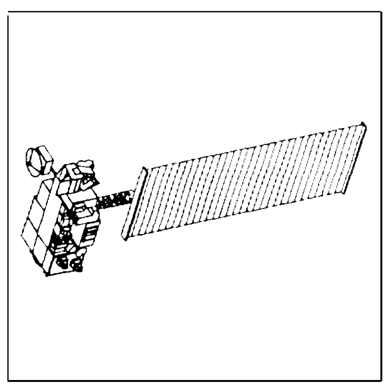
Remote Sensing and the U.S. Future in Space 2

Civilian satellite remote sensing has demonstrated its utility to a variety of users. Its future will depend on how well the systems meet the needs of data users for:

- monitoring the global environment;
- long-term global change research and assessment;
- monitoring and managing renewable and nonrenewable resources;
- mapping, charting, and geodesy; and
- national security purposes.

The future of satellite remote sensing will also be closely tied to the overall direction and strategy of the U.S. civilian and military space programs, which are changing in response to broadening U.S. political and economic agendas. The National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), Department of Defense (DoD), and the Departments of Interior (DOI), Agriculture (DOA), and Energy (DOE), maintain substantial expertise in remote sensing. **The diversity of remote sensing applications in government and the private sector, and the potential conflict between public and private goods greatly complicate the task of establishing a coherent focus for space-based remote sensing programs.**



THE CHANGING CONTEXT OF SATELLITE REMOTE SENSING

For the past several years, representatives from government, industry, and academia have engaged in a vigorous debate over the future of America's civilian space program.[1] This debate, spurred in part by the end of the Cold War and other dramatic changes in the world's political, economic, and environmental fabric, has reaffirmed the fundamental tenets of U.S. civilian space policy, first articulated in the National Aeronautics and Space Act of 1958. Participants in this debate have generally agreed that publicly supported U.S. space activities should:

- demonstrate international leadership in space science, technology, and engineering;
- contribute to economic growth;
- enhance national security;
- support the pursuit of knowledge; and
- promote international cooperation in science.[2]

Policymakers further agree that U.S. space activities should:

- include consideration of commercial content;[3] and
- support research on environmental concerns, including the U.S. Global Change Research Program.4

In addition, policymakers have generally supported the four major program elements of U.S. civilian space efforts-space science, environmental observations conducted from space, maintaining a piloted space transportation program, and developing a permanent human presence in space. However, policymakers continue to debate, primarily through the budget and appropriations processes, how much to invest in space activities relative to other federally funded activities, and what weight to give each element of the U.S. space program.[5] The yearly distribution of priorities within the overall civilian space budget will have a marked effect on how much benefit the United States will derive from remote sensing activities.

For most of the first three decades of the U.S. space program, weather monitoring and military reconnaissance have exerted the primary influences on remote sensing planning and applications. More recently, worldwide concern over the degradation of local environments and the increasing threat of harmful global change from anthropogenic causes have begun to influence the direction of the U.S. space program. Scientists disagree over the magnitude of potential global change, its possible consequences, and how to mitigate them. Yet they do agree that future environmental changes could affect the global quality of life and threaten social structure and economic viability. Because adaptation to, and remediation of, environmental change could be expensive, predicting the extent and dynamics of change is potentially very important. Scientists face two major impediments in attempting to understand whether harmful global change is occurring and, if so, how to mitigate its effects: large uncertainties in existing climate and environmental models, and large gaps in the data that support these predictive models. Hence, the United States has decided to increase the funding allocated to characterizing and understanding the processes of global environmental change.

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[1] See, for example: Vice President's Space Policy Advisory Board, *A Post Cold War Assessment of U.S. Space Policy* (Washi.ngtom DC: The Wbite House, December 1990); Advisory Committee on the Future of the U.S. Space Program, *Report of the Advisory Com"ttee on the Future of the U.S. Space Program* @%shingtom DC: U.S. Government Printing OffIce, December 1990).

