Project

Issue: The need for greater awareness of environmental problems and issues and increased commitment to help preserve the planet.

Action: Produced videos "We Can Make a Difference" and "One Small Wish for This Earth" which were presented to many nearby public schools and featured songs written, arranged and sung by students. "Environmental Race" workshop. Encouraged participation in the "Earth Treaty Process" in which children write a letter to mother Earth outlining their hopes and fears, and a promise of all the things they will do to help save the earth. Participation in the World Women's Congress for a Healthy Planet. Media coverage.

Outcome: Greatly increased awareness of environmental issues and concerns which has motivated many people to initiate recycling, conversation and other projects or activities.

Future Plans: Preparing a new video focusing on the need for people to live life in harmony with nature and showing the importance of Earth ethics. Discussion with the Disney channel about three-minute "We Can Make a Difference" segments edited and hosted by children and aired daily on the Disney channel.

Individual
Aged 14

CHRISTIAN MILLER
1, Leaman Lane
Palm Beach, Florida 33480
USA

A TURTLE PERSERVATION PROGRAM – "Kids Can Save Sea Turtles"

Issue: Many endangered species-listed sea turtle hatchlings die each day and need protection/guarding from animal and human predators and poachers.

Action: First, Christian underwent training and then obtained a Florida Department of Natural Resources Permit. After a giant sea turtle has lumbered up on to the beach and laid its batch of 100 to 150 eggs, Christian marks the nest, watches and guards it; later the number of eggs, and other data are recorded. After hatching, any baby turtles that are trapped in the nest are released into the sea before they die from heat or attacks by predators such as raccoons, dogs, or crabs. Christian started this project when eight years old and is now fourteen.

Outcome: The date over 12,000 baby sea turtles have been saved. Research studies have been carried out and data and reports are regularly provided to the Department of Natural Resources. Christian has received a number of honorable mentions and awards and has been featured extensively in the local media.

Youth Movement/ Networking Agency
Youth aged 12-30

SOUTH AFRICAN YOUTH COORDINATION ON DEVELOPMENT AND ENVIRONMENT (SAYCODE)
P.O. BOX 67067
South Africa
Netherlands, Antilles

A PROGRAM TO CREATE A NETWORK OF YOUTH INVOLVED IN THE ENVIRONMENT – Claystomping Network

Issue: Lack of unity and friendship amongst youth involved in the environmental activities.

Action: Creation of a Networking agency and adoption of claystomping as a means for getting youth together in a fun and non-threatening way. Youth mix dry clay and water with their feet and form tiles which are used to create a mural as a symbol of goodwill amongst its creators.

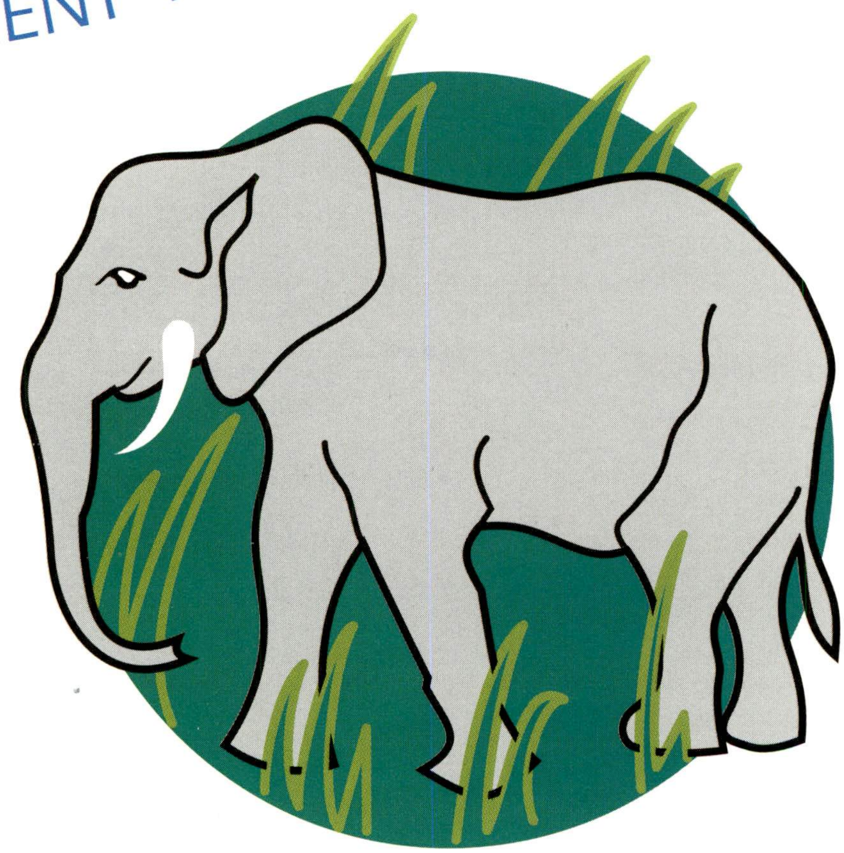
Outcome: This simple and inexpensive project is within the capacity of nearly everyone and can help create peace and unity; clay is a universal substance that goes beyond borders or boundaries.

icting our planet will require new and often disturbing solutions. Don't be
nope for progress, and less for survival. Far-reaching problems like global
lutions. All your decisions must endure the test of time and embrace the
centuries from now.

effective organizations. Don't work against us, work with us. When you
uided by the principle that "By youth, for youth" will build the strongest
not by us, and it therefore cannot be for us.

el today. They must not feel that their lives and their futures are controlled
mpower the disempowered. We must pay special attention to the needs
f our nations, as well as to those of youth.
history, but to move beyond the past, as well. The United Nations
repeat the decisions and mistakes of the past. 1992 must not be
oint where we can embrace our Southern neighbors in new
. We hope that the South will be able to learn from the
the governments of the world come to recognize youth as
ur fullest potential.
progress. We are frightened by our responsibilities in
oth in solving the problems and in convincing our
owever. Such a course of action will be difficult
It is, however, a challenge worth the effort.
and are more than willing to help out
That you won't join us in facing
t fear. That you will is our
hope.

AL YOUTH FORUM PARTICIPANTS
RONMENT PROGRAMME

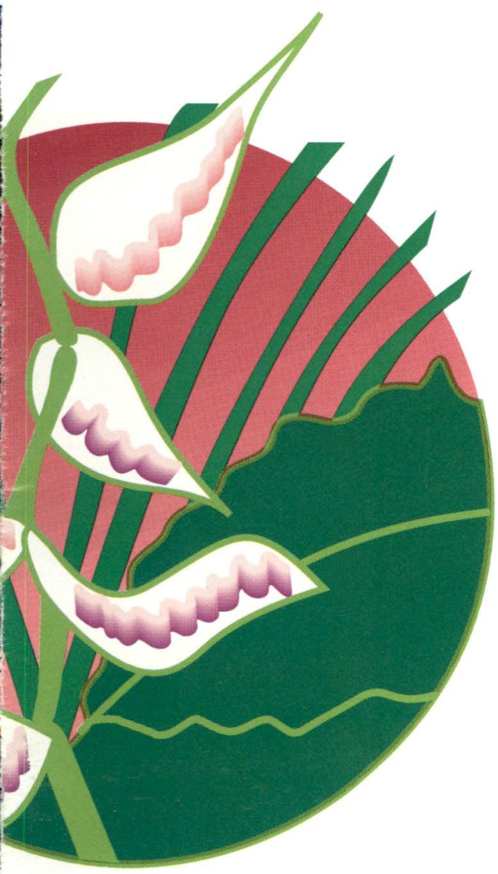


GLOBAL Y

MAY 14 - 15,

3. Be prepared to make real change in the world. The disturbing events affi
afraid to make those difficult decisions. Without them, there can be little h
warming, ozone depletion and the debt crisis cannot be solved by small so
lessons of history. Build a world that we'll be happy to live in decades or even

4. Respect our own structures. As youth, we have built many large and e
establish new projects, you often undermine our old ones. Always be gu
partnerships. If we do not have a controlling voice in an organization, it is



It is our great hope that future generations will be spared the fear that we fe
by the slips of paper that cross your desks. We must all work together to e
and rights of women, the poor, the landless, and the indigenous peoples o
We have many other hopes. We hope to learn the lessons of
Conference on Environment and Development in Brazil should not
1972. We hope the nations of the North will mature to the p
attempts to link our environment and development concerns
mistakes of the North, and not repeat them. We hope that
the greatest of renewable resources, helping us to reach o
As youth, we commit ourselves to change and
dealing with these issues, but we will do our best, b
peers to help us. We expect no less from you, ho
to follow. No one knows this better than us.
Today's youth recognize that challenge,
in our common efforts for change.
this challenge is our greates
greatest

WRITTEN AND RATIFIED BY GLOB
UNITED NATIONS ENVIR

High School
Students aged 11-17

BROMLEY HIGH SCHOOL
Blackbrook Lane, Bickley
Bromley, Kent, BR1 2TW
England

A WASTE MANAGEMENT AND TREE PLANTING PROGRAM

Issue: Irresponsible waste disposal, environmental neglect and abuse.

Action: Neglected area was cleared of hazardous substances, rusty cans, glass, polystyrene and an abandoned motorbike. Ascertained who was responsible for this improper waste disposal and agreed to more suitable alternative means of disposal, e.g. recycling of cans. Established habitat "corridor" between park land and school, and planted hedges and trees. Sponsorship obtained for local supermarkets.

Outcome: School grounds enhanced and environment club committed to on-going planting and watering of trees and maintenance of weed-free area. Long-term field studies possibility established.

School
560 Children aged 4-14

VROOM LEARNING CENTER
18 WEST 26th Street
Bayonne, N.J. 07002
USA

ADOPT-A-PARK PROGRAM – A Reforestation and Park Ecosystem Maintenance Project

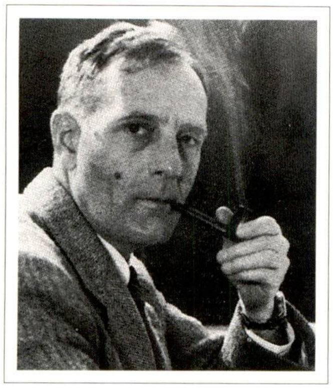
Issue: The need to reforest and recondition a neglected 100 acre urban park, encourage greater stewardship and overall global environmental concern.

Action: Each child is assigned a 50' x 50' plot of land, plants a tree on it every spring and maintains an ecological stewardship of it for 10 years. Fifteen sponsors are recruited by every child to support that stewardship and are encouraged to lobby government officials to support environmental issues.

Outcome: Over 3,000 trees have been planted and the park has been beautified. The school has earned the National Arbor Day Project Award and President Bush's Take Pride in America Award. Youth have gained a sense of stewardship and an advocacy/lobbying group has been established.

HUBBLE SPACE TELESCOPE

UPDATE: 18 Months in Orbit



"From our home on the Earth, we look out into the distances and strive to imagine the sort of world into which we are born. Today we have reached far out into space. Our immediate neighborhood we know rather intimately. But with increasing distance our knowledge fades rapidly, until at the last dim horizon we search among ghostly errors of observations for landmarks that are scarcely more substantial.

The search will continue. The urge is older than history. It is not satisfied and it will not be suppressed."

—Edwin P. Hubble
(1889-1953)

HUBBLE SPACE TELESCOPE

In April 1990, Space Shuttle *Discovery* launched Hubble Space Telescope — perhaps the most ambitious scientific mission NASA has ever undertaken.

Then, in June 1990, came the disappointing news of spherical aberration in the HST primary mirror. Many concluded prematurely that the project had no future.

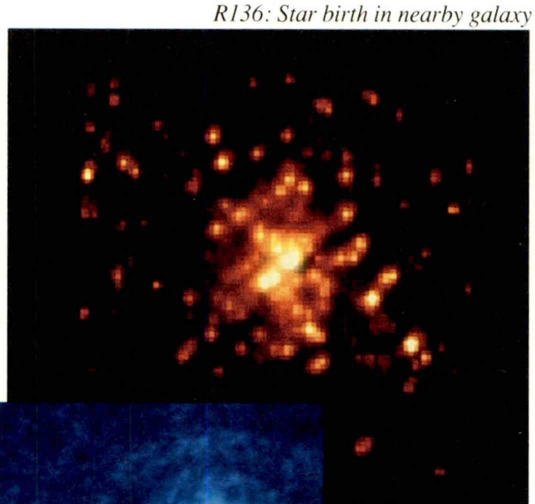
But now, after 18 months in orbit, HST is in routine operation and has surprised its early critics by producing results at the forefront of science. Regular Shuttle servicing missions should permit the telescope to achieve its original scientific goals over a planned 15-year observing lifetime.

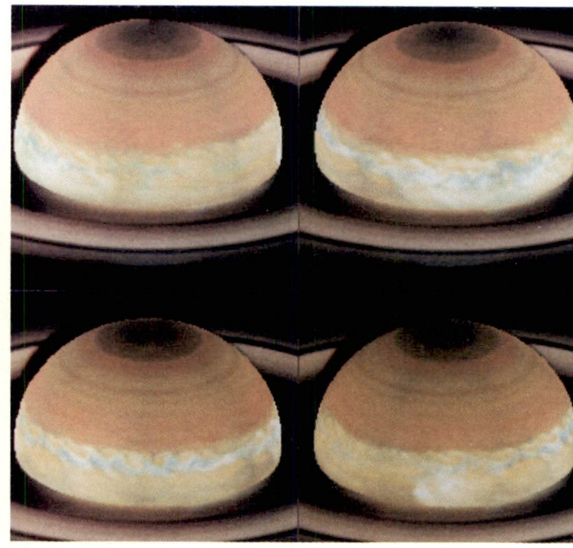
UPDATE: 18 Months in Orbit

CONTENTS

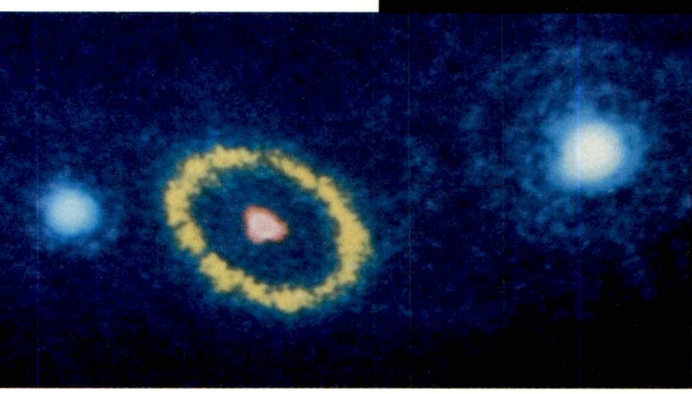
The First 18 Months

R136: Star birth in nearby galaxy



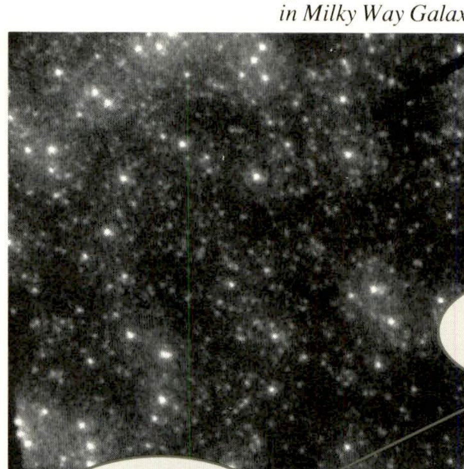


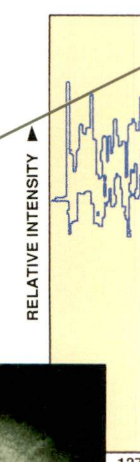
Saturn: Planet-wide atmospheric storm

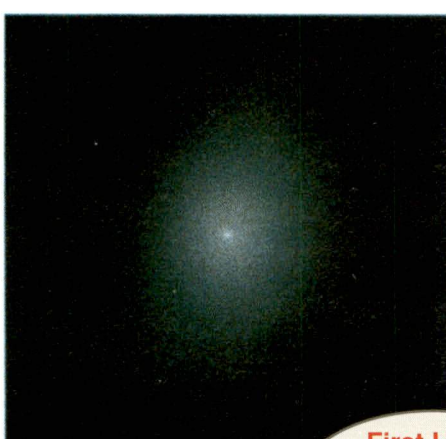


Supernova 1987A: Exploding star in the Large Magellanic Cloud, a nearby galaxy

M14: Old globular star cluster in Milky Way Galaxy







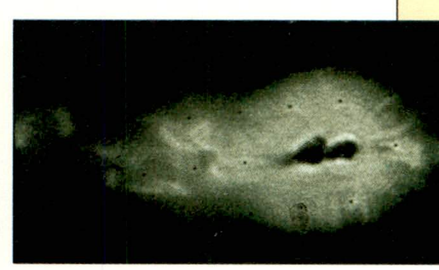
NGC 7457: Distant galaxy with black-hole candidate at center

Imaging Begins

First Light: European Faint Object Camera

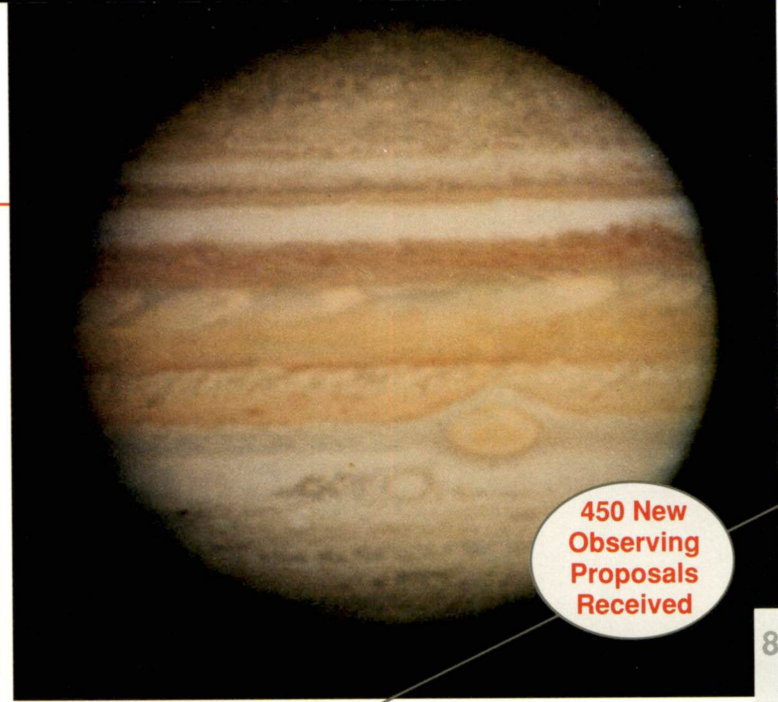
First Light: Wide Field/ Planetary Camera

Einstein Cross: Quasar quadruply imaged by gravitational-lens galaxy (center)

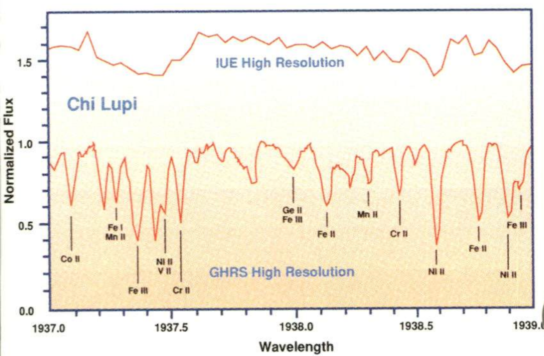


R Aquarii: Matter ejected from young, evolving star

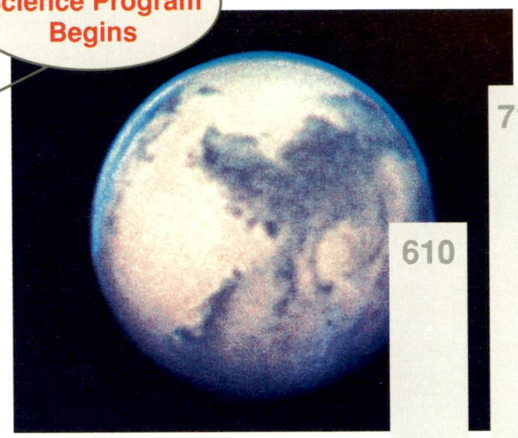
1990 APRIL JUNE AUGUST OCTOBER



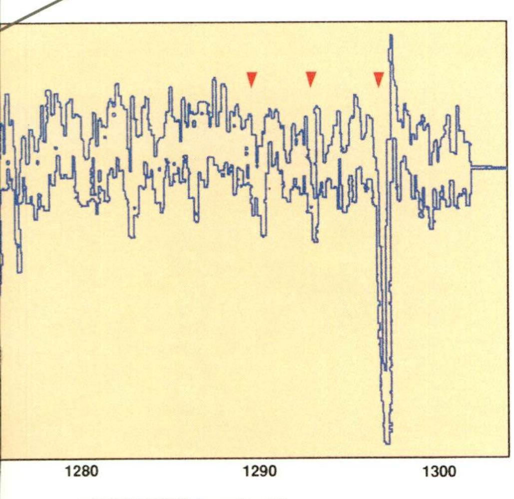
Jupiter: Atmospheric circulation patterns



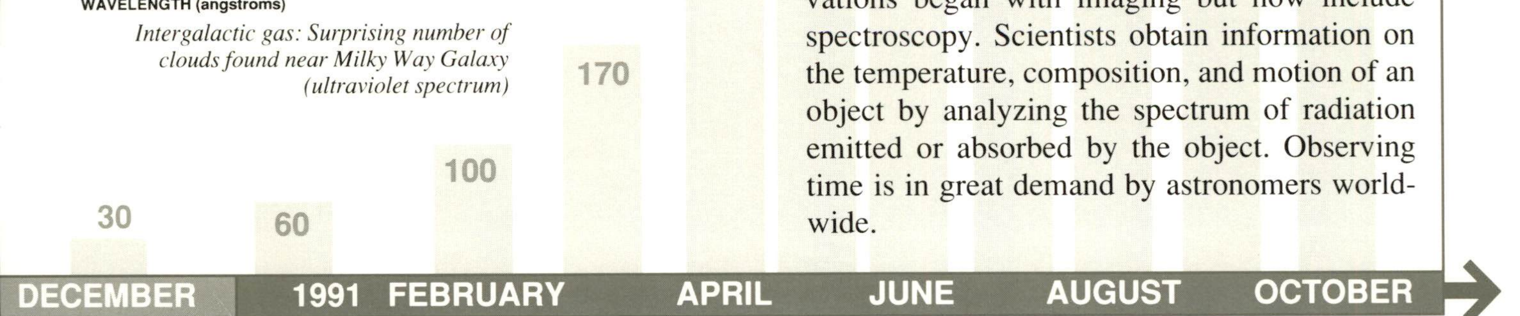
Chi Lupi: Chemistry of stellar atmosphere (ultraviolet spectrum)