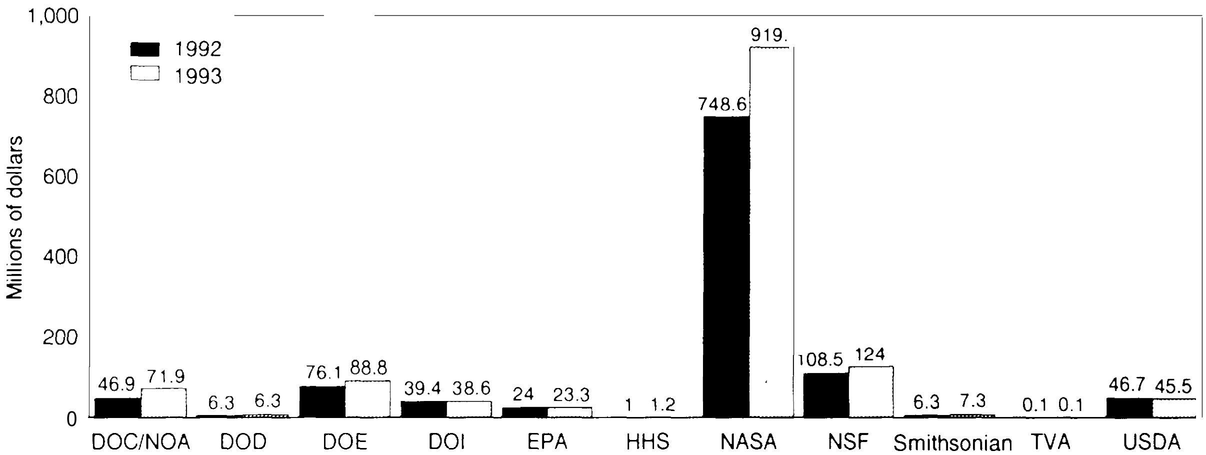
[2] *The National Aeronautics and Space Act of 1958* (Public Law 85-568), Sec. 102.

[3] 1986 amendment to the National Aeronautics and Space Act of 1958; *A Post Cold War Assessment of U.S. Space Policy,* op. cit.; *Repon of the Advisory Committee on the Future of the U.S. Space Program,* op. cit.

4 A *post cold warAsses~nt Of U.S. Space Policy;* op. cit.; *Report of the Advisory Cow"tree on the Future of the U.S. Space program,* op. cit.

[5] Note, for example, that funding for space *station Freedom has survived three* major attempts within Congress to terminate it. Opponents of the space station have vowed to continue their efforts to terminate the space station program in the 103d Congress.

Figure 2-1—1992 and 1993 U.S. Global Change Research Program Budgets, **by Agency**



KEY: DOC/NOAA–Department of Commerce/National Oceanographic and Atmospheric Administration; DOD–Department of Defense; DOE–Department of Energy; DOI–Department of Interior; EPA–Environmental Protection Agency; HHS–Health and Human Services; NASA–National Aeronautics and Space Administration; NSF–National Science Foundation; Smithsonian–Smithsonian Institution; TVA–Tennesee Valley Authority; USDA–US Department of Agriculture.

SOURCE: U.S. Global Change Research Program.

Several Federal agencies are involved in gathering global change data and/or analyzing them to provide environmental information. The U.S. Global Change Research Program (USGCRP) was organized to coordinate the Federal global change research effort and give it focus and direction. The interagency Committee on Earth and Environmental Science (CEES) oversees the development and implementation of USGCRP.[6] CEES was established to advise and assist the Federal Coordinating Council for Science, Engineering Sciences, and Technology (FCCSET) within the White House Office of Science and Technology Policy. For fiscal year 1993, Congress appropriated $1.327 billion among Federal agencies for global change research (figure 2-1).7 NASA's spending on global change research equals about 69 percent of this total. Thus, **in budget terms, NASA has become the de facto lead agency for global change research. In large** part this follows from the fact that space systems are inherently costly to build, launch, and operate.