Mars: Finest surface detail ever seen from vicinity of Earth

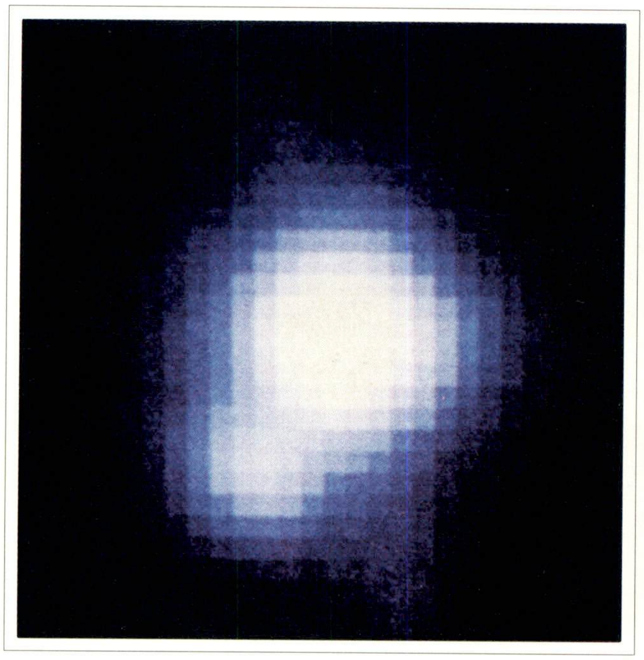


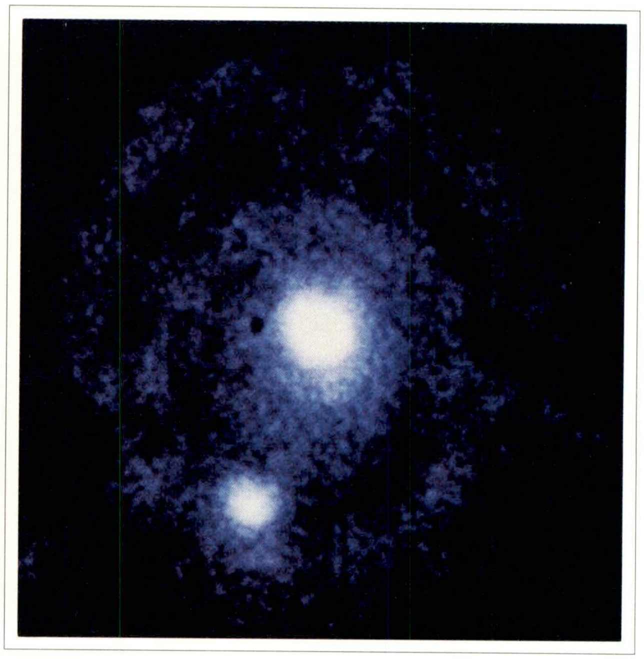
Intergalactic gas: Surprising number of clouds found near Milky Way Galaxy (ultraviolet spectrum)



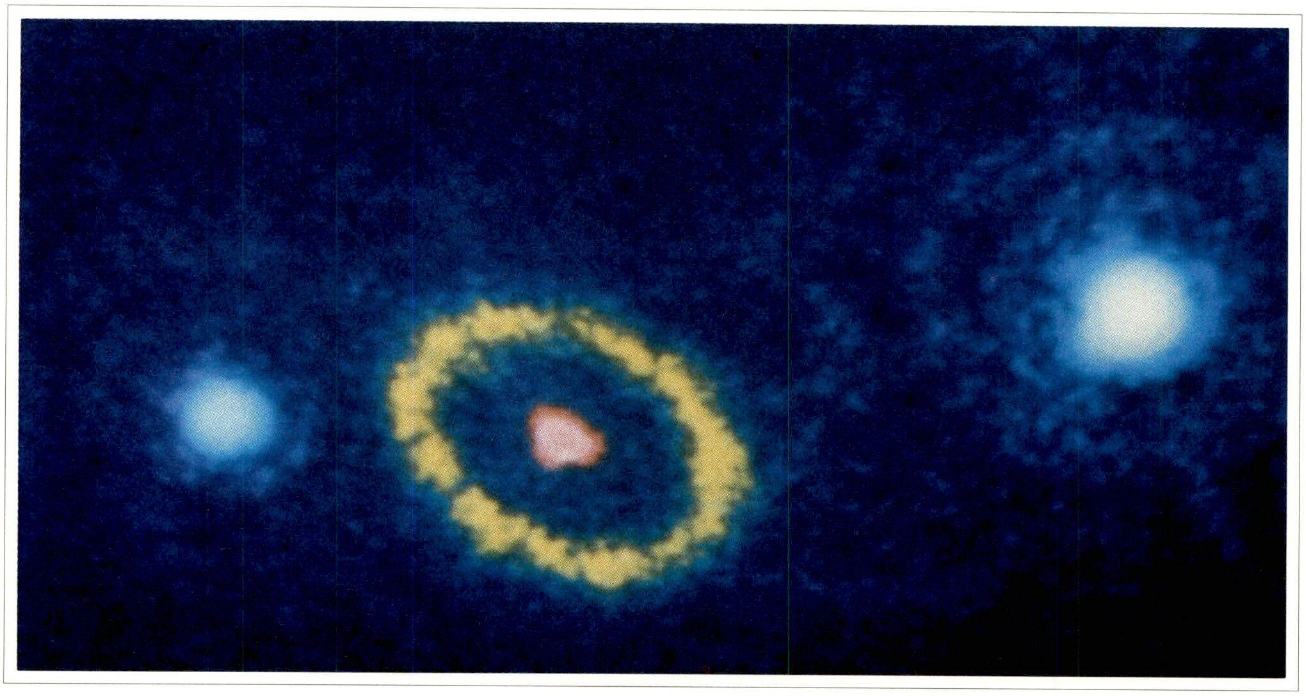
More than 1,900 observations of nearly 900 astronomical objects have already been carried out by HST. Observations began with imaging but now include spectroscopy. Scientists obtain information on the temperature, composition, and motion of an object by analyzing the spectrum of radiation emitted or absorbed by the object. Observing time is in great demand by astronomers worldwide.

"I Thought It Was Broken"





Pluto and its close satellite Charon, barely distinguishable as separate bodies in a ground-based image (left), are clearly separated in the HST image (right). Because Charon is half the size of Pluto, this system is often called the "double planet."



Ring of gas around Supernova 1987A, shown in this HST image, was ejected many thousands of years prior to the blast. In combination with spectroscopy by NASA's International Ultraviolet Explorer satellite, HST measurements of the ring's angular size yielded the distance to the supernova.

Q: What's the real story with HST? I thought it was broken.

A: Hubble Space Telescope is the most capable optical telescope available to astronomers today, despite the mirror problem. It is producing images and spectral observations that place HST programs at the forefront of astronomy.

Q: How is that possible?

A: First of all, HST has greater clarity of view than any ground-based optical observatory, both because of the substantial light-gathering power of its 94-inch mirror and because of its location in space above the distorting effects of Earth's atmosphere. In addition, its location in space permits HST to observe ultraviolet radiation that does not penetrate the atmosphere.

Q: But what about the mirror problem?

A: Because the mirror was so perfectly polished — albeit to a slightly incorrect shape — the effects of the spherical aberration can often be removed by computer processing. Many processed images reveal breathtaking detail never before seen from the ground.

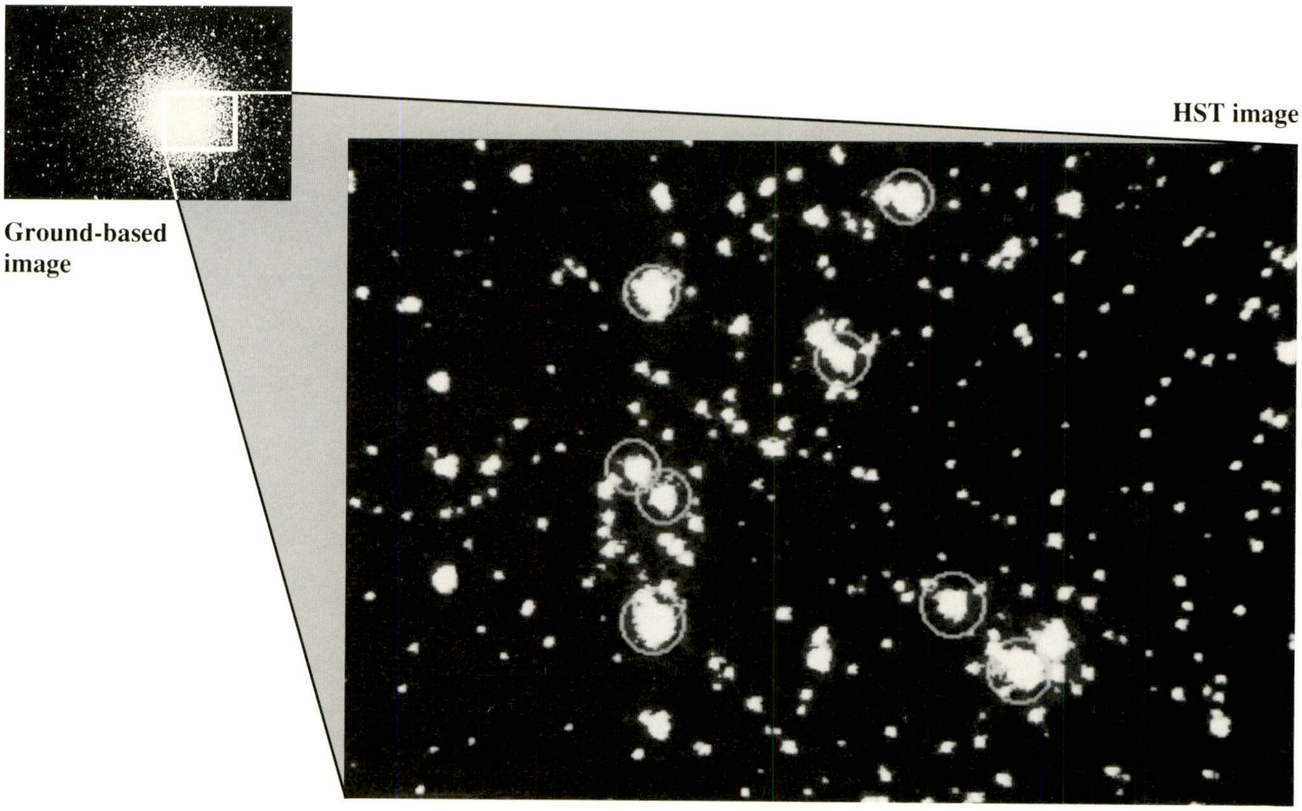
Q: What is the long-range future of Hubble Space Telescope?

A: Bright. Through Shuttle servicing missions, which were planned from the beginning, we can achieve the capabilities intended for HST early in the observatory's 15-year mission lifetime. Over this period, HST should be able to achieve its original scientific objectives.

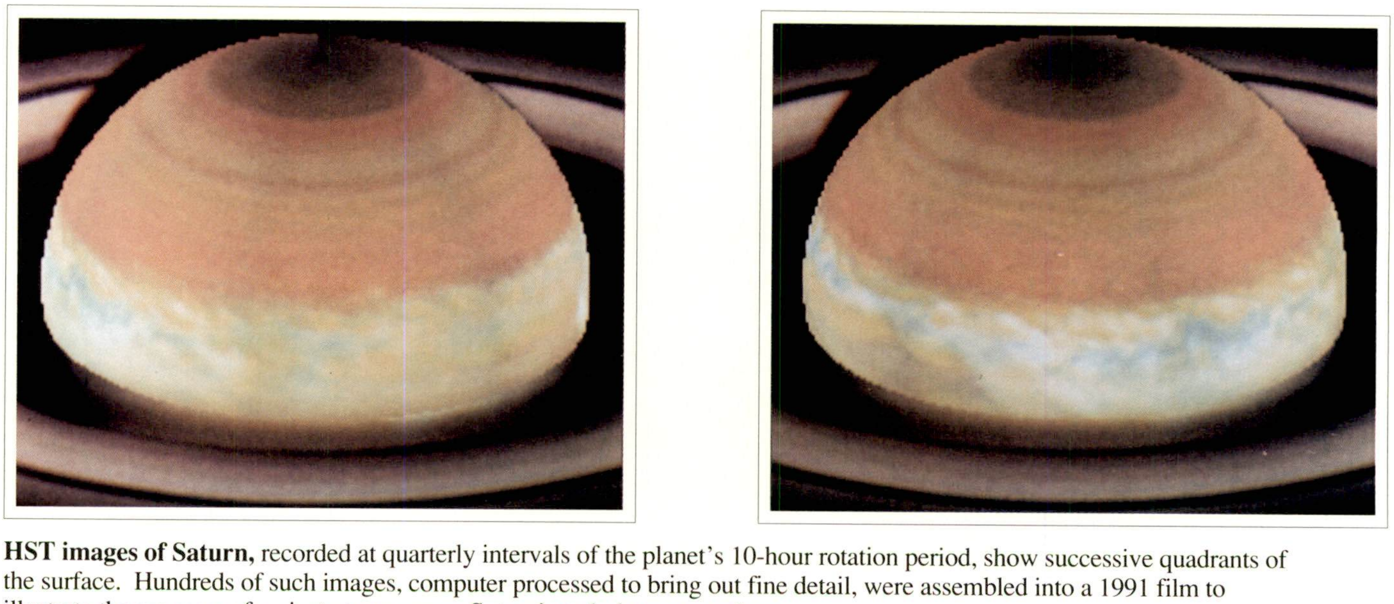
In Fact,

Hubble Space Telescope is the most powerful optical telescope in the world today: it offers unmatched ability to image fine detail and to study ultraviolet radiation from astronomical objects.

Achievements Amid Challenges



Star Regeneration in 47 Tucanae. In the cores of old globular clusters like 47 Tucanae, thousands of stars are crowded into a region less than one light-year across. Could these ancient stars ever be regenerated by stellar mergers or collisions? Ground-based telescopes have not been able to answer this question; their images of such cluster cores (top left) are smeared out by atmospheric turbulence. But in the core of 47 Tucanae, HST's clear view from space (above) has revealed dozens of hot blue luminous stars radiating away energy so rapidly that they cannot have survived since the birth of the cluster itself. These observations provide the first convincing evidence of recent star regeneration in old clusters.



HST images of Saturn, recorded at quarterly intervals of the planet's 10-hour rotation period, show successive quadrants of the surface. Hundreds of such images, computer processed to bring out fine detail, were assembled into a 1991 film to illustrate the progress of a giant storm across Saturn's turbulent atmosphere.

Q: Have you had to meet other challenges, besides the mirror?

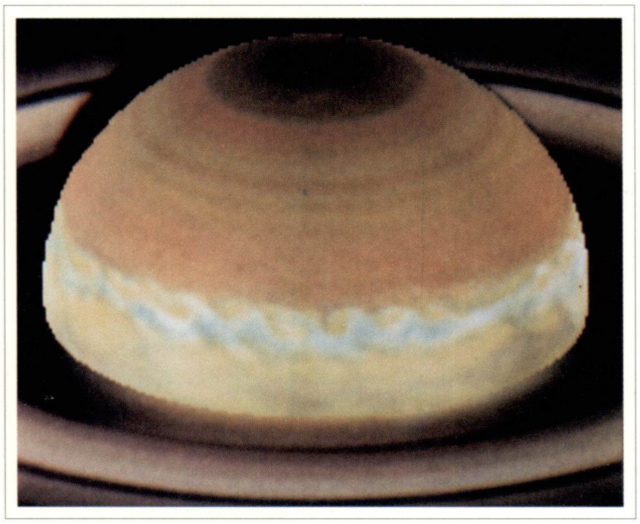
A: Yes — which is not surprising for a complex system with 400,000 different parts. For example, the solar-power arrays supplied by the European Space Agency make HST "jitter", or shake, every time the spacecraft orbits into and out of daylight. But we have fixed most of the problem by writing special computer programs for the HST pointing system.

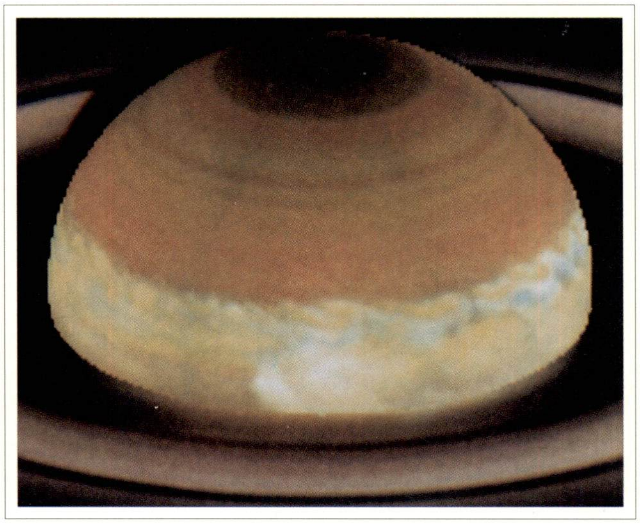
Q: Is HST especially vulnerable to malfunctions?

A: Quite the opposite. HST, as well as being serviceable in space, was designed to provide high redundancy and extensive backup capabilities. For example, two gyroscopes used for pointing control have stopped functioning; but we've activated two spare gyros to continue normal operation, and another spare is still available. Overall, very few of HST's reserve capabilities have been needed so far.

Q: So the capability for forefront science remains high?

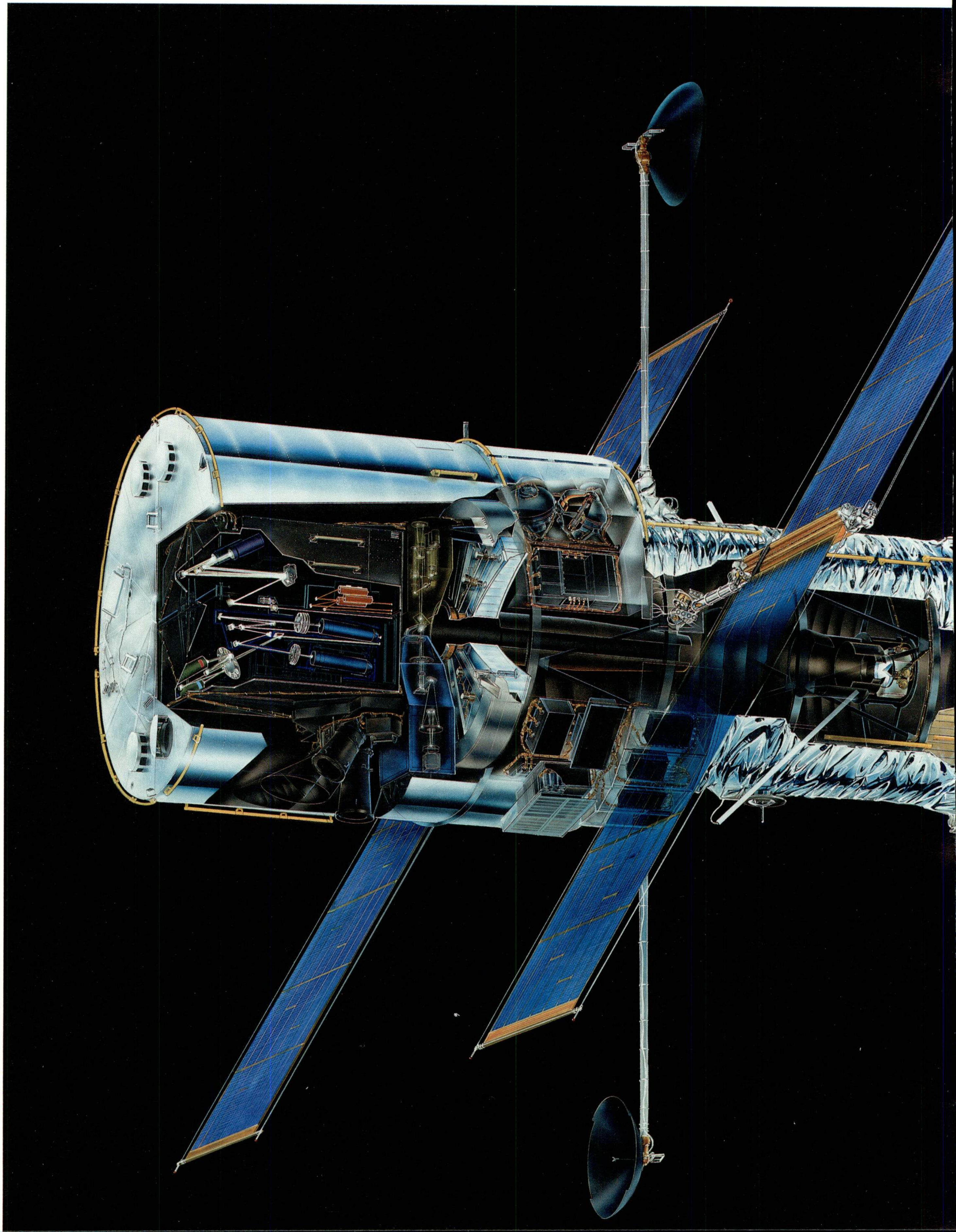
A: Yes. Consider scientific papers presented at the January 1992 meeting of the American Astronomical Society. Of the papers reporting space science observations — which represented 25 percent of all the observational papers — one out of four described HST results. And demand for observing time remains strong. In 1991, some 450 scientific groups submitted new proposals to use the telescope.





The storm was revealed in September 1990 by ground-based observations. The HST observing schedule was quickly modified to permit HST to track the disturbance, which by November had spread to cover most of the planet. The white areas in these images are believed to be immense clouds of ammonia ice crystals, lofted to high altitudes by violent winds.

Breakthroughs In Technology



Hubble Space Telescope, the creation of ten thousand people over two decades of inspired effort, is by far the most complex and advanced space observatory ever built. The HST project team produced major technological breakthroughs in order to meet the most demanding observing requirements in space-science history.

Support Structure:

Constructed of lightweight, low-expansion, hand-formed graphite-epoxy tubes, the structure holds HST optical components aligned within 1/10,000 of an inch during two abrupt temperature changes every 96 minutes as HST orbits into and out of sunlight.

Pointing Control System:

The most accurate ever devised for astronomy, incorporating unique, high-spin-rate gyroscopes shielded against vibration and electromagnetic disturbances caused by space radiation and solar flares — reduces pointing instability to an angle less than the width of a dime seen 200 miles away.

Ultraviolet Performance:

The ultraviolet optical system is the most capable ever launched for astronomical observations in this region of the electromagnetic spectrum. It has reflecting surfaces of unprecedented cleanliness and smoothness to maximize the amount of ultraviolet radiation available for imaging and spectroscopic analysis.

Serviceability:

This is the first NASA space mission designed for regular Space Shuttle maintenance and upgrading over a planned 15-year mission lifetime. Forty-nine types of key components, including gyroscopes, are accessible and readily replaceable on orbit to maintain and expand HST capabilities.

Current Capabilities

Q: What was HST designed to do?

A: HST was designed to provide three capabilities:

1. High angular resolution — the ability to image fine detail;
2. Ultraviolet performance — the ability to produce ultraviolet images and spectra; and
3. High sensitivity — the ability to detect very faint objects.

Q: What can HST currently do?