Because space-based remote sensing offers a broad scale, synoptic view and the potential to create consecutive, consistent, well-calibrated data sets, it provides a powerful means of gathering data essential to understanding global environmental change. Space-based remote sensing also contributes substantially to general progress in the Earth sciences necessary to model environmental processes and interpret observed environmental changes. However, sensors based on satellite platforms have significant limitations of spatial resolution, flexibility, and timeliness. For many important global change research questions, sensors mounted on airborne platforms and surface facilities provide data much more effectively or efficiently (see app. B). Thus, the space component is only one aspect of these activities, and must be planned in conjunction with the other components as an integrated data collection system.

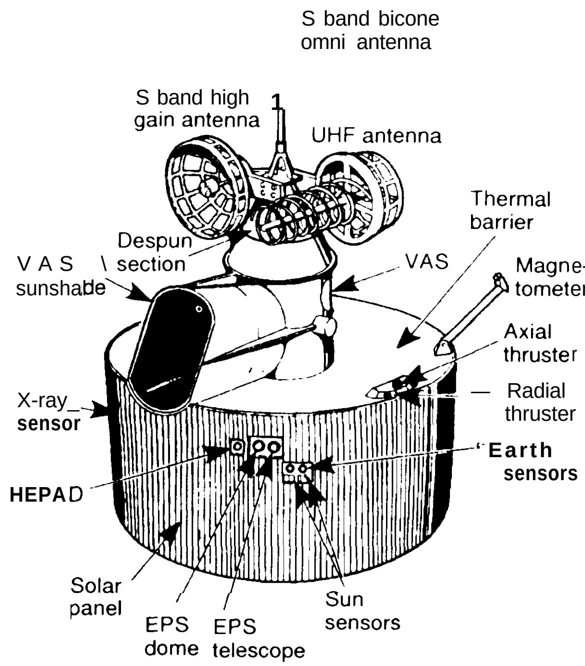
[6]Through its Subcommittee on Global Change Research.

[7]The President's Budget called for devoting $1.372 billion to global change research programs. The appropriated level for fiscal year 1992 w&i $1.11 billion.

NOAA'S ENVIRONMENTAL EARTH OBSERVATIONS

NOAA's operational meteorological satellite systems, managed by the National Environmental Satellite, Data and Information Service (NESDIS), consist of the Geostationary Operational Environmental Satellites (GOES—figure 2-2) and the Polar-orbiting operational Environmental Satellite (POES), also referred to as the Television InfaredObserving Satellites (or TIROS —see figure 2-3). GOES satellites, which orbit at geostationary altitudes,[8] provide both visible-light and infrared images of cloud patterns, as well as "soundings," or indirect measurements, of the temperature and humidity throughout the atmosphere. NOAA has been operating GOES satellites since 1974. Data from these spacecraft provide input for the forecasting responsibilities of the National Weather Service, which is also part of NOAA. Among other applications, the GOES data provide advance warning of emerging severe weather, as well as storm monitoring.

Figure 2-2—The Geostationary Operational Environmental Satellite



SOURCE: Loral Corp.

The POES satellites, which circle Earth in low polar orbits,[9] provide continuous, global coverage of the state of the atmosphere, including elements of the weather such as atmospheric temperature, humidity, cloud cover, and ozone concentration; surface data such as sea ice and sea surface temperature, and snow and ice coverage; and Earth's energy budget. The National Weather Service also uses these satellite data to create its daily weather forecasts.

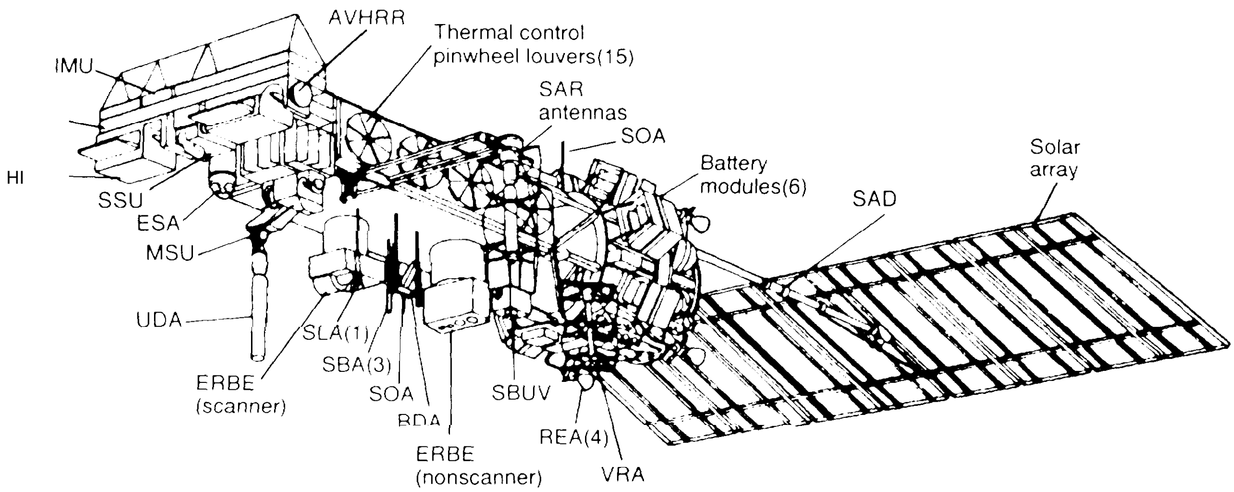
Data from both satellite systems also contribute to the long-term record of weather and climate, maintained by NOAA in its archives.[10] The data that NOAA has already collected and archived constitute an important resource for the study of global change. NOAA and NASA have begun to assemble data sets from these archives for use in global change research projects. However, the data are also limited because the satellite instruments are not calibrated to the level required for detecting subtle changes in global climate, or minute environmental responses to climate change. If future sensors aboard NOAA's satellites were to incorporate better calibration techniques, they could make more substantial contributions to global change research. **If Congress believes it is important to improve the utility of data gathered from the NOAA sensors for**

[8] Oeostationary orbit is a special case of the geosynchronous orbi~ in which satellites orbit at the same rate as any point on Earth's equator. A geostationary satellite appears to maintain the same position above the equator throughout a 24-hour cycle, and is therefore able to monitor weather conditions within its field of view on a continuous basis.

s Satellites in polar orbit circle in orbits that pass over the poles. They are therefore capable of gathering data from the entire surface as the Earth spins on its axis. The revisit period of these satellites depends on the altitude at which they orbit and the field of view of the sensing instrument.

10 m,pm NOAA wcmws are Natiod Climatic Data Center, Asheville, NC; National Oceanographic Data Center, Washingto% DC; and National Geophysical Data Center, Boulder, CO.

Figure 2-3-NOAA-9, One of the Polar-Orbiting Operational Satellite Series



NOAA has launched 12 satellites in this series, also known as the TIROS satellites. NOAA-9 is only partially operational, but its Earth Radiation Budget Sensor (ERBE) continues to provide information to climate researchers.

SOURCE: Martin Marietta Astro Space.

global change research it may wish to direct NOAA to plan for sensors with more sensitive calibration. Because improved calibration would require moderate additional cost, Congress would also need to increase NOAA's budget for satellite procurement and operation.

The term "operational" applied to NOAA's satellite systems refers primarily to the way in which they are managed. Such systems have a large established base of users who depend on the regular, routine delivery of data in standard formats. Significant changes in data format or in the types of data delivered can mean great expense for these users. Gaps or loss of continuity in the delivery of data may also have a substantial negative economic impact. Research satellite systems, on the other hand, generally have short-term (3 to 5 years) commitments from agencies, and have a much smaller base of users. Because these users may also directly contribute to instrument design, they are more able to adjust to major changes in data format.