A: HST currently provides the first two capabilities. First of all, for the brighter sources:

1. Computer processing can be used to bring out much finer image detail than can be provided by ground-based telescopes. In addition,
2. Ultraviolet spectroscopy has been exceptionally productive, helping astronomers to understand the composition and dynamics of objects in our Galaxy and to map the distribution of intergalactic gas clouds.

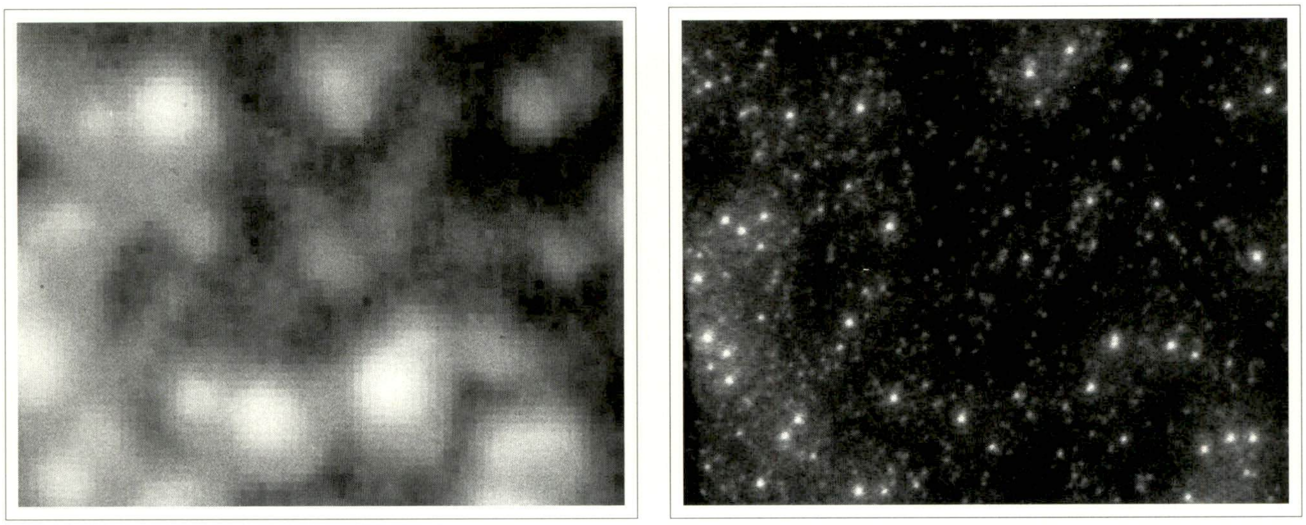
Q: How will you be able to study faint objects?

A: Computer processing can't be used for very faint objects — too much light is scattered by the aberration to permit reliable image reconstruction. But,

3. Corrective optics, to be provided by the first Shuttle servicing mission, will bring this scattered light back into focus, allowing HST to achieve its original design goal and reach very distant stars and galaxies.

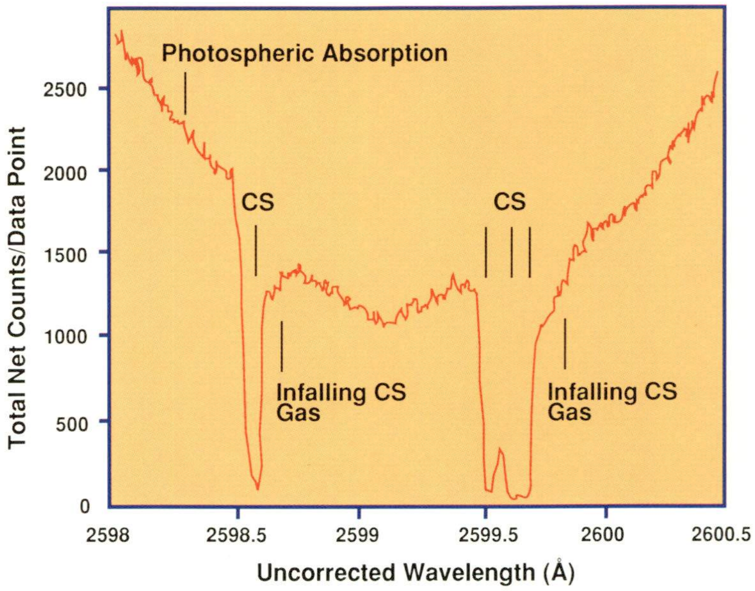
Capabilities Checklist:

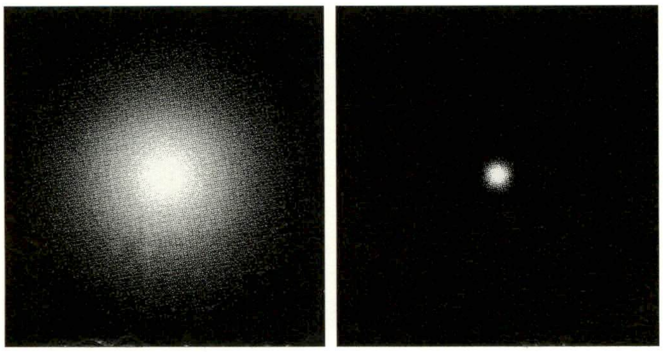
- [x] **High angular resolution — ability to image fine detail.**
- [x] **Ultraviolet performance — imaging and spectroscopy.**
- [x] **High sensitivity — ability to detect very faint objects (after first servicing mission).**



High angular resolution of HST is illustrated by comparison of a ground-based image of the globular cluster M14 (left) and an image recorded by HST (right) after computer processing. The ground-based image is heavily blurred by atmospheric turbulence and cannot reveal individual stars in the cluster center.

Ultraviolet spectroscopy of the star Beta Pictoris by HST reveals streams of circumstellar gas (CS) falling into the star. From earlier optical and infrared observations, Beta Pictoris is known to be surrounded by an orbiting disk of matter that may be a planetary system in the process of formation. The HST ultraviolet observations probe the central regions of the system and provide new insights into its dynamics.





High sensitivity will be achieved through correction of spherical aberration by the first Shuttle servicing mission. The current HST image of a star (illustrated schematically at left) is broadened by the effect of the aberration. The corrected stellar image (illustrated schematically at right) will meet the HST design goal by concentrating 60 to 70 percent of the light within a small region near the image center, enabling HST to study much fainter objects.

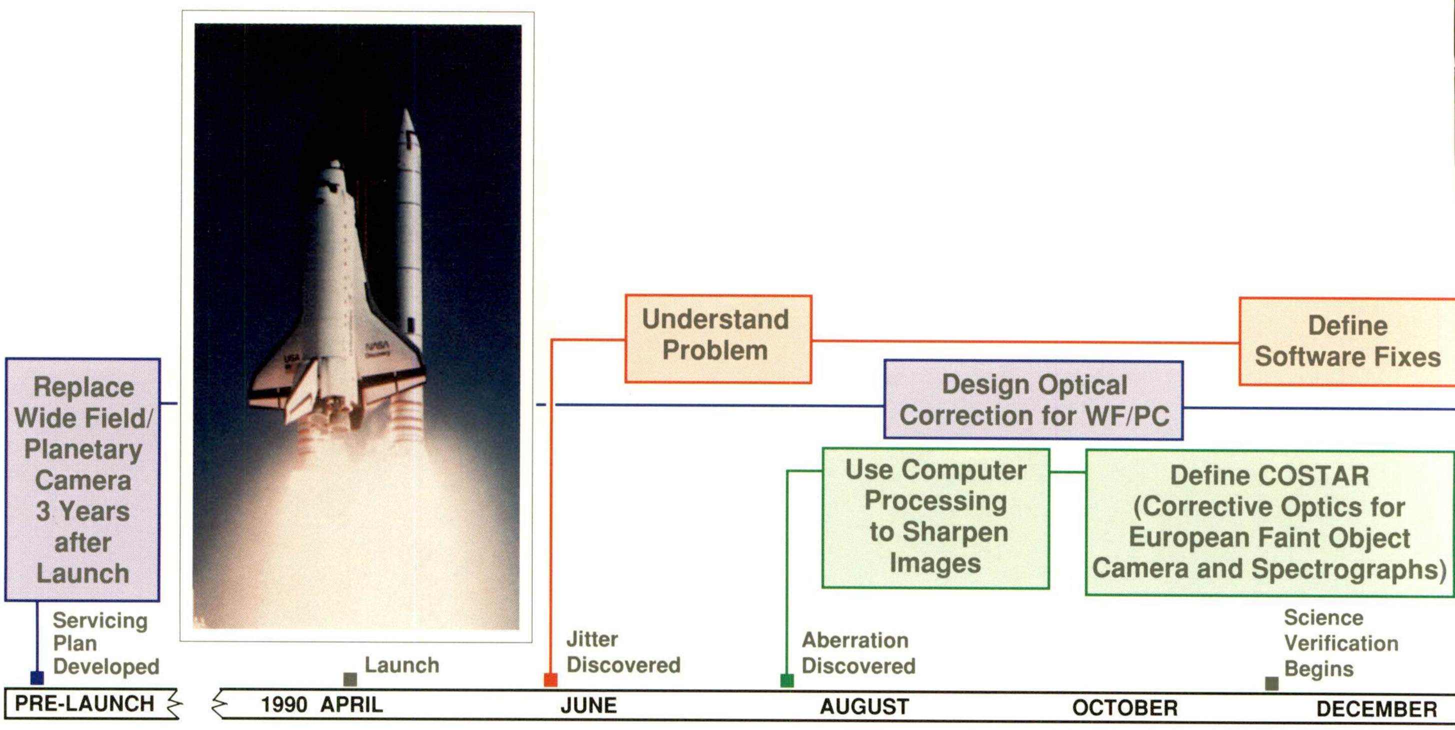
Servicing Plan

Q: How does Shuttle servicing fit into your plans?

A: HST is designed to be serviced by Space Shuttle crews. It has 49 different types of key components readily replaceable in space, and 74 replacement parts are available right now. We have always planned servicing missions, at roughly 3-year intervals, to maintain HST's operational capability and to upgrade its scientific performance as new technologies become available.

Q: What will you do on the first mission?

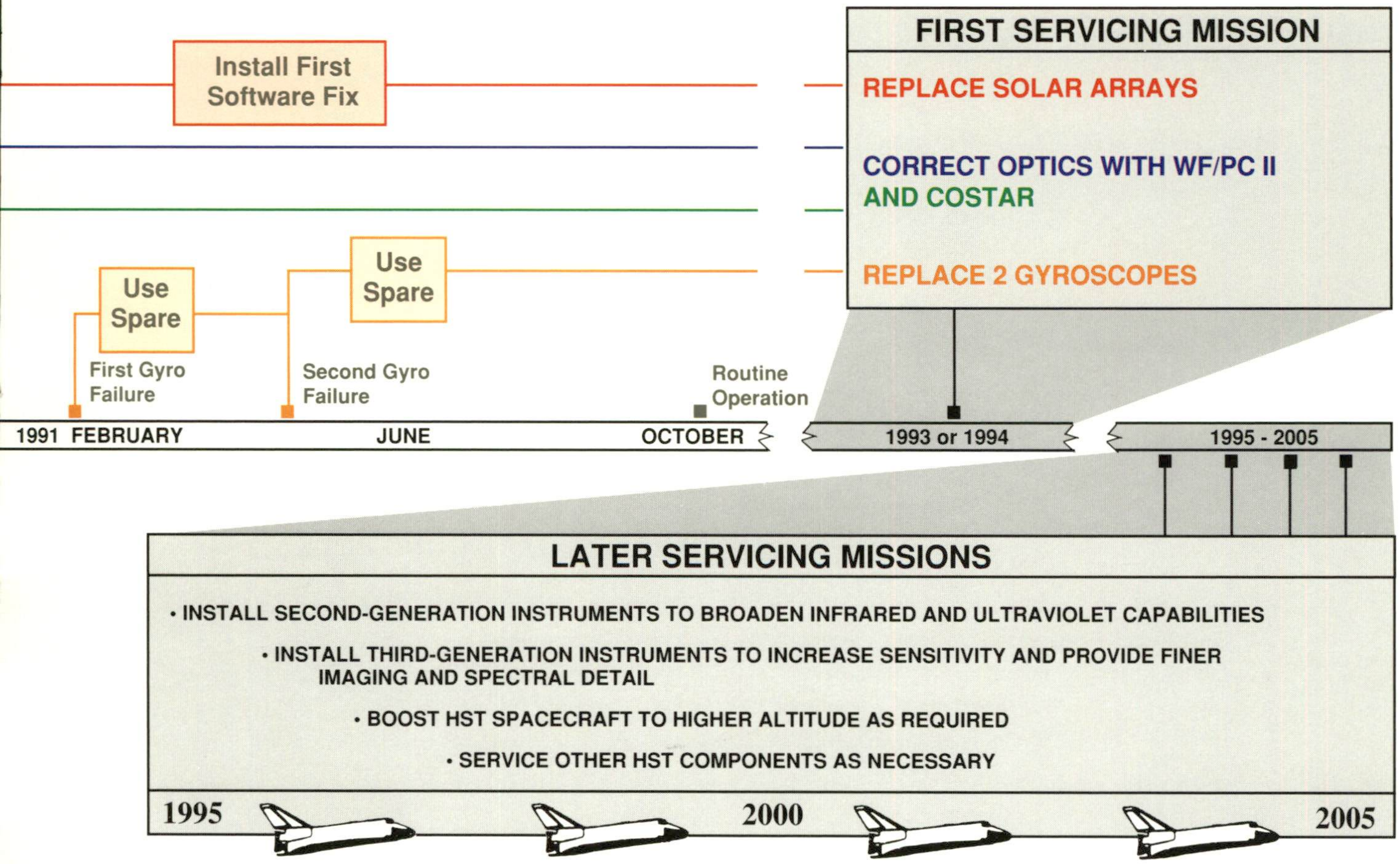
A: Our current baseline planning calls for replacement of the solar arrays, correction of the spherical aberration, and replacement of other components as necessary — for example, gyroscopes — in late 1993 or early 1994.



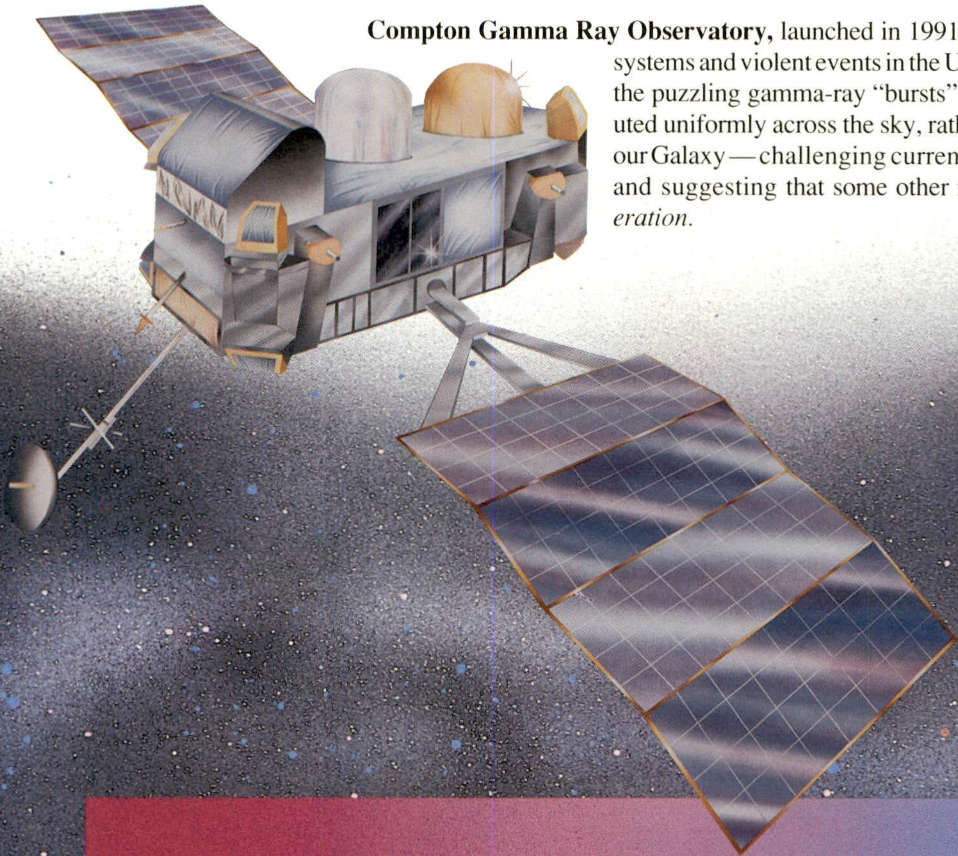
Q: And on later missions?

A: We'll replace remaining first-generation instruments, which represent earlier technology, with much more advanced second- and third-generation instruments to provide even greater capability, particularly for ultraviolet and infrared observations.

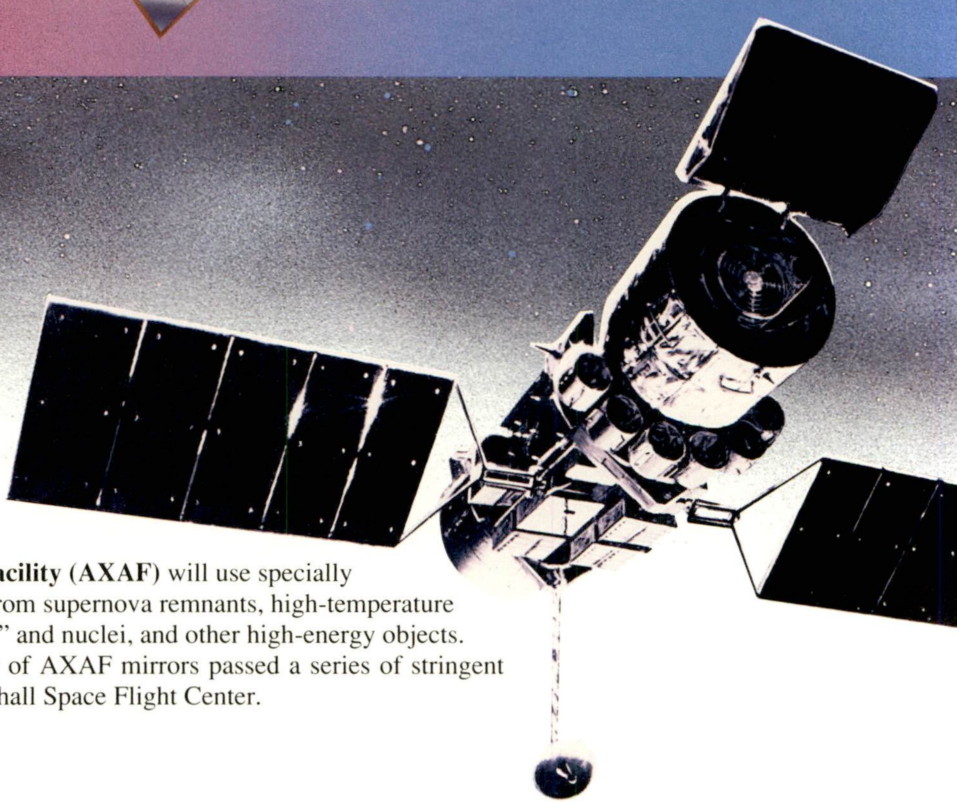
Wide Field/Planetary Camera, workhorse of the HST observing program, will be replaced by an optically corrected camera by astronauts on the first Shuttle servicing mission in late 1993 or early 1994.



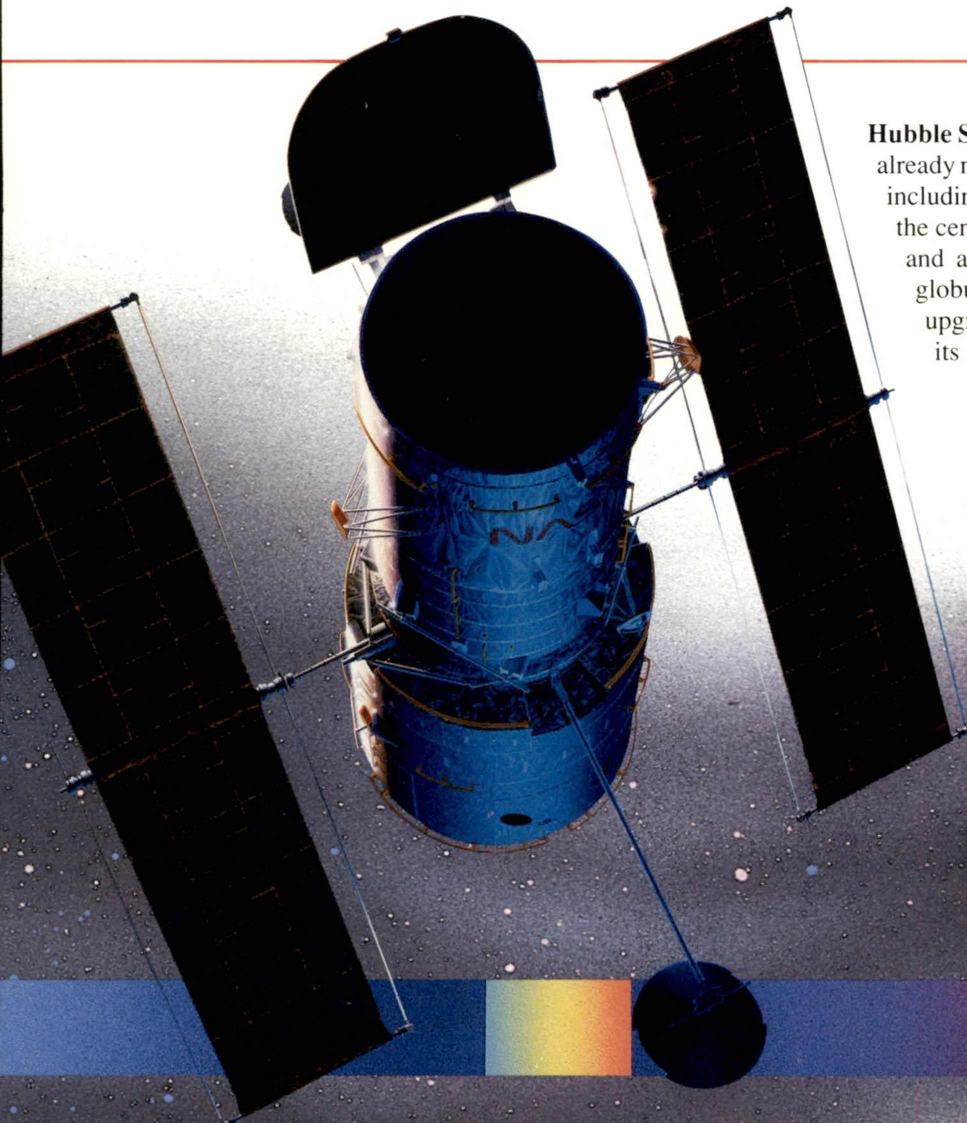
The Great Observatories



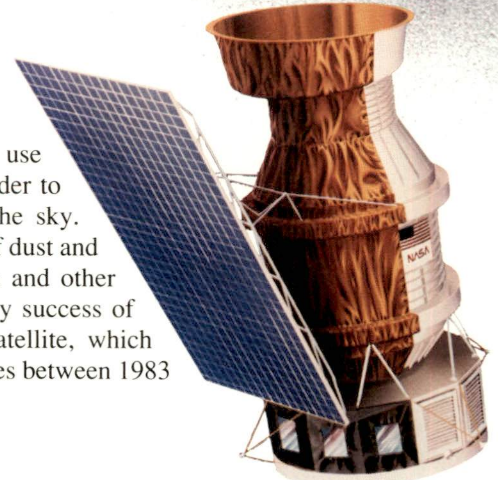
Compton Gamma Ray Observatory, launched in 1991, is now investigating the most energetic systems and violent events in the Universe. Compton has already shown that the puzzling gamma-ray "bursts" observed by earlier satellites are distributed uniformly across the sky, rather than concentrated toward the plane of our Galaxy—challenging current theories of burst origin in neutron stars and suggesting that some other mechanism must be responsible. *In operation.*