DEFENSE METEOROLOGICAL SATELLITE PROGRAM

The Air Force Space Command operates the Defense Meteorological Satellite Program (DMSP—figure 2-4), to support DoD's special needs for weather data. DMSP employs a satellite platform very similar to the NOAA POES system, and operates in near-polar orbit, but carries somewhat different instruments.

Critics of the policy of maintainingg separate polar orbiting systems argue that the United States cannot afford both systems.[11] DoD and NOAA counter that each satellite system serves a unique mission. The NOAA satellites routinely provide data to thousands of U.S. and international users. DMSP serves a variety of specialized military needs and provides valuable microwave data to the civilian community. Previous attempts to consolidate the two systems have resulted in increased sharing of data and other economies. However, because of the different requirements

11 U.S. Congress, General Accounting Office, NSIAD 87.107, *U.S. Weather* Satellites: *Achieving* Economies *of Scale* (Washington, DC: U.S. Government I%nting Office, **1987).**

for data from the two existing systems, such efforts have not led to an integrated system.

Congress may wish to revisit the question of the possible consolidation of DMSP and the NOAA polar orbiting system as it searches for ways to reduce the Federal deficit. Such a study should look for innovative ways for NOAA and DoD to work in partnership to carry out the base missions of both agencies.

NASA'S MISSION TO PLANET EARTH

In conjunction with its international partners, the United States plans a program of civilian Earth observations to provide, by the early years of the next century, the comprehensive collection of data on resources, weather, and natural and human-induced physical and chemical changes on land, in the atmosphere, and in the oceans. These programs are unprecedented in both their scope and their cost.

NASA's Earth Observing System (EOS) of satellites is the centerpiece of NASA's Mission to Planet Earth. It is being designed to provide continuous high-quality data over 15 years[12] that can be related to the scientific study of:

1. large-scale transport of water vapor;
2. precipitation;
3. ocean circulation and productivity;
4. sources and sinks of greenhouse gases (gases such as carbon dioxide and methane that contribute to greenhouse warming) and their transformations, with emphasis on the carbon cycle;
5. changes in land use, land cover, and the hydrology and ecology of the land surface;
6. glacier and polar ice sheets and their relationship to sea-level;
7. ozone and its relationship to climate and the biosphere; and
8. the role of volcanic activity in climate change.

EOS planners expect these data to assist in understanding and monitoring the physical, chemical, and biological processes of global change, predicting the future behavior of Earth systems, and assessing how to react to global change.

Measurements of these global change processes can be divided into two types:[13]

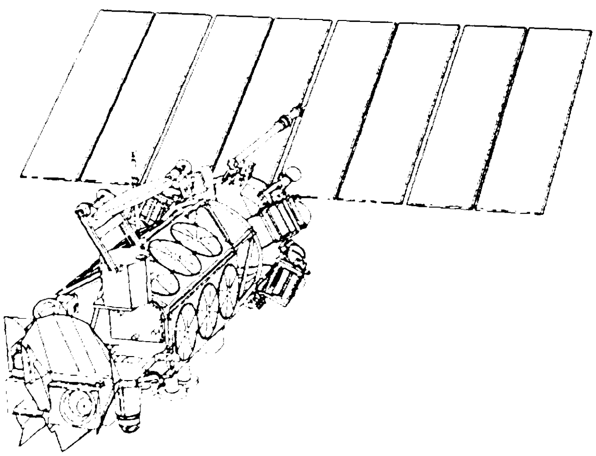
1. Long-term monitoring-to determine if climate is changing, to distinguish anthropogenic from naturally induced climate change, and to determine global radiative forcings and feedback.
2. ''Process" studies-detailed analysis of the physics, chemistry, and biology that govern processes ranging from the formation of the Antarctic ozone hole to the gradual migration of tree species.