Advanced X-Ray Astrophysics Facility (AXAF) will use specially designed mirrors to image X rays from supernova remnants, high-temperature stellar atmospheres, galactic "halos" and nuclei, and other high-energy objects. In September 1991, the initial pair of AXAF mirrors passed a series of stringent performance tests at NASA's Marshall Space Flight Center. *In development.*



Hubble Space Telescope (HST), launched in 1990, is already making discoveries at the forefront of science, including clouds of high-velocity gas spiraling into the center of an accretion disk around Beta Pictoris and a stellar "fountain of youth" in the ancient globular cluster 47 Tucanae. HST will receive upgrades through Shuttle servicing missions over its 15-year mission lifetime. *In operation.*



Space Infrared Telescope Facility (SIRTF) will use optics cooled to extremely low temperatures in order to detect millions of faint infrared sources across the sky. Particular targets include the dense, warm clouds of dust and gas that pervade star-forming regions in our own and other galaxies. SIRTF will build upon the extraordinary success of NASA's Explorer-class Infrared Astronomical Satellite, which carried out the first all-sky survey of infrared sources between 1983 and 1985. *Technology under development.*

Space Telescope
Neil Boyle
NASA Art Program

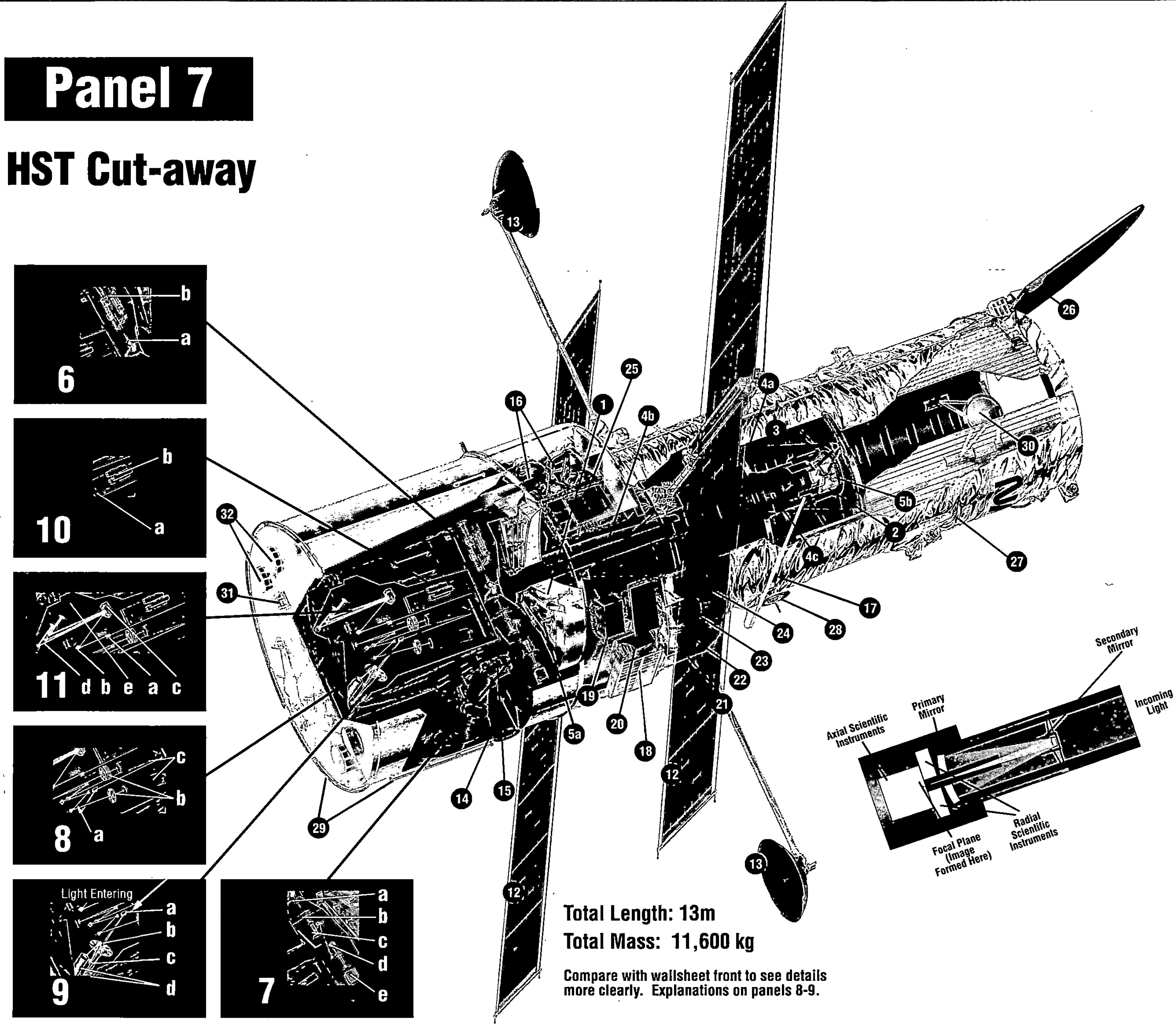
National
Aeronautics and
Space
Administration

Illustration by George Ladas

WED-101:11/91

Panel 7

HST Cut-away



Total Length: 13m

Total Mass: 11,600 kg

Compare with wallsheet front to see details more clearly. Explanations on panels 8-9.

Panel 8

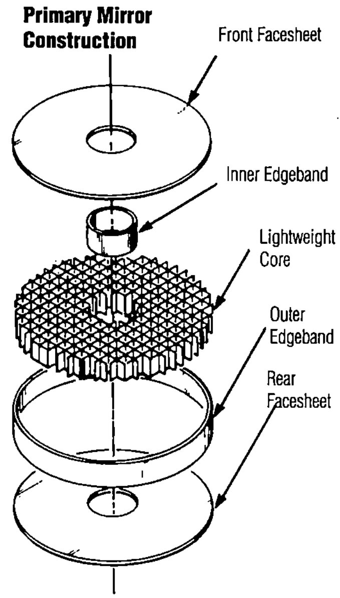
Key to Detailed Cutaway

HST is a high-quality telescope with scientific instruments — the *Optical Telescope Assembly* (OTA) — housed inside of a spacecraft, or *Support Systems Module* (SSM). Numbers below go with labels on panel 7. Colors, where indicated, refer to the full-color diagram on the front of the wallsheet.

The Telescope

Light entering the telescope first strikes the *primary* mirror, from which it is reflected toward the smaller, *secondary* mirror. The secondary reflects the light back through a hole in the center of the primary, allowing the light to reach the scientific instruments. This basic telescope design is called *Cassegrain*, after its 17th century inventor; HST uses the *Ritchey-Chrétien* modification of Cassegrain's design, in which hyperboloid-shaped mirrors are used to improve the optical performance.

1. Primary mirror: 2.4-meter diameter, with a 60-cm central hole. Shape is a concave hyperboloid. Ultra-low-expansion glass, kept at nearly constant temperature (21°C), prevents thermal warping. Visible and ultraviolet reflectivity provided by an 80-nanometer (nm) thick layer of aluminum, overcoated with 30-nm of magnesium fluoride. Construction is a "sandwich" of 2 glass plates joined by glass honeycomb ribs; at



826 kg, its mass is about 1/4 that of a solid mirror of the same size.

2. Secondary mirror: 0.3-meter diameter, convex hyperboloid shape; ultra-low-expansion glass with same coatings as primary. Mass 12.3 kg.

3. Mirror Support Structure: a lattice of lightweight, but rigid, graphite-epoxy tubes that hold the primary and secondary mirrors in precise alignment.

4a, 4b, 4c. Light Baffles: prevent stray light from interfering with observations. Main baffle (4a) lines walls of telescope; central baffle (4b) extends from the hole in the primary mirror; secondary baffle (4c) surrounds the secondary mirror.

5a, 5b. Mirror Actuators: computer-controlled rods that can make slight changes to the mirror shapes. 24 actuators (5a) can manipulate the primary mirror; 6 actuators (5b) for the secondary.

Scientific Instruments

HST carries a total of 8 instruments: 4 (3 FGSs and WF/PC) mount *radially*, in bays that lie at right angles to the telescope axis; they can be pulled out like large drawers for replacement. Four other instruments, each the size of a telephone booth, mount *axially* (parallel to the telescope axis); large, hinged doors allow astronauts to reach them for replacement.

6. Fine Guidance Sensor (FGS): 3 identical FGSs (1 shown) track stars very accurately. Information from 2 FGSs is needed to point the telescope in space, since there are 2 coordinate directions on the sky (e.g., east-west and north-south); the third can be used for astrometry. An FGS measures how far, in angle (e.g., seconds of arc), a star is located from the telescope axis by looking for *interference* between light waves from the star that strike opposite sides of the primary mirror. (If the star is precisely aligned with the telescope axis, starlight from either side of the mirror will travel exactly the same distance to reach the FGS; any deviation measures how far the star is off the telescope axis.) The light path is shown in green on wallsheet front. Light enters an FGS via a pick-off mirror (a); bounces among a set of (not labelled) prisms, beam splitters, and mirrors; and ultimately is recorded by detectors called *photomultiplier tubes* (b).

7. Wide Field/Planetary Camera (WF/PC): primarily for visible and ultraviolet imaging. In "wide field" mode the field-of-view is 2.7 minutes of arc across; in "planetary" mode it is 1.2 minutes across. Light (path shown in blue) enters via pick-off mirror (a); passes through a shutter (not labelled); through a selection of 50 filters — used to block unwanted wavelengths of light — on a "filter carousel" (b); and bounces off 1 of 2 (for the 2 operating modes) pyramidal mirrors (c) that split the beam into 4 parts, each representing 1/4 of the final image. A "relay" mirror (not labelled) directs light back through a "mini-Cassegrain telescope" (d) to form an image on 4 (for the 4 parts of the beam) CCD-containing cameras (e).

8. Faint Object Camera (FOC): (provided by European Space Agency) for imaging with higher resolution, but narrower field-of-view, than WF/PC. Light paths are shown, in blue, for each of its 2 independent, side-by-side camera systems (different fields-of-view). In each, entering light goes through 3 reflections (a) that direct it through a selectable filter carousel (b) to be recorded by an image-intensifying, television-type camera tube (c).

9. Faint Object Spectrograph (FOS): for moderate- to low-resolution, visible and ultraviolet spectroscopy. Entering light, shown in green, is deflected toward the detectors by a prismatic mirror (a); passes through a filter on a filter/grating carousel (b); reflects off a mirror (c) back to the carousel; where a selected *grating* disperses light into a spectrum and reflects it to either of 2 "Digicon" detectors (d), optimized for either shorter (bluer) or longer (redder) wavelengths. (A Digicon is a special type of detector that amplifies the signal from faint objects.)

10. High Speed Photometer (HSP): a very sensitive light meter that measures the intensity and color of light, and rapid fluctuations in brightness. HSP has no moving parts. It has 4 light-entrance holes (not shown), each with a filter/aperture assembly consisting of 13 color filters and 3 apertures; the desired hole/filter/aperture combination is selected by slightly maneuvering the spacecraft. Light is shown, in orange, emerging from each of 3 apertures; reflecting off ellipsoidal relay mirrors (a); and entering the tube-shaped detectors (b) that measure the absolute brightness of the light.

11. Goddard High Resolution Spectrograph (GHRS): for high-resolution ultraviolet spectroscopy. Light, shown in white, enters through either a small or large aperture; a shutter (a) blocks the large aperture when the small aperture is in use. A relay mirror (b) reflects light to a grating and mirror carousel (c) that disperses light into a spectrum and reflects it to "cross-disperser" gratings (d); these help to sort the spectra and reflect the light to the 2 Digicon detectors (e), optimized for either shorter or longer ultraviolet wavelengths.

Support Systems Module (SSM)

The SSM is like the Observatory building of a ground-based telescope, containing all of the systems (e.g., electronics, power, etc.) necessary to support the telescope. It is built in 4 main sections, stacked like cannisters (see diagram next panel).

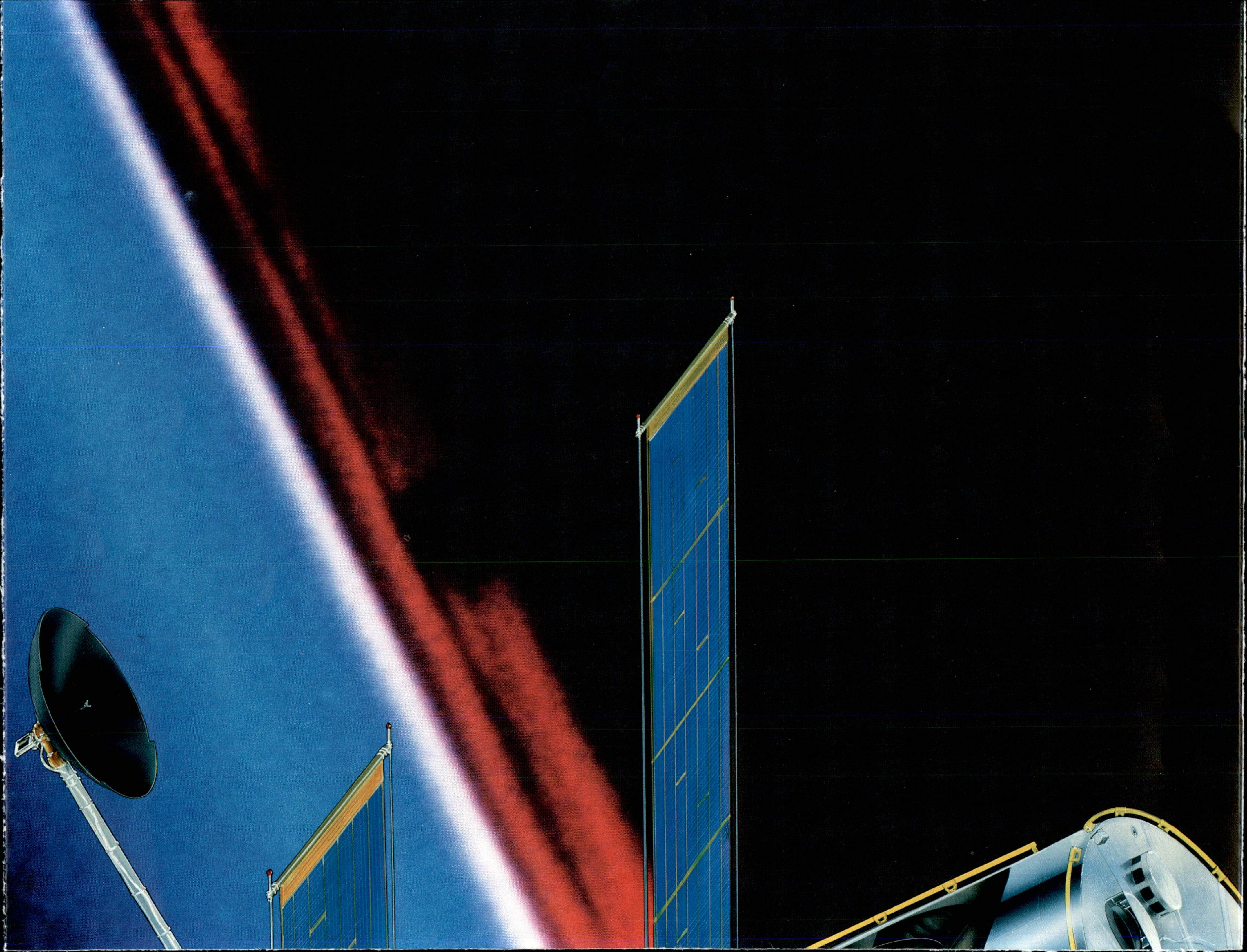
12. Solar Arrays: (provided by European Space Agency) main source of power for the telescope; collected solar energy can be stored in batteries until needed. Each measures 2.4 by 12.1 meters, together they provide an average power of 5,000 watts.

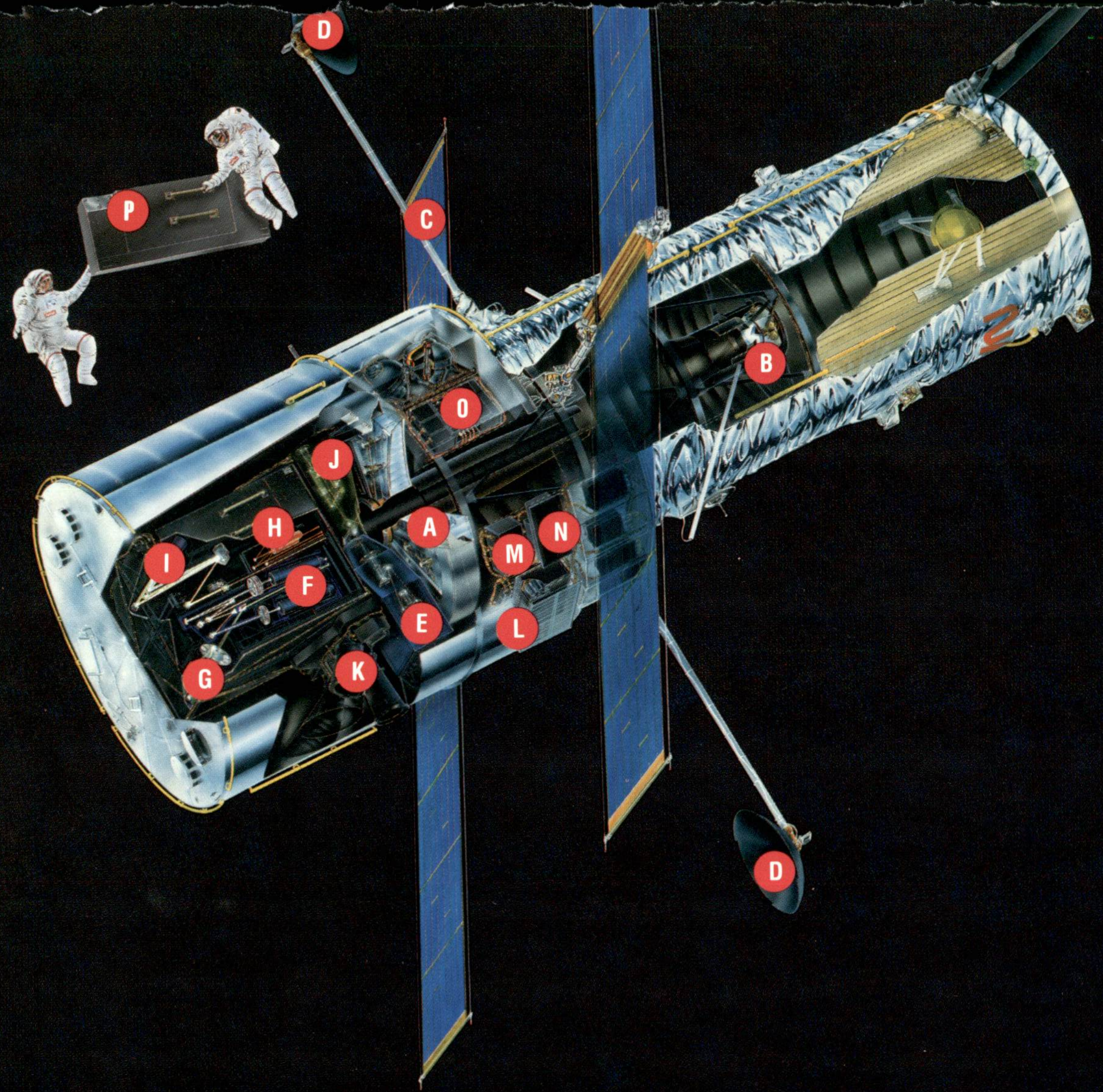
13. Communications Antennas: the main link between the ground and the spacecraft; signals are relayed through NASA's Tracking and Data Relay Satellite System (TDRSS).

14. Star Trackers: 3 of these detectors locate and track bright stars for course positioning of the telescope.

15. Gyroscope Units: 3 of these each contain 2 gyroscopes (for a total of 6 gyroscopes) that sense changes in the telescope's orientation in space (i.e., the direction in which the telescope is pointing).

16. Reaction Wheels: 4 large wheels (2 shown), each 59 cm in diameter, 45 kg in mass, and spinning at up to 3,000 rpm, control the telescope's orientation in space. Changing the spin rates of the





A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P

Panel 9

wheels causes the spacecraft to rotate (through transfer of angular momentum); HST can turn up to 90 degrees in 18 minutes.

17. Magnetic Torquer Bars: 4 large bar-shaped electromagnets (1 shown) react against Earth's magnetic field to generate torque that helps to control the reaction wheel speeds.

18. Batteries: 6 nickel-hydrogen batteries (3 shown) provide power when the telescope is in the Earth's shadow; recharged with power from the solar panels.

19. Spacecraft Computer: controls the systems of the SSM.

20. Data Management Unit: decodes commands passed between ground and spacecraft computers.

21-24. Electronic boxes: for command and control of the mirror actuators (21), Fine Guidance Sensors (22), and optical telescope assembly (23, 24).

25. Science Computer: controls the science instruments.

26. Telescope (Aperture) Door: closes only when necessary for telescope protection.

27. Insulating Blanket: 15 layers of aluminized Kapton, and an outer layer of Teflon, help maintain thermal stability.

28. Grapple Fixture: attachment point for Shuttle's Remote Manipulator System ("robotic arm").

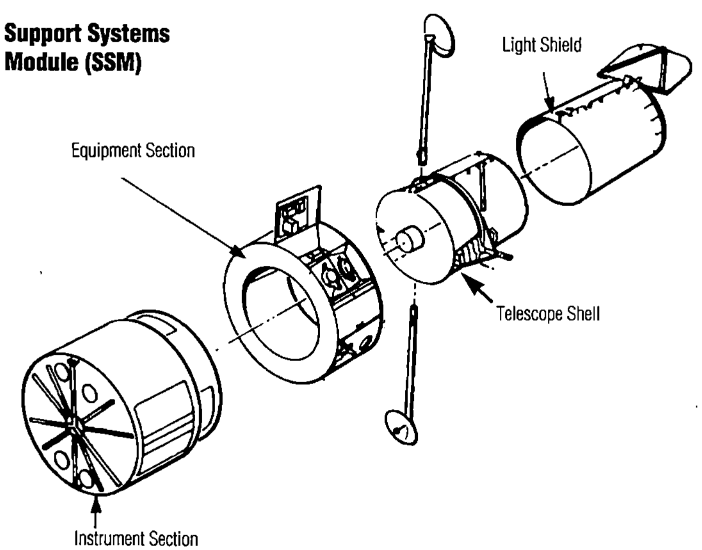
29. Hand Rails: for use by visiting astronauts.