Some scientists have raised concerns over 1) whether the EOS program as currently configured is optimally designed to perform these different missions, 2) whether the EOS program will address the most pressing scientific and policy-relevant questions, and 3) whether important data on issues such as global warning will be available soon enough to assist policymakers. EOS program officials point to repeated and extensive reviews by interdisciplinary panels in the selection of instruments and instrument platforms as evidence that their program is properly focused. The central role of the EOS program has resulted in a USGCRP budget that is heavily weighted toward satellite-based measurements. As a result, some researchers express concern that:

12 To *achieve* 15-year data sets, EOS ' *'AM' and* "PM' platforms would be flown 3 times (the nominal lifetime of these platforms is 5 years). Scientists expect that 15 years will be long enough to observe the effects of climate change caused by the sunspot cycle (1 1 years), several El Nines, and eruptions of several major volcanoes. This period would be sufficient to observe the effects of large-scale changes such as deforestation. Scientists are less certain whether it will be possible to distinguish the effects of greenhouse gases on Earth's temperature from background fluctuations.

13 See app. B for more details of the distinction between these hVO types of data.

Figure 2-4-A Defense Meteorological Satellite



These satellites are similar to the NOAA satellite shown in figure 2-3, although the sensor suite is somewhat different.
SOURCE: Department of Defense.

1. The limitations of satellite-based platforms will prevent process-oriented studies from being performed at the level of detail that is required to address the most pressing scientific questions;
2. Continuous long-term (decadal time-scale) monitoring is at risk, because of the high-cost, long lead times, and intermittent operations that have historically characterized the design, launch, and operation of multi-instrument research satellites.

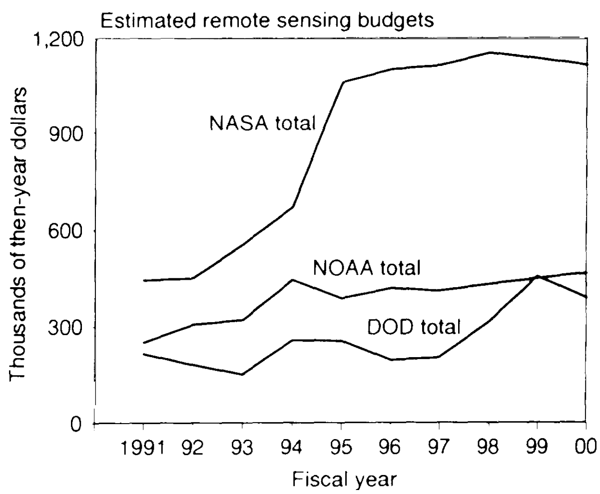
According to those holding these views, a more balanced EOS program would provide greater support for small satellites, and a more balanced USGCRP program might include greater support for groundbased measurement programs, including ocean measurement systems, and alternative sensor platforms, such as long-duration, high-altitude UAVS. **Greater support for complementary non-space-based elements of the USGCRP could be provided either by redirection of already tight NASA budgets, or from greater support for the USGCRP from the DOE, DoD, and other relevant departments and agencies. If Congress wishes to improve U.S. efforts in global change research it could direct each agency to provide explicit support for data that would complement the data gathered by satellite. This** may require a few tens of millions of dollars of additional funding annually between now and the end of the century. Such additional funds would be quite small compared to the $8 billion EOS program, but would vastly enhance the value of the data from the EOS satellites.