30. Shuttle Support: points of support for telescope in Shuttle cargo bay.

31. Hooks: used to anchor replacement parts during astronaut servicing.

32. Gas Purge Vents: to expel contaminating gasses.

Support Systems Module (SSM)



Information For Educators

Many books and magazine articles, too numerous to list here, can give more information about HST or astronomy. In addition, NASA is continually developing educational programs and materials, including classroom activities, related to HST and other NASA missions.

NASA CORE

CORE is a center established for the national and international distribution of NASA produced educational materials in audiovisual format. Educators can obtain a catalogue of these materials and an order form by written request, on school letterhead, to: NASA Central Operation of Resources for Educators (CORE), Lorain County Joint Vocational School, 15181 Route 58 South, Oberlin, OH 44074.

NASA Spacelink

Spacelink is a computer service of NASA for educators containing NASA information and educational materials. The service includes current NASA news, data about America's aerospace program, classroom materials, and other information useful to teachers and students. Spacelink may be accessed by a computer with a modem through a long distance phone line or the Internet. The data line number for Spacelink is **(205) 895-0028**.

HST Information on CompuServe

In addition to Spacelink, NASA makes HST materials available through the CompuServe electronic information service. The toll-free number for CompuServe is 1-800-848-8990.

NASA Teacher Resource Centers

For additional information, contact the NASA Teacher Resource Center (TRC) nearest you. TRCs are located at:

Ames Research Center
Mail Stop T025
Moffet Field, CA 94035
(415-604-3574)

Jet Propulsion Laboratory
4800 Oak Grove Drive
Mail Stop CS-530
Pasadena, CA 91109
(818-354-6916)

Kennedy Space Center
Mail Stop ERL
Kennedy Space Ctr, FL 32899
(407-867-4090)

Langley Research Center
Mail Stop 146
Hampton, VA 23665-5255
(804-864-3293)

Johnson Space Center
Mail Stop AP-4
Houston, TX 77058
(713-483-8696)

Stennis Space Center
Building 1200
Stennis Space Ctr, MS 39529
(601-688-3338)

Goddard Space Flight Center
Mail Stop 130.3
Greenbelt, MD 20771
(301-286-8570)

Lewis Research Center
Mail Stop 8-1
Cleveland, OH 44135
(216-433-2017)

Alabama Space and Rocket Center
National Teacher Resource Center
Huntsville, AL 35807
(205-544-5812)

About this Wallsheet

We have designed this wallsheet primarily for educational use. The front shows an artist's rendition, in full-color, of the inner workings of the Hubble Space Telescope. The back contains explanatory text and illustrations, arranged for easy reproduction on copying machines.

- Panels 1-3 provide an introduction to HST and space astronomy.
- Panels 4-6 provide an introduction to the different ways that astronomers analyze starlight.
- Panels 7-9 provide detailed information about how HST works. Panel 7 is a miniature reproduction of the full-color wallsheet image; its numbered call-outs, explained on panels 8-9, identify important components of HST.

Please Send Comments

In such a limited amount of space, we cannot provide all of the information we would like. To help us in designing future wallsheets, please send comments or criticisms, to:
Mail Code FEP, NASA Headquarters,
Washington, D.C. 20546.

Panel 6

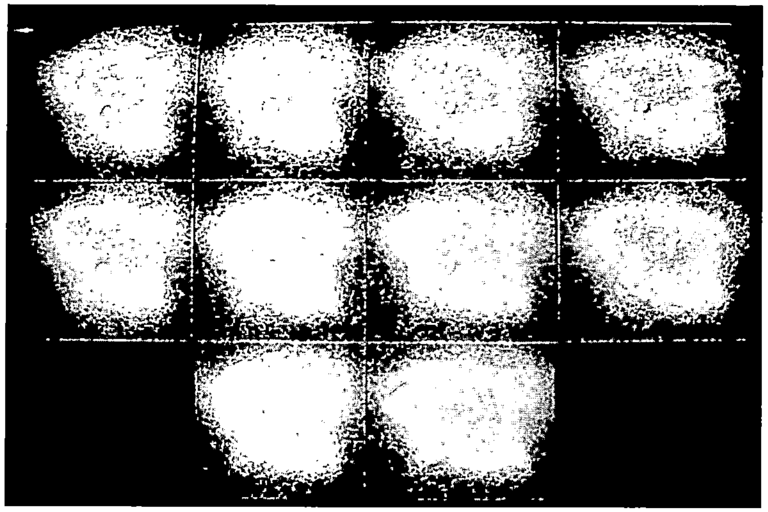
Further HST Capabilities

Photometry

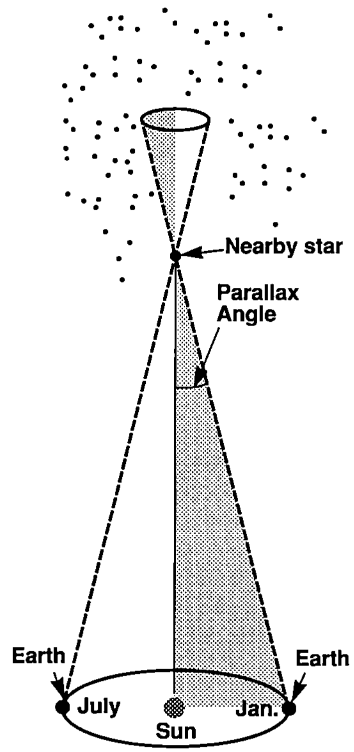
Photometry is the measurement of the total amount of light received from an object. All of HST's instruments are capable of photometry, but the High Speed Photometer (HSP) is dedicated to the measurement of rapid changes in brightness. The HSP can measure changes in brightness occurring in as short a time as 10 microseconds. Among the objects HSP studies are the disks of material spiraling into black holes and rapidly rotating neutron stars, or *pulsars*. The Crab Nebula, for example, contains a pulsar whose rotation makes it seem to blink on and off 30 times each second.

Astrometry

Astrometry is measuring the precise location of stellar positions in the sky. Astrometric studies can reveal the orbital motions of binary stars, and are critical to measuring distances in the universe. As the Earth orbits the Sun, nearby stars appear to shift their positions against the more distant background allowing direct calculation of their distances; this *stellar parallax* is the basis upon which all greater distances are estimated. HST carries three Fine Guidance Sensors (FGS) that can be used for astrometry in addition to their primary function of helping the telescope to point accurately in space.



On and off: pulsar in the Crab Nebula, a supernova remnant.



Stellar parallax is the apparent annual shift in the position of a nearby star. The smaller the parallax angle, the more distant the star.

The Search for Planets

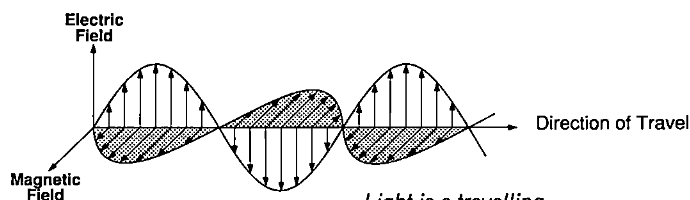
Do other stars have planets? Though most astronomers believe that planets should be common throughout the universe, no direct proof of planets beyond our solar system has yet been obtained. The problem is one of scale: to see a planet like the Earth around even a nearby star is equivalent to searching for a speck of dust a few meters from a bright light bulb — viewed from a distance of thousands of kilometers! Even with HST, it is a near-impossible task.

There is somewhat greater hope that astrometry with HST might reveal larger planets, the size of Jupiter or larger. The gravitational effect of an orbiting planet should cause tiny shifts in the position of a star; the shifts can be detected through astrometry. In addition, HST's spectrographs are being used to study disks of material around some nearby stars, like *Beta Pictoris*, which may be solar systems in the process of formation.

Artist's conception of Beta Pictoris gas disk, based on HST spectroscopy.

Polarimetry

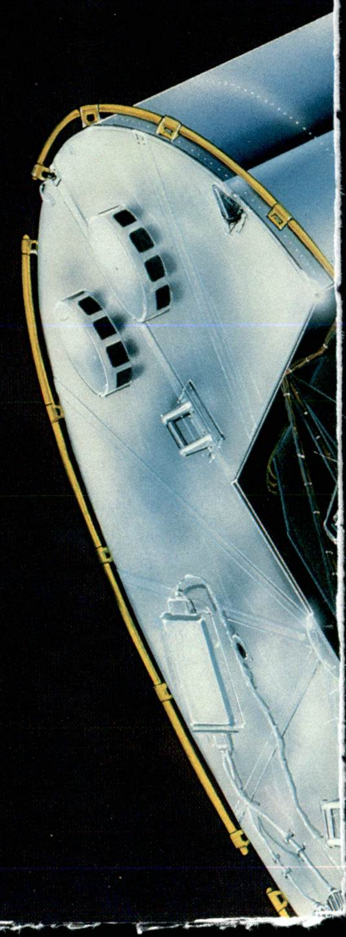
Every photon of light is a travelling *electromagnetic* wave, in which alternating electric and magnetic fields are oriented in fixed, perpendicular directions in space. Polarimetry is the study of the orientations of those fields — called the *polarization* — in the many photons coming from a distant object. Light is *polarized* if all of its photons have their electric and magnetic fields oriented the same way. The polarization of light can reveal subtle details about cosmic structures, such as the existence of dust clouds or magnetic fields. WF/PC, FOC, FOS, and HSP are all capable of some polarimetry.

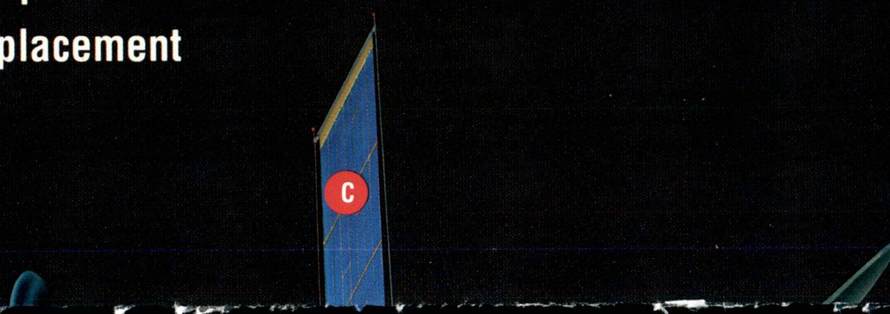


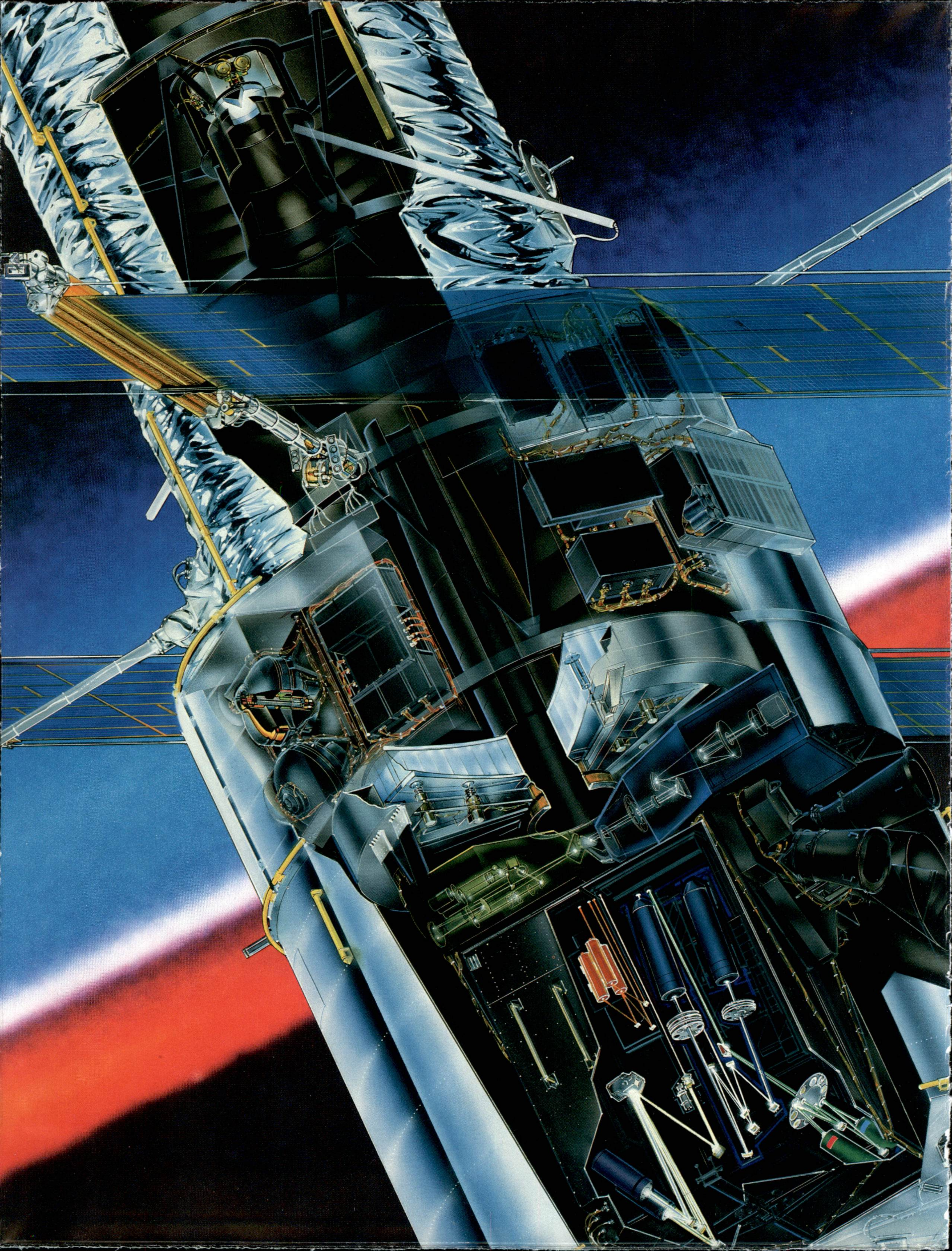
Light is a travelling electromagnetic wave.

NASA. From its vantage point beyond our planet's turbulent and obscuring atmosphere, the Hubble Space Telescope views the cosmos with unprecedented clarity.

A. Primary mirror
B. Secondary mirror
C. Solar Arrays
D. Communications Antennas
E. Wide Field/Planetary Camera
F. ESA Faint Object Camera
G. Faint Object Spectrograph
H. High Speed Photometer
I. Goddard High Resolution Spectrograph
J. Fine Guidance Sensor (1 of 3)
K. Fixed Head Star Trackers (3)
L. Nickel Hydrogen Batteries (3 of 6)
M. Spacecraft Computer
N. Data Management Unit
O. Science Computer
P. Modular Replacement Instrument





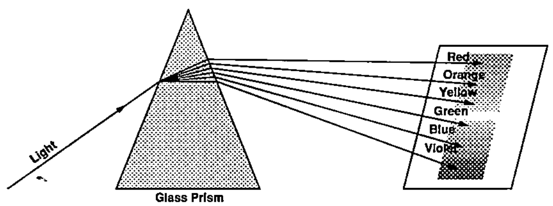


Panel 5

Spectroscopy: What are things made of?

What is spectroscopy?

Spectroscopy is the study of light split into its component colors — its spectrum — by a prism or by a finely-etched grating. Ordinary light is a mixture of many individual "pieces" of light, or photons, each of which is characterized by its wavelength (see electromagnetic spectrum diagram on panel 2). A prism or grating sorts the photons by wavelength; with visible light, this produces a rainbow of color.



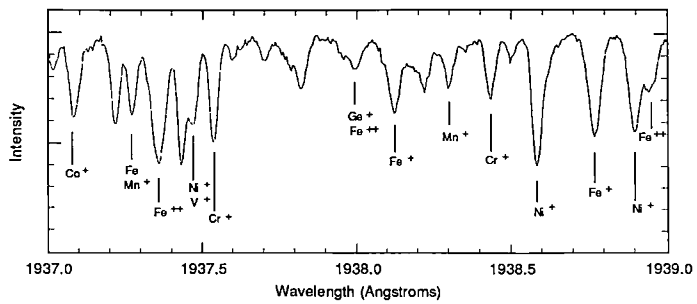
A spectrograph is an instrument, containing prisms or gratings, that records the intensity of light at each wavelength; two recorded spectra are shown below. While a perfect "rainbow" would make a smooth curve, the examples show that astronomical spectra usually reveal many *spectral lines*: dips, or *absorption* lines, where some wavelengths of light have been absorbed by material in the distant object or between the object and the Earth; and bumps, or *emission* lines, where the object has emitted specific wavelengths. By analyzing the spectrum, and the sizes and shapes of the spectral lines, astronomers can infer a wealth of information about a distant object including its temperature, density, chemical composition, rotation rate, and structure.

Chemical Fingerprints

Every chemical element emits or absorbs light at specific wavelengths, forming a chemical "fingerprint" in its spectrum. The spectrum of light from pure hydrogen, for example, can be easily distinguished from that of helium, or of any other chemical. By studying the many "fingerprints" in the spectrum of a star, astronomers can deduce its chemical composition.

Spectrographs on HST

The detail seen in a spectrum depends on its spectral resolution, or how widely the colors (wavelengths) of the light are dispersed. Although astronomers always desire high-resolution spectra, dispersing light widely makes it difficult to see faint objects. HST carries two spectrographs: the Goddard High Resolution Spectrograph (GHRS) for detailed study of the spectra of bright objects, and the Faint Object Spectrograph (FOS) for lower spectral resolution study of dim objects.

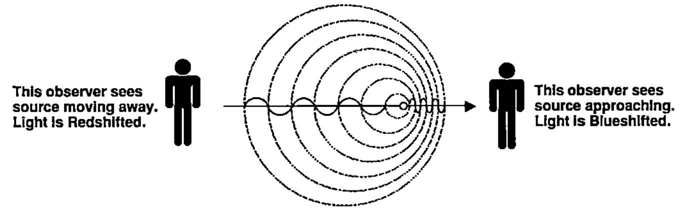


HST spectrum of the star Chi Lupi (GHRS). Absorption lines are caused by chemical elements in the star's outer layers. Standard chemical abbreviations are used; each "+" indicates a missing electron in the absorbing atoms.

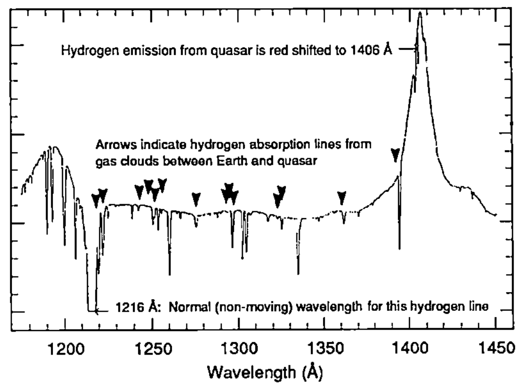
Measuring Velocity With the Doppler Effect

The Doppler effect allows astronomers to measure how fast a distant object is moving toward or away from the Earth. If an object is moving toward us, all of its characteristic spectral "fingerprints" will be shifted from their normal (i.e., measured in a lab on Earth) wavelengths to shorter, or bluer, wavelengths; if it is moving away, its spectrum will be shifted to longer, or redder, wavelengths. The greater the amount of the "blueshift" or "redshift," the faster the object is approaching or receding, respectively. (The expansion of the universe was first inferred from Edwin P. Hubble's discovery that the spectra of distant galaxies always show redshifts, and more distant galaxies show greater redshifts.)

The Doppler effect can be understood simply by considering the wave nature of light. If the source of the light is moving toward us, the waves will seem "bunched up" to shorter wavelengths. If the source is moving away, the waves will seem stretched out to longer wavelengths. The Doppler effect also occurs with sound waves, manifested by the familiar change in pitch as a vehicle "whizzes" by.

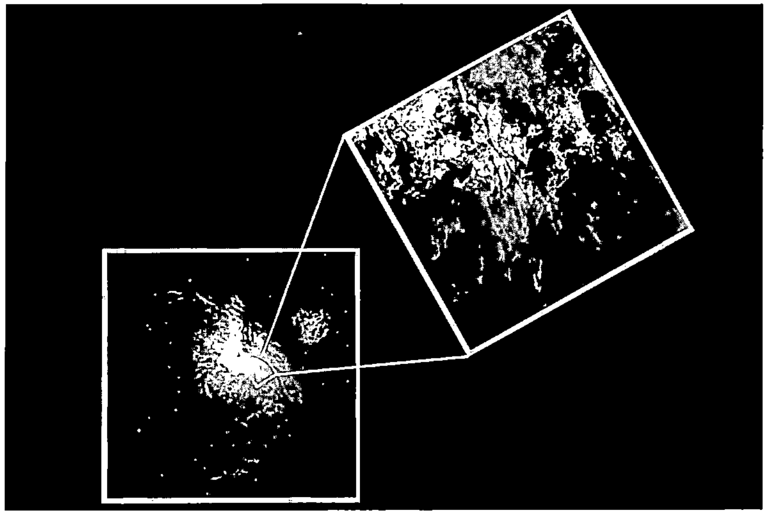


HST spectrum of quasar 3C273 (GHRS). The many hydrogen absorption lines, each with a different redshift, prove that many giant clouds of hydrogen gas lie between Earth and the quasar.



Panel 4

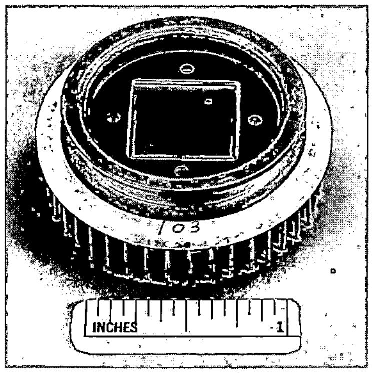
Imaging: What do Things Look Like?



HST reveals detail in a one light-year square region of the Orion Nebula. (WF/PC)

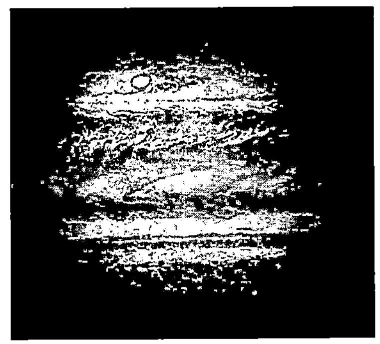
Images reveal structure
Although images are the most familiar method of portraying astronomical observations, imaging is just one of five basic observational techniques used by astronomers. The others — spectroscopy, photometry, astrometry, and polarimetry — will be discussed in the following panels. Images reveal the structure of distant objects. In the Orion Nebula, a star forming region about 1,500 light-years away, HST has revealed intricate patterns of gaseous clumps and filaments; the colors of the structures (not seen in this black and white reproduction) reveal that they contain hydrogen, oxygen, and sulfur.

Recording Images
Instead of using photographic film, which responds to light by changing *chemically*, HST uses detectors that respond to light *electronically*. This allows data to be directly recorded and analyzed with computers, and to be transmitted by radio to astronomers on the ground. One type of detector, used in HST's Wide Field/Planetary Camera, is the "charge coupled device," or CCD. Besides a wide variety of applications in astronomy, CCDs are used in many camera and video technologies.



A modern CCD is a small silicon chip.

Cameras On HST
HST's first generation of instruments includes two cameras designed specifically for astronomical imaging. The Wide Field/Planetary Camera (WF/PC) studies objects like planets, clouds of dust and gas, and galaxies. The European-built Faint Object Camera (FOC) offers slightly higher spatial resolution and greater sensitivity at short wavelengths (blue and ultraviolet light), but has a smaller field-of-view. The WF/PC will be the first scientific instrument to be replaced on HST; its successor, WF/PC-2, will include corrective optics to counteract the spherical aberration of HST.

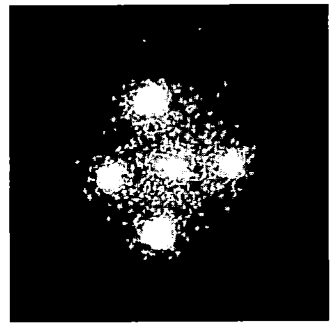


HST image of Jupiter. (WF/PC)

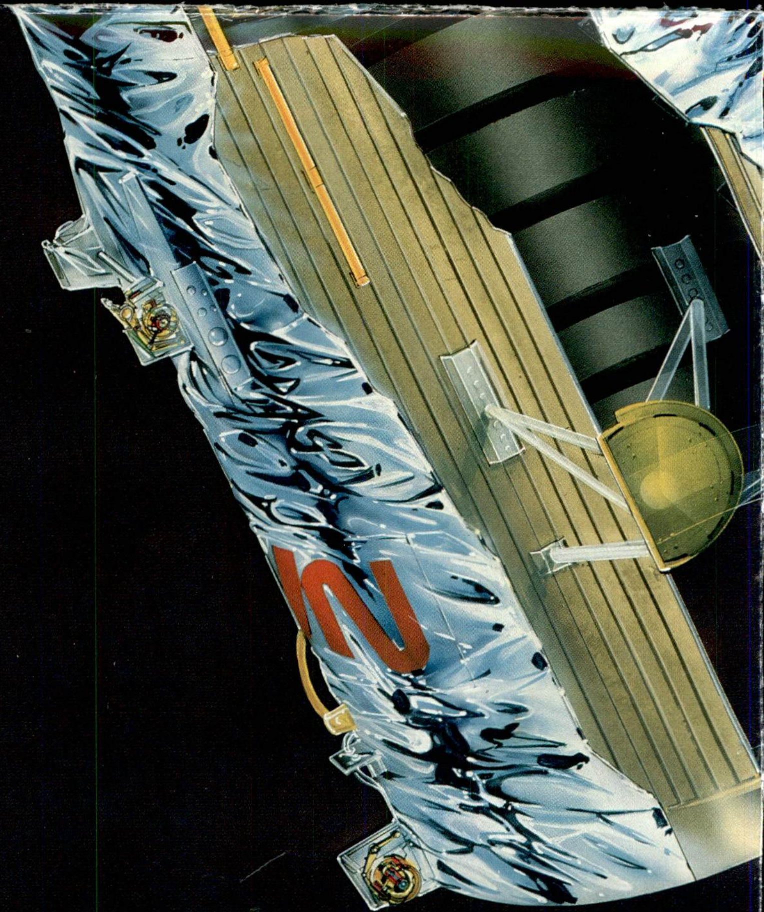
Images Distorted by Gravity

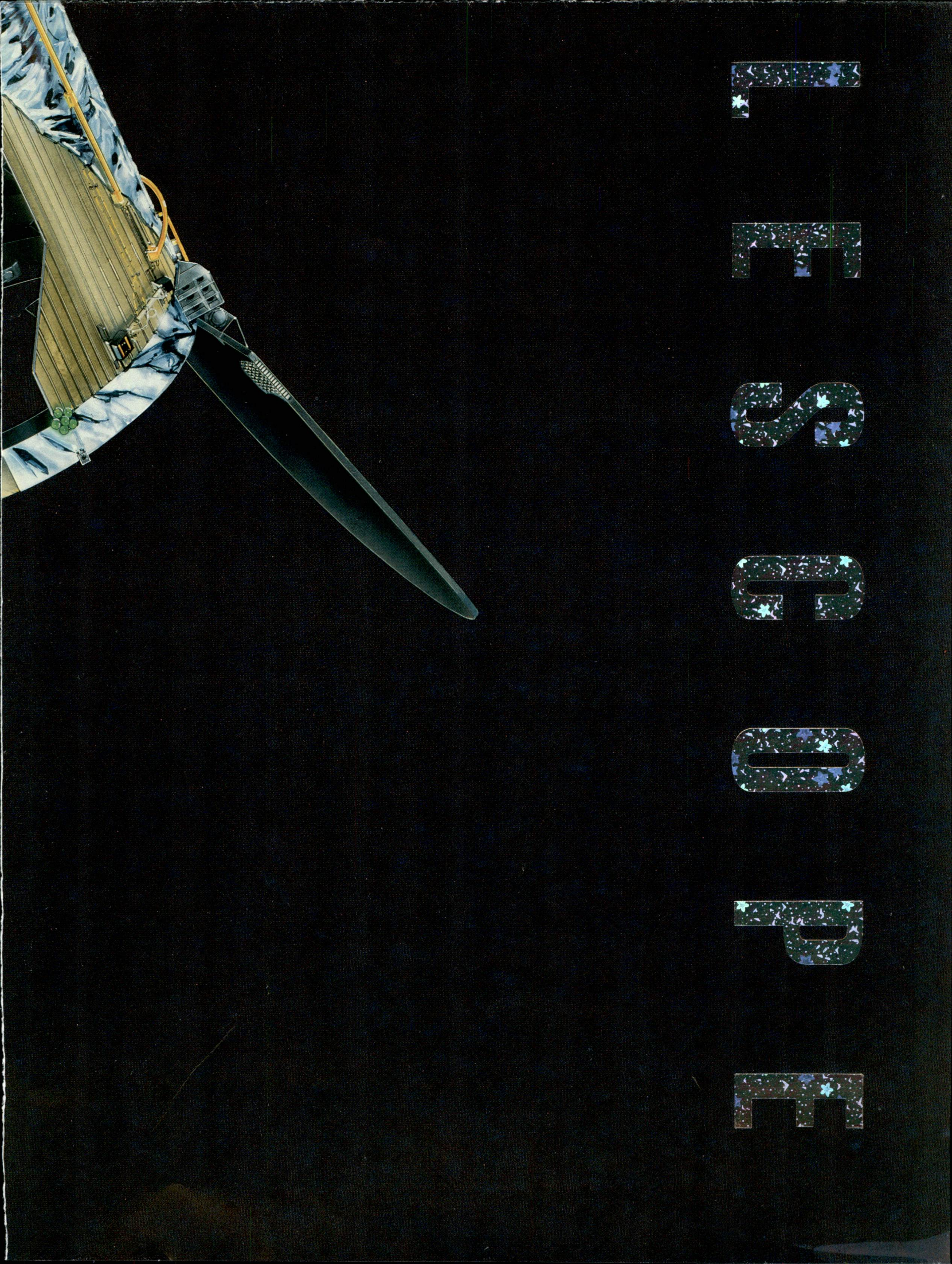
The four images that make up the "Einstein Cross" (gravitational lens G2237+0305) all are of the same quasar, yet no optical magic was worked by human astronomers. How, then, does nature give us a picture showing four distinct images of the same thing? The answer lies with Einstein's general theory of relativity. According to this theory, the very structure of space and time (*space-time*) is "warped" by matter to produce the effect of gravity. In a sense, the presence of a large mass causes space to be curved in much the same way that a bowling ball lying on a trampoline causes the stretched fabric to bend; the difference is that the trampoline is 2-dimensional, while space is 3-dimensional. (And space-time is 4-dimensional.)

Light travelling through curved space will be bent; in analogy with lenses made of glass, this bending of light by gravity is called *gravitational lensing*. The exact number and arrangement of the multiple images of an object seen in a gravitational lens depends on the particular geometry and alignment of the background and foreground objects, in this case a distant quasar and a much closer galaxy. In the Einstein Cross, four images (astronomers believe a fifth may be hidden by the galaxy) are distributed around the image of the lensing galaxy.



The Einstein Cross. (FOC)



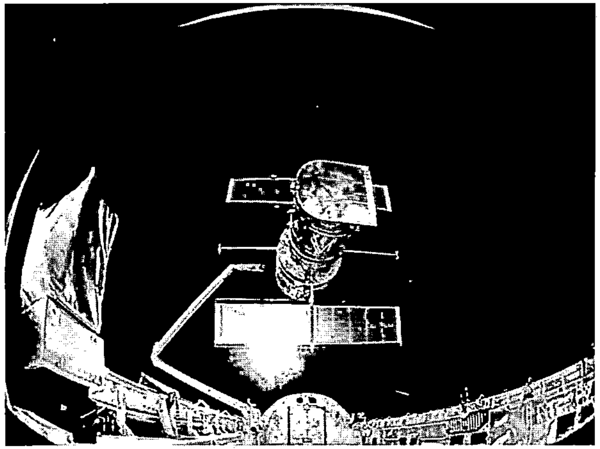

LESCOPE

Panel 1

Introduction to the Hubble Space Telescope

An Observatory In Space
The Hubble Space Telescope (HST) was placed into a 610-kilometer, 95-minute orbit around the Earth by the Space Shuttle Discovery in April 1990.

Communication with the unmanned observatory is maintained through a series of ground stations and through the specialized communication satellites known as NASA's Tracking and Data Relay Satellite System (TDRSS).

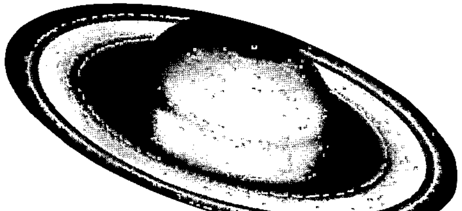


Deployment of the Hubble Space Telescope from the Space Shuttle Discovery.

Servicing HST
The scientific capability of any telescope depends not only on its mirror, but also on its instruments for recording the collected light. HST was designed to allow new instruments to be easily installed as old ones become obsolete. Servicing missions by the Space Shuttle, planned approximately every three years, will include repairs and other necessary maintenance in addition to instrument replacement.

Artist's conception of astronauts replacing HST's Wide Field/Planetary Camera.

Exciting Science
Despite its well-publicized primary mirror flaw, HST has established itself as a uniquely powerful astronomical observatory. Among its first-year achievements are: the study of a rare storm on Saturn; the first image clearly resolving Pluto and its moon Charon; a new understanding of the dynamics in galactic cores, revealing evidence of massive black holes; the first detailed images of the expanding cloud from the stellar explosion Supernova 1987A; the surprising discovery of vast clouds of intergalactic gas; and much more.



Saturn, viewed from a distance of 1.4 billion kilometers by HST. WideField/Planetary Camera

Guide to The Hubble Space Telescope. This 9-page guide to the Hubble Space Telescope, printed on the back of a NASA wallsheet, may be copied and distributed freely for educational purposes.

Edwin P. Hubble, 1889-1953

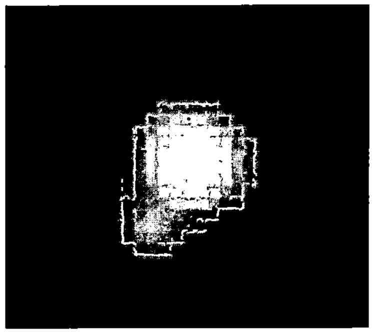
Once offered a chance to box as a professional heavyweight, the namesake of HST opted instead to pursue a career in astronomy. Among his many contributions were the first definitive proof that other galaxies exist beyond our own Milky Way, and his subsequent discovery that the entire universe is expanding. The latter discovery led astronomers, soon thereafter, to theorize that our universe had a beginning some 10 to 20 billion years ago in what we now call the *Big Bang*.

"From our home on the Earth, we look out into the distances and strive to imagine the sort of world into which we were born. Today we have reached far out into space. Our immediate neighborhood we know rather intimately. But with increasing distance our knowledge fades, and fades rapidly, until at the last dim horizon we search among ghostly errors of observation for landmarks that are scarcely more substantial. "The search will continue. The urge is older than history. It is not satisfied and it will not be suppressed." — Edwin P. Hubble

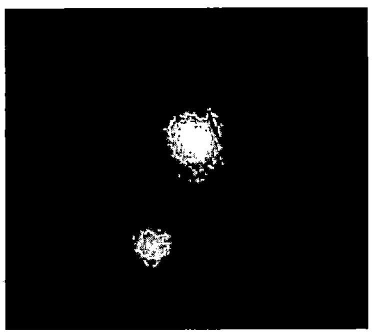
Panel 2

Space Astronomy

Pluto and its moon Charon, clearly resolved for the first time.



Ground-based image.



HST image (Faint Object Camera).

Twinkle, Twinkle, Little Star

"Twinkling" is not a property of stars themselves, but is a result of distortions caused by atmospheric turbulence. This same turbulence blurs celestial images recorded by ground-based telescopes. In contrast, the ability of a space telescope to distinguish fine detail — its *spatial resolution* — is theoretically limited only by its size. (New technologies are enabling substantial improvements in ground-based resolution, but they are still unlikely to match the resolving power of HST in the foreseeable future.)

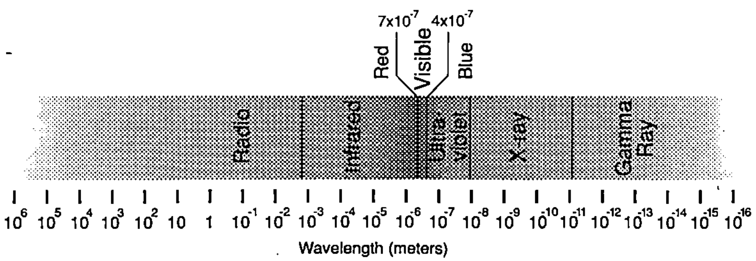
Beyond visible light

The visible light that our eyes can see is only a very tiny part of the complete *electromagnetic spectrum*. Each portion of the spectrum reveals new insights into the cosmos but only visible light, radio, and parts of the infrared spectrum can penetrate our atmosphere; the rest of the electromagnetic spectrum can be studied only from space. HST's mirrors can collect infrared, visible, and ultraviolet light; though its first generation of instruments includes only visible and ultraviolet detectors.

Despite many superior capabilities, HST will not make ground-based telescopes obsolete. Because astronomical studies, including follow-ups to HST discoveries, often require far more observing time than can be made available on a single space telescope, demand on ground-based telescopes will continue to grow for many years to come.

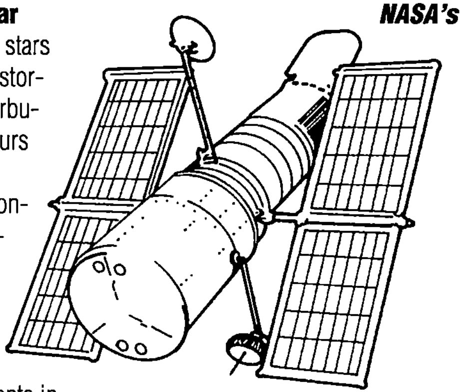
The Great Observatories

NASA designed HST as only the first in a series of four *Great Observatories* that, together, will span a wide portion of the electromagnetic spectrum. The Gamma Ray Observatory (GRO), second of the Great Observatories, was launched in April 1991. The third and fourth Great Observatories, instruments for studying X-rays and infrared radiation, respectively, are planned for launch in the late 1990's.

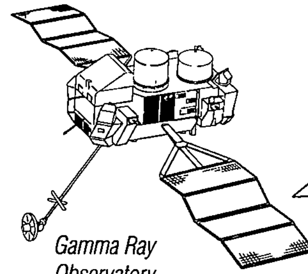


The electromagnetic spectrum.

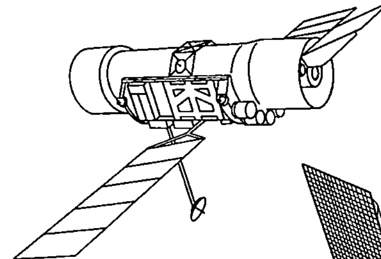
NASA's Great Observatories



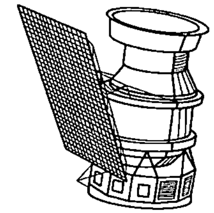
Hubble Space Telescope



Gamma Ray Observatory



Advanced X-ray Astrophysical Facility

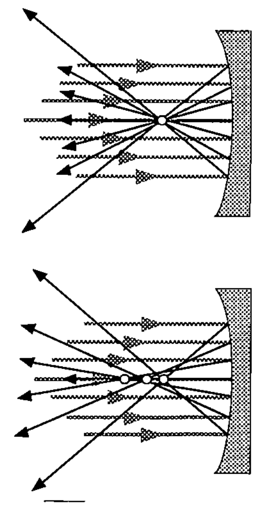


Space Infrared Telescope Facility

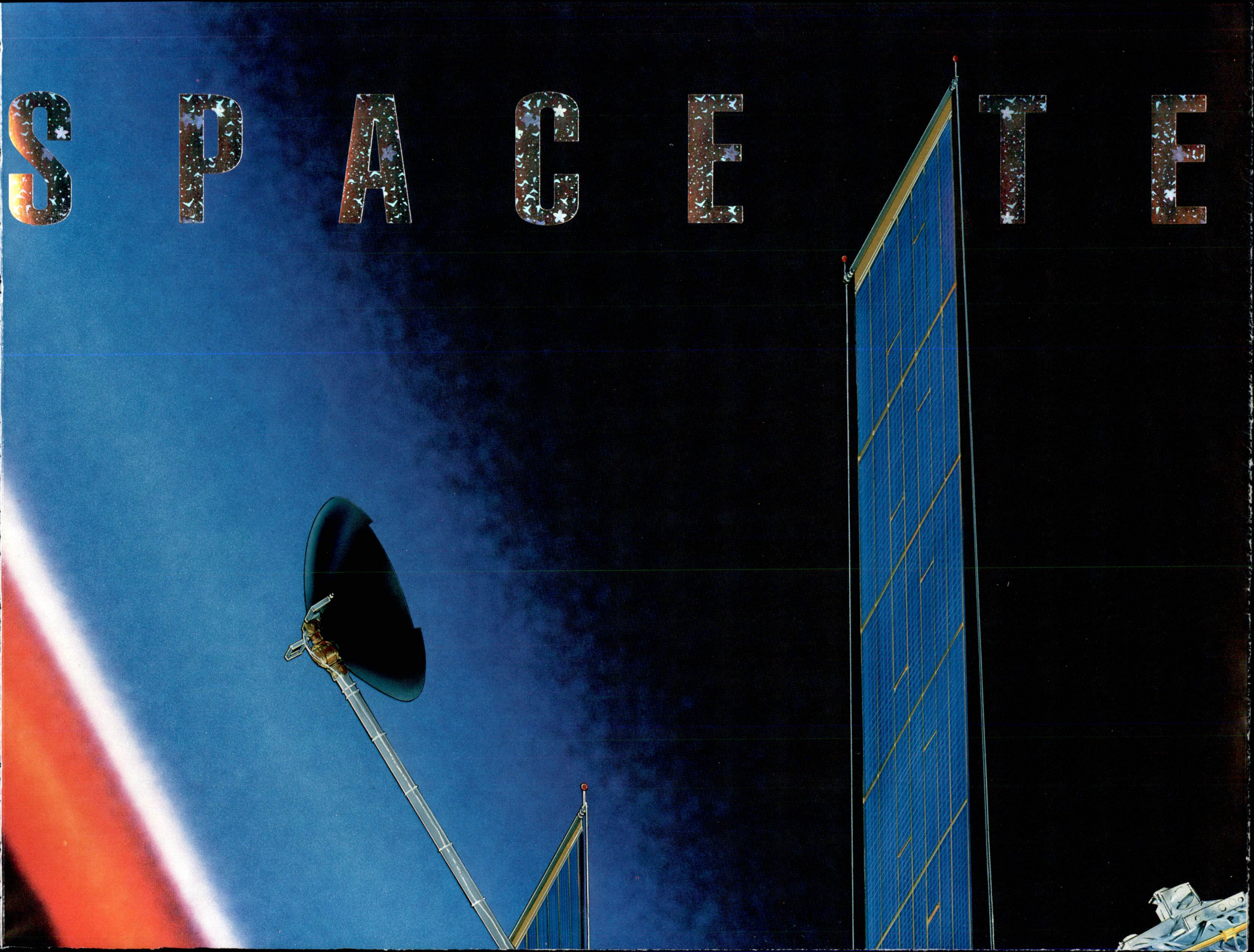
Mirror Trouble

Shortly after launch, HST was discovered to suffer from *spherical aberration,* a slight blurring caused by a manufacturing error: the curvature of the primary mirror was made too shallow by about 1/50th the width of a human hair (2 micrometers). In a perfect telescope mirror, all reflected light rays from a star converge to a single focal point. With spherical aberration, light from different parts of the mirror focuses at different points, causing the image in the focal plane to be smeared. In an HST image, only about 15% of the light from a star forms a sharp, "core" image; the rest forms a fuzzy "halo" around the core.

How does this impact the science of HST? For studies of bright objects, like planets or nearby star clusters, computer image processing to remove the fuzzy "halos" can overcome the distortion caused by the spherical aberration. Many important scientific studies, however, particularly those requiring high-resolution imaging of faint objects, cannot be accomplished by HST in its current state. Fortunately, it is believed that corrective optics — "glasses" for the HST — can be placed aboard the observatory during routine servicing missions by Shuttle astronauts. HST's observing schedule has been reshuffled so that those scientific programs most severely affected can be postponed until the corrective optics are in place.



Comparison of the sharp focus of a perfect telescope mirror (top) with the diffuse focus of a mirror with spherical aberration (bottom).


S P A C E T E

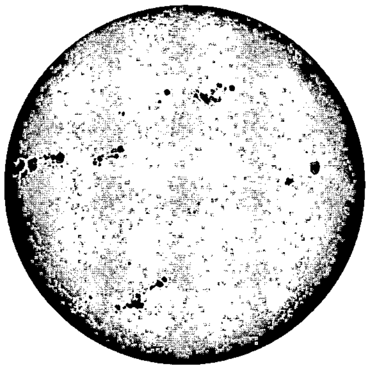
H U B B L E

A technological marvel revealed

Five stories tall, with a mass of 11,000 kilograms, orbiting the Earth at 28,000 kilometers an hour, the Hubble Space Telescope is the most technologically complex satellite ever launched by

Panel 3

Time and Space



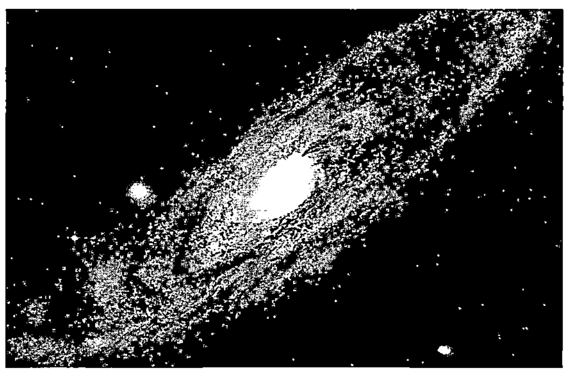
Light from the Sun takes about 8 minutes to reach the Earth.

Seeing Into the Past

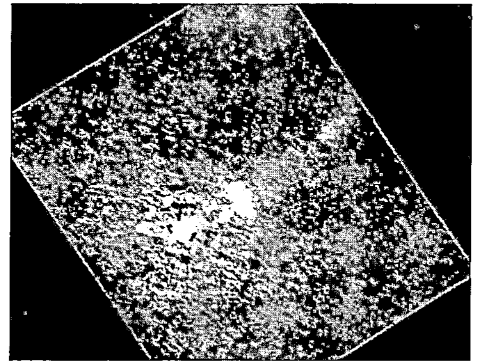
Perhaps the most remarkable fact about any astronomical telescope is its ability to peer not only into the depths of space, but into the depths of time. Because it takes time for light to cross the vast expanses of space, the light that reaches us shows objects as they were in the past, when their light first left. For example, if we study a star whose light travelled for ten years to reach us (i.e., it is ten light-years distant), then we are studying the star as it was ten years ago. The further distant an object lies, the further back in time we see.

> A light-year is the *distance* (it is not a unit of time) that light can travel in one year. Since all light travels at the *speed of light*, 300,000 km/s, a simple unit conversion shows light travels about 9.5 trillion km in one year (multiply the speed of light by the number of seconds in a year):
>
> $$300{,}000\ \frac{km}{s} \times 60\ \frac{s}{min} \times 60\ \frac{min}{hr} \times 24\ \frac{hr}{day} \times 365\ \frac{day}{yr} = 9.5\ \text{trillion}\ \frac{km}{yr}$$
>
> Thus, saying "one light-year" is just a special way on saying "9.5 trillion km".

The Great Galaxy in Andromeda.



HST image of quasar "PKS 021-36," which has ejected a gigantic "jet" of material. (Faint Object Camera)



Images of Time

As we look to distant galaxies, we realize that astronomical images are pictures of both space and time. The Andromeda galaxy, for example, is a vast conglomeration of stars that lies over 2 million light-years away and stretches some 100,000 light-years in diameter. As a result, we not only see the galaxy as it looked more than 2 million years ago, but light from the near edge in this image left some 100,000 years later (because it is 100,000 light years closer to us) than light from the far edge! The image spans 100,000 years of history that occurred over 2 million years ago. In fact, time and space are deeply intertwined, as demonstrated by Einstein in his *Theory of Relativity*.

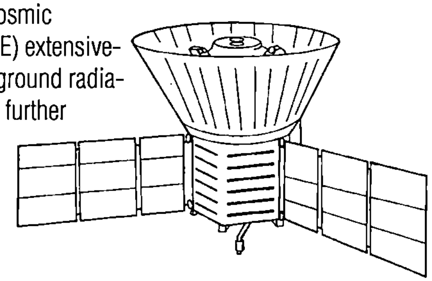
Observing the Early Universe

Because light from very distant objects takes so long to reach us, we see them as they were in the distant past — when the universe was much younger than it is today. Thus, we can directly observe conditions in the early universe simply by looking to great distances in space. We learn how our universe has evolved by comparing objects from the young universe (i.e., at great distances) with similar objects from the universe of today (i.e., nearby). Quasars, for example, are sources of extreme energy buried in the cores of some galaxies; because the most energetic quasars are found only at great distances in space, they must represent a stage in galactic evolution that is eventually outgrown.

The Big Bang

Astronomers believe that the Universe, meaning both space and time, began with an event called the *Big Bang*. The foundation of the Big Bang theory rests on Edwin P. Hubble's discovery that the entire Universe is expanding: if the Universe is growing bigger, then it must have been smaller in the past. Extrapolating the expansion rate back in time yields an age for our Universe of between 10 and 20 billion years; the uncertainty reflects the difficulty astronomers have in accurately measuring cosmic distances, a problem which HST may help overcome.

The universal expansion is not the only evidence for the Big Bang, however. Today, the Big Bang theory is supported by a vast array of theoretical predictions that have been verified by observation. The foremost example is the *cosmic background radiation*, the remnant radiation from the heat of the Big Bang, which was theoretically predicted over a decade before its discovery in 1963. NASA's Cosmic Background Explorer (COBE) extensively studied the cosmic background radiation in 1989-1991, lending further support to the Big Bang theory.



NASA's Cosmic Background Explorer.

Hubble Space Telescope,

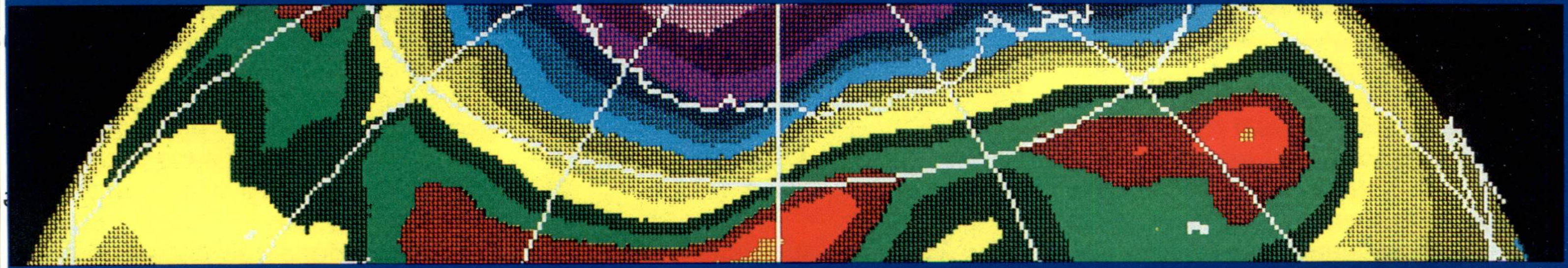
launched in April 1990, is now in routine operation, chalking up a succession of scientific accomplishments despite a number of technical challenges. The tracking of a rare, giant storm on Saturn, the unexpected detection of numerous clouds of hydrogen gas near our Galaxy, and the discovery of a stellar "fountain of youth" in 47 Tucanae, together with the exciting spectroscopy of Beta Pictoris, are only some of the triumphs recorded to date.

HST's current scientific capabilities are outstanding, and its future capabilities will be even better. The first Shuttle servicing mission, in late 1993 or early 1994, will end the "jitter" caused by the solar arrays and give HST the high sensitivity needed to observe very distant stars and galaxies. Later servicing missions will install the powerful second- and third-generation instruments that have been planned from the start. With these scheduled performance enhancements, HST will be able to achieve its original scientific goals over a planned 15-year observing lifetime.

We choose to go to the Moon in this decade, and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one that we are unwilling to postpone, and one that we intend to win. . ."

— President John F. Kennedy
September 12, 1962

NASA

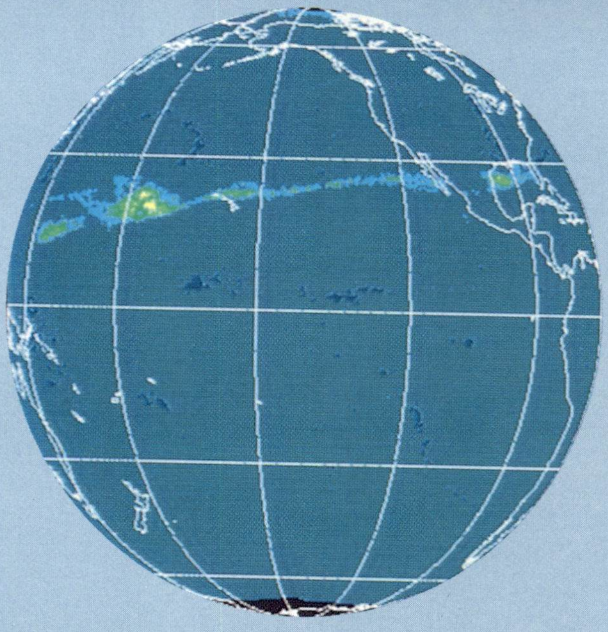


Monitoring and Measuring Ozone

The Total Ozone Mapping Spectrometer (TOMS). . .

Volcanic Sulfur Dioxide Observations

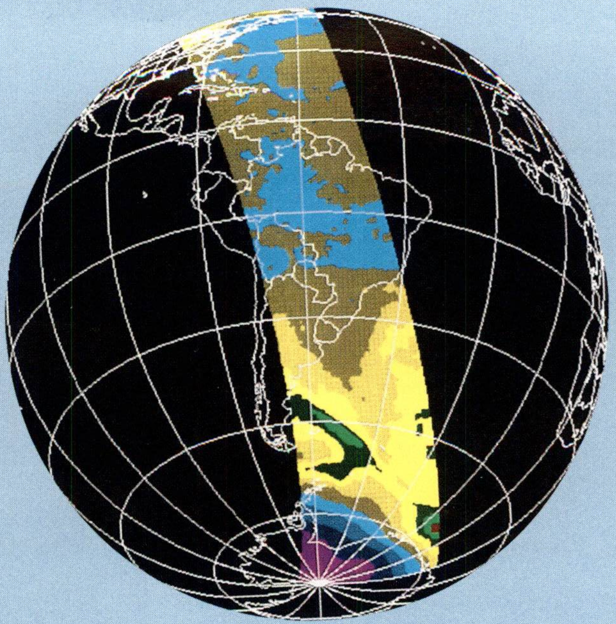
TOMS has also proven valuable in monitoring sulfur dioxide (SO_2) emissions resulting from volcanic eruptions. TOMS' SO_2 mapping capability makes it possible to observe all the world's volcanoes daily, then track the plumes and measure SO_2 output during the infrequent eruptions. Such a set of observations, extended over a few decades, will result in more accurate assessment of global volcanic sulfur flux.



TOMS reading of sulfur dioxide resulting from the eruption of El Chichon. The highest levels are shown in the greenish-yellow areas over the Gulf of Mexico and the Western Pacific.

Future Missions

Plans for future missions include placing a TOMS on the Soviet Meteor-3 satellite in the early 1990s. TOMS has been selected to fly on NASA's Small Explorer Mission and a TOMS is also being considered for flight on the Japanese Advanced Earth Observations Satellite (ADEOS). These three missions would ensure a continuation of the TOMS data set into the mid-1990s.



The TOMS aboard the Nimbus polar-orbiting satellite takes ozone measurements from north to south along its orbit path, in "swaths" such as that shown at right.

For further information:

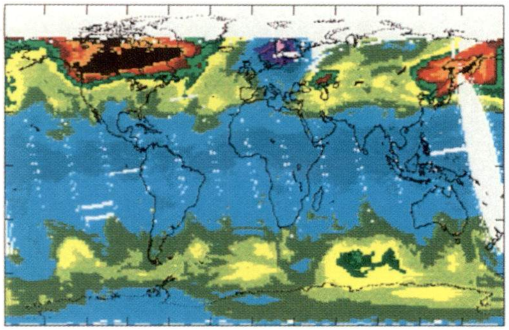
Robert D. Hudson/Arlin J. Krueger
Laboratory for Atmospheres
Space and Earth Sciences Directorate
Goddard Space Flight Center
Greenbelt, MD 20771
(301) 286-5485

George F. Esenwein/Robert T. Watson
National Aeronautics and Space Administration
Earth Science and Applications Division
600 Independence Ave., S.W.
Washington, D.C. 20546
(202) 453-1723/453-1681

Front Panel: Low levels of ozone over the South Pole, October 1987

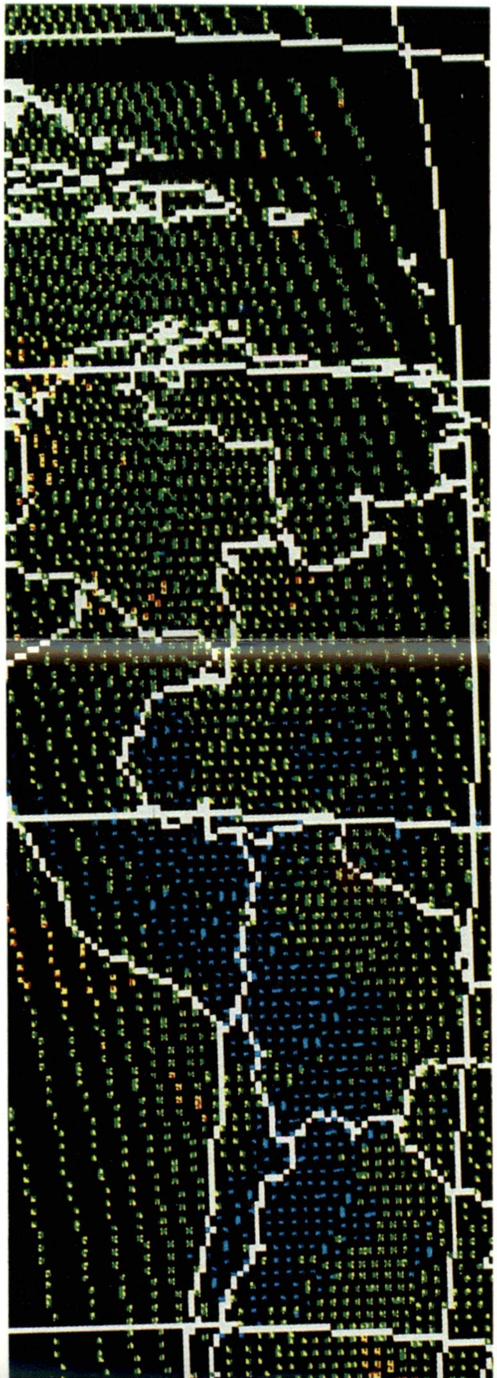
TOMS' Role in Ozone Monitoring

Ozone acts as a shield against harmful ultraviolet radiation from the sun. The well-known ozone "hole" over Antarctica and the distribution of ozone over the globe have been mapped in detail by measurements taken by a NASA-developed ozone sounding instrument, the Total Ozone Mapping Spectrometer (TOMS). Since it was launched aboard NASA's Nimbus-7 polar-orbiting satellite in 1978, TOMS has provided reliable, high-resolution mapping of global total ozone on a daily basis.



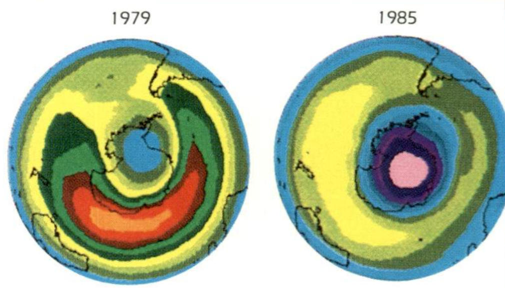
TOMS derived map of global ozone for February 1, 1989. The pink- and purple-shaded area over Scandinavia represents low-ozone levels (125-175 Dobson units). The red, orange, and black areas over Canada and northeast Asia represent high levels (425-475 Dobson units).

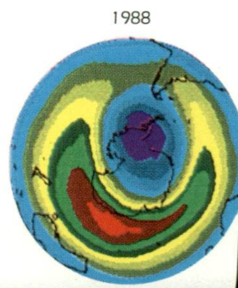
TOMS is vital to the continuing effort to understand the dynamics of ozone depletion. Having measured and mapped the decrease in global ozone, the crucial problem now facing researchers is to determine how much of the change in global ozone is due to man-made causes



Ozone Measurement Using TOMS

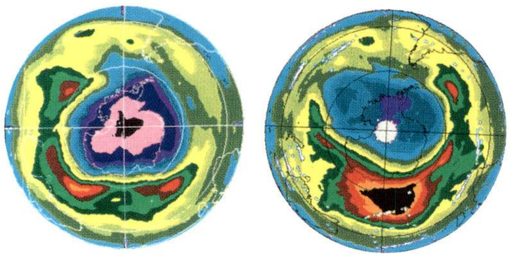
The TOMS instrument is a second-generation backscatter ultraviolet ozone sounder. It consists of a modified Ebert-Fastie polychromator with fixed exit slits at six wavelengths for the measurement of total ozone under all daytime observing and geophysical conditions. TOMS' spectral region covers the near ultraviolet wavelengths where sunlight is only partially absorbed by the total column of ozone. In order to provide the mapping capability, the field of view of the polychromator is modified by a foreoptics system and swept across the flight path of the spacecraft, producing a swath of observations that bridges the region between adjacent orbits to produce daily global coverage.





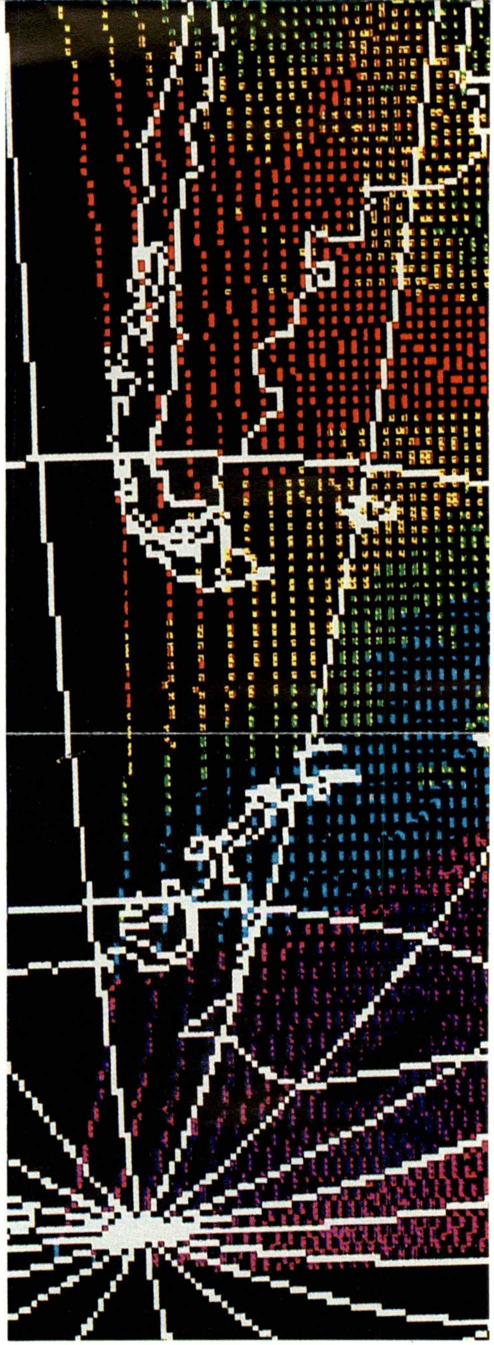
October mean ozone distribution over Antarctica for the years 1979,1985, and 1988. With the support of TOMS, scientists have now assembled a 10-year database of ozone decline.

global ozone is due to man-made causes (such as chlorofluorocarbon [CFC] production) and how much is attributable to natural atmospheric processes. Separating these causative factors requires a data record that is long compared to a solar cycle (11 years) of observations. Having already completed 10+ years of observations, TOMS has proven invaluable in meeting this requirement, and mission planning is underway to extend the TOMS record through the 1990s.



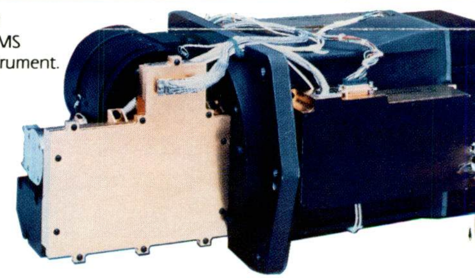
On the left is the now-famous TOMS south polar plot for October 5, 1987, showing historically low ozone distribution over Antarctica. Juxtaposed on the right is a plot for September 15, 1988, showing dramatic differences in Antarctic springtime ozone from year to year.

Prior to the development of TOMS and its predecessor, the Nimbus-4 Backscatter Ultraviolet (BUV) instrument, ozone measurements were obtained via ground-based Dobson Spectrophotometer stations (named for a pioneer in ozone studies). These data, while reliable, are limited because the stations only measure ozone in the atmosphere directly above them, and most of the 90+ Dobson stations are located in the northern hemisphere and mid-latitudes. The global observational capability afforded by TOMS eliminates these obstacles.



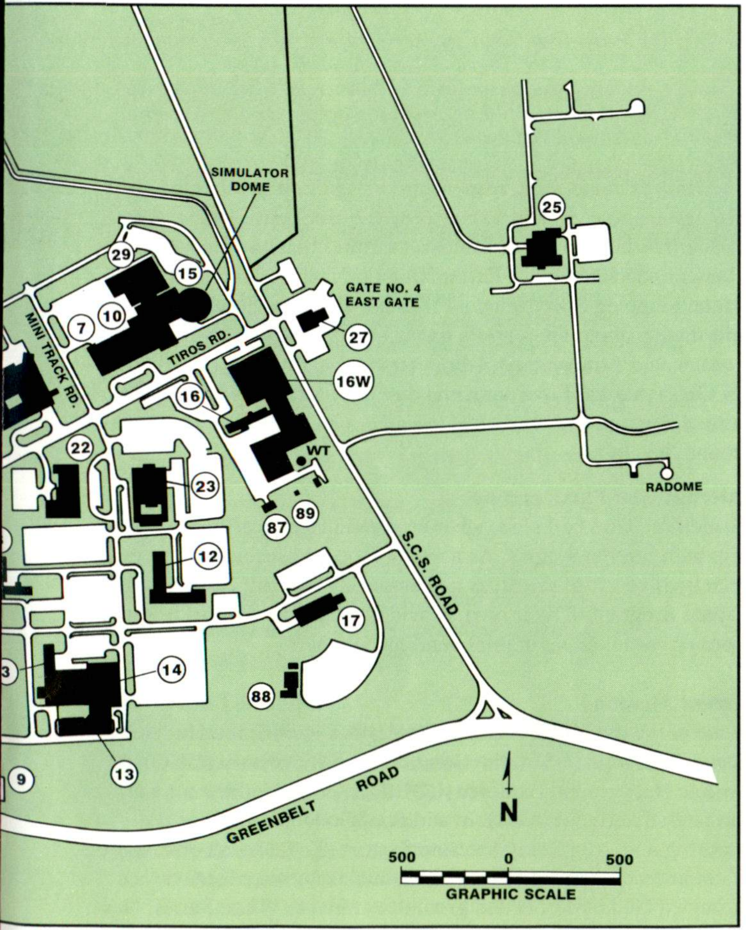
TOMS measures total ozone by observing both incident solar irradiance and backscattered ultraviolet radiation at six wavelengths between 310 and 380 nm. Backscattered radiation consists of solar radiation that has penetrated through the stratosphere to the troposphere, where it is scattered by air molecules and clouds back through the stratosphere to the satellite sensors. Along that path, a fraction of the UV is absorbed by ozone. By comparing the amount of backscattered radiation with periodic observations of the incident solar irradiance at identical wavelengths, the Earth albedo can be calculated. By determining the change in albedo at the selected wavelengths, the amount of ozone above the surface can be derived.

The TOMS instrument.



In addition to various "housekeeping" sensors to monitor the well-being of the instrument, TOMS uses several in-flight calibration modes to assess system performance. These include a wavelength calibration system to check the stability of the spectrometer, and a gain calibration system to check system output-input ratios during the radiance and irradiance measurement modes.

18 Administrative Support Building, Information Technology Center
19 Technical Support Building
20 Technical Support Building, Mailroom
21 Meteorological Systems Development Laboratory, Cafeteria, Library, Credit Union
22 Space & Terrestrial Applications Facility
23 Data Interpretation Laboratory
24 Central Heating & Refrigeration Plant
25 Networks Text & Training Facility & Hydromechanical Laboratory
26 NASA Space Science Data Center
27 Transportation Facility, Hazardous Waste Chemical Storage Facility
28 Technical Processing Facility
29 Spacecraft Systems Design & Integration Facility
30 Quality Assurance & Detector Development Laboratory
87 Gas Cylinder Storage Building
88 Visitor Center
89 Ordnance Building
90 Day Care Center
97 Plant Maintenance Support Facility, Health Unit
98 Center Management Building
99 Center Management Facility



NASA
National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

Goddard Space Flight Center

"Leading the world into the future"

Godd:
"Spac

For more
(GSFC) h
exploratio
ments an
Earth and
people fr
Today, th
site contr
Center, lo
rolling M

One of ni
(NASA)
nel with
missions
commun
analyze c
stretchin
position
ultraviol
astrophy
name a f

That scie
staff that
instrume
sensors,

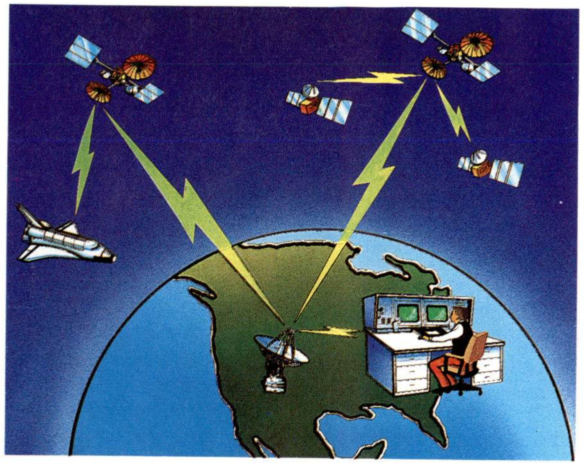
Goddard
work pri
where th
ing the i
conducti
and the

RIGHT:
Center is
rocket pr
Russia, a
envisione
insight, G

COVER:
Goddard
Center th
one of G
Center:
GSFC en
orbiting
Backgrou
designed
and techn
1989 on

Goddard Facilities

In addition to the primary facility in Greenbelt, Maryland, Goddard has management responsibility for the Wallops Flight Facility on the Eastern Shore of Virginia near Chincoteague; for the Goddard Institute for Space Studies in New York City, and for the Tracking and Data Relay Satellite System ground terminals at White Sands, New Mexico. The Space Telescope Science Institute in Baltimore is operated under contract to Goddard, and the National Scientific Balloon Facility in Palestine, Texas, is managed by Goddard through its Wallops Flight Facility.



The TDRSS network, with its constellation of satellites, beams messages from space to Earth and from Earth to orbiting satellites.

Wallops Flight Facility

Wallops is a special facility for suborbital research, including a launch range and complete research airfield, wholly owned and operated by NASA. Wallops is responsible for projects using sounding rockets, scientific balloons and aircraft which provide simple, flexible and inexpensive methods of conducting scientific investigations.

Sounding rockets carry scientific instruments several hundred miles into space while balloons, as huge as 28 million cubic feet, take payloads of up to 6,000 pounds (2,700 kg) to altitudes as high as 30 miles (48 km). The sounding rockets and balloons are launched from locations all over the world, with recent launches having been carried out in the Antarctic, New Zealand, Norway, Canada and Alaska. The scientific balloon program is considered number one in the world.

Aircraft at Wallops are used as platforms for instruments to collect data at altitudes up to 40,000 feet (12,200 m).

A sounding rocket is readied for launch at Wallops Flight Facility. These rockets fly near-vertical paths carrying scientific instruments to altitudes from 40 miles to hundreds of miles.

Wallops aircraft research also includes runway traction studies, a project involving a Microwave Landing System (MLS)—the instrument landing system of the future, and investigations into the stall/spin characteristics of general aviation aircraft.

Goddard Institute for Space Studies (GISS)

Basic research in space and Earth sciences in support of GSFC's programs is carried out at the Goddard Institute for Space Studies (GISS). Since 1961, GISS has fulfilled its research mission in cooperation with Columbia University and other institutions of higher learning.

Current research at GISS is aimed at a broad study of global change, an interdisciplinary research initiative addressing natural and human-made changes in our environment. Recent studies have focused on the "greenhouse effect," which refers to the ability of certain gases in the atmosphere to trap heat radiation and warm the Earth's surface. As carbon dioxide, released by burning fossil fuels, and other trace gases are added to the atmosphere, significant changes in global climate are expected. Related studies are aimed at understanding humanity's impact on the stratospheric ozone layer, which shields us from harmful ultraviolet radiation.

Space Spinoffs

Among the greatest benefits of America's space exploration and aeronautics research programs are spinoffs. Goddard's Office of Commercial Programs has generated thousands of secondary applications that adapt new aerospace technology to an almost endless list of fields, including public safety, transportation, industrial processes and pollution control, medicine, energy systems, construction and law enforcement.

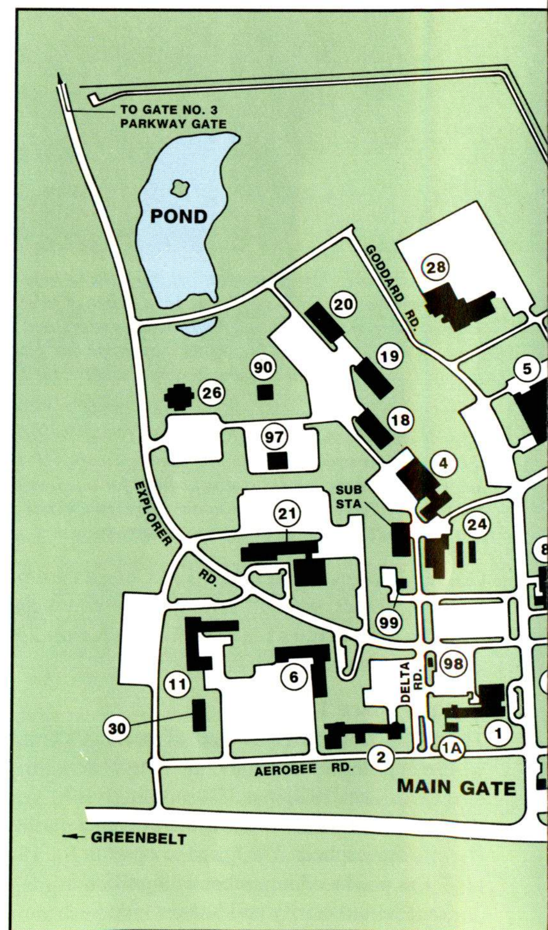
As we move toward the 21st century, Goddard looks forward to playing a continuing, significant role in our Nation's effort to expand knowledge of the Earth and its environment, the Solar System and the Universe. As it has done in the past, the Center will concentrate all its resources to assure that NASA and the United States remain number one in space!

Directions: From Washington, take the Baltimore-Washington Parkway north; from Baltimore, take the Baltimore-Washington Parkway south to Route 193 East. Remain on 193 for 2 miles. Goddard Space Flight Center is on the left.

Goddard Space Flight Center

Main Site Buildings

1 Space Projects Building, Cafeteria, Personnel, Travel, Security ID; GEWA
2 Research Projects Laboratory
3 Central Flight Control & Range Operations Building
4 Plant Operations Building
5 Instrument Construction & Installation Laboratory
6 Space Sciences Laboratory
7 Payload Testing Facility
8 Administration Building
9 Main Gatehouse
10 Environmental Testing Laboratory
11 Applied Sciences Laboratory
12 Tracking & Telemetry Laboratory
13 Network Control Center Facility
14 Spacecraft Operations Facility
15 High Capacity Centrifuge Facility
16 Logistic & Supply Facility Shipping & Receiving
16W Logistic & Supply Facility
17 Administrative Support Building, Safety Office, Bid Room



Goddard's Mission: "Space Research and Exploration"

For more than 32 years, NASA's Goddard Space Flight Center (GSFC) has been at the forefront of space research and exploration, carrying out many milestones in space achievements and helping lead the world to new knowledge about the Earth and the universe. The Center started in 1959 with 157 people from the Naval Research Laboratory Vanguard group. Today, there are more than 4,000 civil servants and 8,000 on-site contractor personnel directly involved in the work of the Center, located on a campus-like setting on 1,100 acres of rolling Maryland countryside just outside of Washington, D.C.

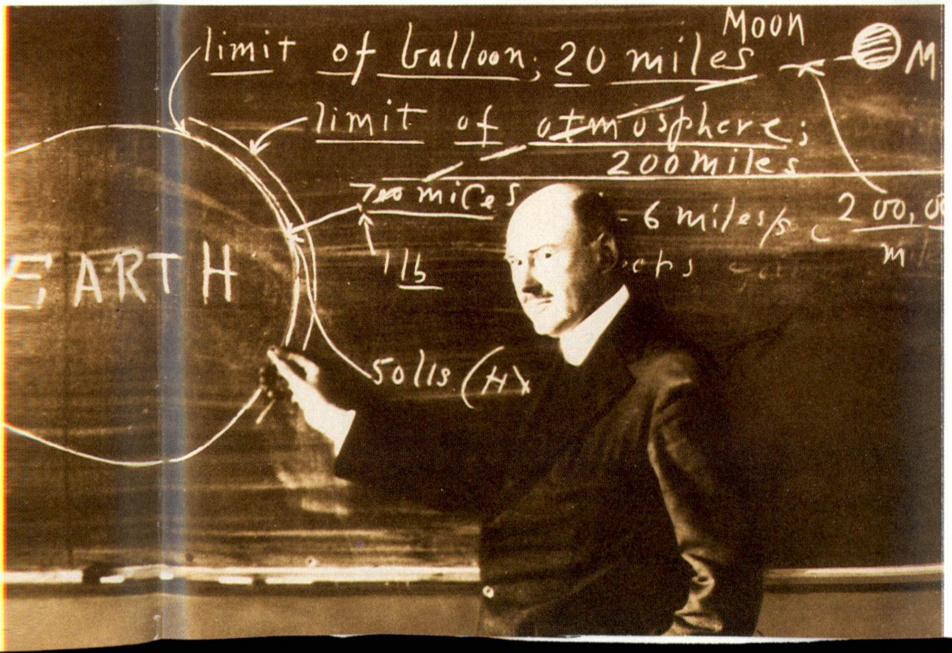
One of nine National Aeronautics and Space Administration (NASA) centers, Goddard is a unique facility that has personnel with the expertise that encompasses all phases of space missions: that is, to design, build and test spacecraft; to communicate with, track and operate satellites in orbit, and to analyze data from them. With its activities and facilities stretching literally around the world, Goddard has grown to a position of preeminence in a variety of scientific disciplines — ultraviolet and infrared astronomy, solar physics, high-energy astrophysics, planetology, climatology and Earth sciences — to name a few.

That scientific expertise is supported by a strong engineering staff that has generated many technological advancements in instruments, spacecraft and ground data systems, cryogenic sensors, lasers and spacecraft thermal systems.

Goddard has more scientists than any NASA center, and they work primarily in six laboratories on the Center where they specialize in everything from measuring the impact of a volcano on the atmosphere to conducting basic research on astronomy, the Earth and the space environment.

RIGHT: Dr. Robert Hutchings Goddard, for whom the Center is named, is considered to be the father of modern rocket propulsion. Along with Konstantin Tsiolkovsky, of Russia, and Hermann Oberth, of Germany, Goddard envisioned the exploration of space. A physicist of great insight, Goddard also had a unique genius for invention.

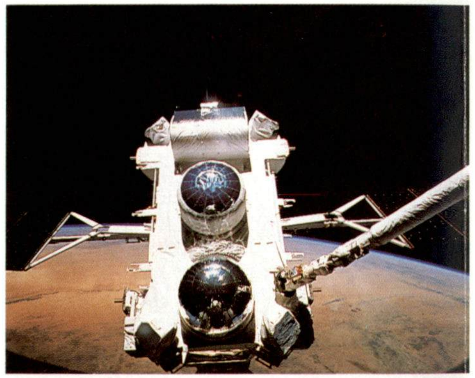
COVER: From concept to scientific data return, Goddard Space Flight Center (GSFC) is the NASA Center that can do it all. Top: A team studies data from one of Goddard's six scientific laboratories. Center: This antenna is one of the many that allow GSFC employees to communicate with the many satellites orbiting Earth. Bottom: Pictured is the Cosmic Background Explorer (COBE) one of the many satellites designed, built and tested by GSFC engineers, scientists and technicians. COBE was launched November 18, 1989 on a Goddard-managed Delta rocket.

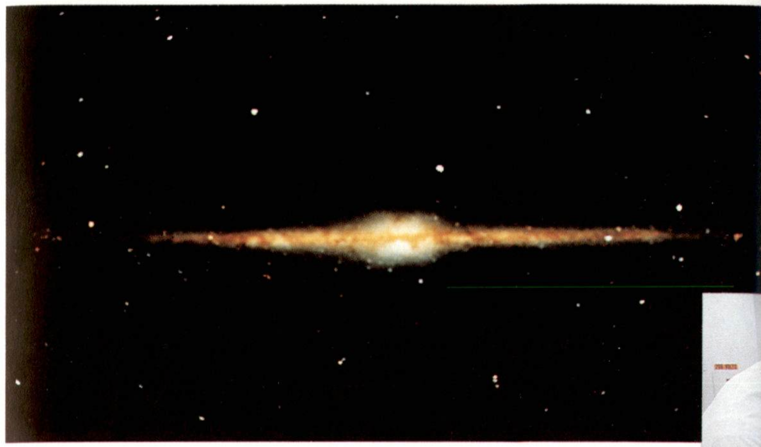


Pioneering Missions to Study Our World

Looking at the past, the Goddard team has compiled a mountain of scientific knowledge that has brought significant advancements to the world. Historically, the Center has been at the forefront of space progress. During its first three decades, the Center developed more than 40 satellites in-house, managed approximately 160 satellites for NASA, launched more than 170 payloads on Delta rockets, flew scientific payloads on more than 2,500 sounding rockets and 550 balloons and provided tracking, communications and data handling for all low Earth-orbiting satellites operated by NASA, including the space shuttles. It has had an active part in a number of significant space "firsts" including the first true meteorological satellite (TIROS) in 1960; the first passive communications satellite (Echo-1) in 1960; the first commercial satellite (Telstar) in 1962, and the first operational geosynchronous satellite (Syncom II) in 1963.

RIGHT: The Gamma Ray Observatory (GRO) hangs from the Remote Manipulator System (RMS) arm on Space Shuttle Atlantis during mission STS-37 in April 1991.





ABOVE: Goddard's Cosmic Background Explorer (COBE) provided this spectacular edge-on view of the Milky Way Galaxy.

RIGHT: The Microelectronics Laboratory of the Mission Operations and Data Systems Directorate is equipped with the latest technology, computer-aided design tools, an array of commercial processor boards and components. It provides the capability to develop systems in-house, from chip design to integration and test.

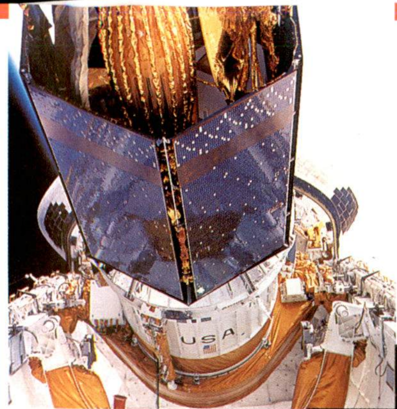
Goddard personnel were responsible for the first satellite to intercept a comet (International Cometary Explorer, 1985). Also, Goddard has launched the Landsat satellites that have resulted in a better understanding of Earth; Nimbus-7, which with its Total Ozone Mapping Spectrometer (TOMS), has brought revealing new information about the world's ozone; and the NOAA (National Oceanic and Atmospheric Administration) and GOES (Geostationary Observational Environmental Satellite) weather satellites that bring the pictures of the Earth's weather patterns to TV screens around the globe.

International Participation

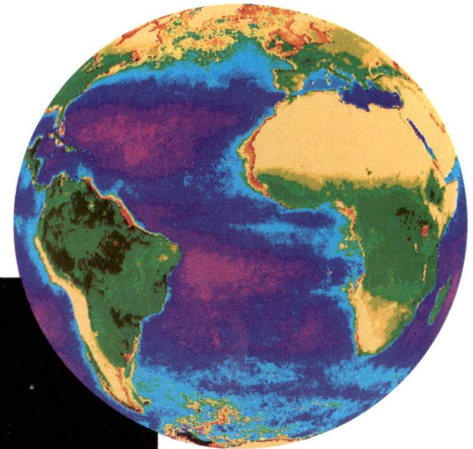
In addition, Goddard always has enjoyed a close working relationship with foreign nations. As a result, Goddard specialists have been involved with scientists and engineers from all countries with a space program of their own, providing advisory support in some cases or participating in joint ventures in others.

Recent Missions

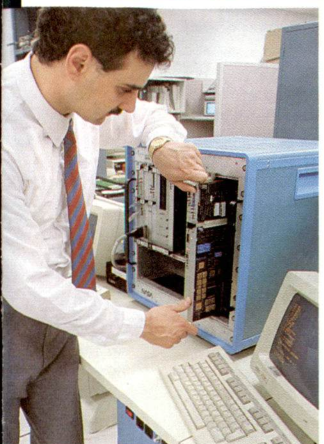
Some of the more recent Goddard missions include the Hubble Space Telescope (HST), the Gamma Ray Observatory (GRO), the Cosmic Background Explorer (COBE), and the Upper Atmosphere Research Satellite (UARS). In addition, Goddard manages the Tracking and Data Relay Satellite System (TDRSS), a constellation of communications satellites that maintains communications through a Goddard-operated ground terminal at White Sands, New Mexico, with Earth-orbiting satellites.



LEFT: The Tracking and Data Relay Satellite (TDRS), shown here in the space shuttle cargo bay just prior to deployment, is part of the Goddard-managed space tracking system that has significantly enhanced NASA's data communications capability.



ABOVE: NASA's Mission to Planet Earth is a program designed to produce the understanding needed to predict changes in the Earth's environment. The centerpiece of Mission to Planet Earth is Goddard's Earth Observing System (EOS) project and its Earth Observing System Data and Information System (EOSDIS).



ABOVE RIGHT: The first polar orbiting platform for the Earth Observing System (EOS) will carry a number of scientific instruments. This spacecraft will help scientists better understand the physical, chemical and biological processes that shape our global environment. The EOS platform will be managed by Goddard for NASA.

RIGHT: The Mission Operations Room (MOR) of the Space Telescope Operations Control Center (STOCC) at Goddard links astronomers on Earth with the orbiting Hubble Space Telescope (HST). As NASA's largest and most complex control center for a scientific satellite, the STOCC enables astronomers to obtain research data with HST much as they would from a large ground observatory.

Goddard serves as the heartbeat of space communications, as a matter of fact, sending commands to and receiving data from up to as many as 20 orbiting spacecraft 24-hours-a-day, seven days a week, 365-days-a-year.

Hubble Space Telescope

The Hubble Space Telescope's Operations Control Center, where engineers control the orbiting observatory, is located at Goddard. The HST, in a 380-mile-high (611 km) orbit, permits astronomers to view the universe unobscured by the Earth's atmosphere. Designed to operate for 15 years, the HST has produced a number of significant images with unprecedented clarity and has provided astronomers with exciting scientific data.

The Hubble Space Telescope and the Gamma Ray Observatory, along with the Advanced X-Ray Astrophysics Facility (AXAF) and the Space Infrared Telescope Facility (SIRTF) comprise NASA's four "Great Observatories," which are designed to provide scientists with unprecedented information about our universe from the entire electromagnetic spectrum.

In the past, Goddard's work has been involved primarily with space studies. In the future, the concentration will be more on Earth studies. As a matter of fact, because of a program that Goddard will manage known as the Earth Observing System, or EOS, Goddard quite likely will become the focus of the world's attention on Earth sciences.

Earth Observing System (EOS)

The EOS mission is the centerpiece of NASA's Mission to Planet Earth program, which, in turn, is part of a national effort involving a number of government agencies known as the Global Change Research Program.

To understand what impact natural and human activity will have on our planet, scientists must develop a better knowledge of how the Earth works as a system—the atmosphere, the oceans and the land. These forces now are recognized to be closely associated in shaping the Earth's weather and climate. However, the fundamental questions of how the system works remain unanswered.

Goddard will manage the EOS, a series of orbiting platforms or observatories launched over a 15-year period to collect data on a wide variety of environmental components; and the Earth Observing System Data and Information System (EOSDIS) which will gather and process the data from EOS for subsequent use by scientists worldwide. The first launch of an EOS observatory is scheduled for 1998.

Goddard also will participate in an Earth Probes program, complementary to EOS, which will use smaller platforms to make critical observations not made by the larger EOS observatories.

In the meantime, Goddard missions planned for earlier launch are expected to collect data that will play a significant role in providing information for the more comprehensive EOS data collections in the late 1990s.

EOS Missions

Among these missions are the Upper Atmosphere Research Satellite (UARS), the Extreme Ultraviolet Explorer (EUVE), Laser Geodynamic Satellite (Lageos II), the Total Ozone Mapping Spectrometer (TOMS) and the Tropical Rainfall Measuring Mission (TRMM).

UARS will provide a detailed study of the Earth's atmosphere and establish a comprehensive data base for an understanding of the ozone depletion. EUVE will map the universe to determine the existence, direction, brightness and temperature of numerous objects which are sources of extreme ultraviolet radiation. Lageos II, a joint venture with Italy, is designed to improve measurements of the Earth's motions and to help understand earthquakes.

Several TOMS missions are planned to supplement the TOMS that was recently launched aboard a Soviet Spacecraft and the TOMS on Nimbus-7. TRMM will make important measurements of variations in precipitation and evaporation in the tropics.