Redirecting funds from within the EOS program would be extremely difficult because the program has already experienced two significant reductions of scope since Congress approved it as anew start in fiscal year 1991. At the time, NASA had estimated it would need about $17 billion between 1991 and 2000 to complete the first phase of its EOS plans. Concerns over NASA's plans to rely on a few extremely large, expensive satellite platforms,[14] and funding uncertainties, caused Congress in the fiscal year 1992 appropriations bill to instruct NASA to plan on receiving only $11 billion during the first phase of EOS.[15] Although this restructuring led to the cancellation of some instruments and a deferral of others, it generally resulted in a lower risk science program that is more heavily focused on climate change. When, during 1992, the magnitude of likely future constraints on the Federal budget became clear, Congress further reduced planned spending for the frost phase of EOS to $8 billion. The congressional action was consistent with an internal NASA effort to reduce the costs of its major programs by about 30 percent. This second reduction of scope has led NASA to cancel additional instruments, increase reliance on foreign partners to gather needed global change data, cut the number of initial data products, and reduce program reserves. Reduction of reserves for instrument design and construction will increase

14 *Report of the Earth Observing Systems (EOS) Engineering Review Committee*, Edward Frieman, chairman, September 1991.

15 See ch. 5, Global Change Research, for a more detailed account of these congressional ftCtiOm.

Figure 2-5—Remote Sensing Budgets for NASA, NOAA and DoD



SOURCE: NASA, NOAA, DoD.

the risk that the EOS instruments will not achieve their planned capability. Further reductions in funding for the EOS program are likely to constrain **EOS scientists and sharply reduce their flexibility to follow the most important global change science objectives.**

Because NASA expects to operate the EOS satellites and its EOS Data and Information System (EOSDIS) for at least 15 years after the launch of the second major satellite in 2000, the program will necessarily take on the characteristics of what has been called an "operational program"—sustained, routine acquisition of data that must be routinely available to researchers and other users on a timely basis. **In order to achieve maximum effectiveness, NASA's EOS program must be organized and operated with great attention to the regular, timely delivery of data.**

Between now and the end of the century, when the first EOS satellites begin to transmit data to Earth, NASA scientists will rely on a series of Earth Probes and other satellites, including NASA's Upper Atmosphere Research Satellite, the U.S./French TOPEX/Poseidon, Landsat, and the NOAA operational satellites for global change data. The data from these systems will be critical for early understanding of certain atmospheric and ecological effects.[16]

NASA'S REMOTE SENSING BUDGET

The Federal budget for building and operating existing and planned civilian satellite remote sensing systems is spread across three agencies —DoD, NASA, and NOAA-but most funds are in NASA's budget (table 2-1 and figure 2-5). Examining NASA's budget for remote sensing activities in the context of its other program commitments reveals that the disparity between NASA's plans and its expected future funding is still growing, despite NASA's recent efforts to reduce its funding gap by reducing the size of EOS, space station, and space shuttle. NASA has projected an overall budget increase of 13 percent between fiscal year 1993 and fiscal year 1996 (figure 2-6, table 2-2). Should anticipated funding not materialize, NASA will have little budget flexibility to respond to unforeseen problems in its Mission to Planet Earth programs.[17]

The large yearly Federal deficit has created pressure to save money in the discretionary portion of the Federal budget. Civilian space activities account for about 2.8 percent of U.S. discretionary budget authority in fiscal year 1993.[18] In appropriating NASA's funds for fiscal year 1992, the House and Senate stated that NASA, which receives the lion's share of the

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16 Ibid.

17 Several observers have criticized NASA'S earlier budgeting as highly unrealistic. U.S. Congress, General Accounting Office GAO/NSIAD-92-278, *NASA: Large Programs* May Consume *Increasing Share of Limited Future Budgets* (Washington, *DC:* U.S. General Accounting Office, September 1992). Ronald D. Brunner, ''Overmnm.it.rmmt at NASA,'' presented at the annual American Astronautical Society Conference, San Francisco, CA, December, 1992.

18 The discretionary portion of the fiscal year 1993 federal budget request was $502 billion.

Table 2-1—Estimated Federal Budgets for Space-Based Remote Sensing Systems: Fiscal Years 1991- 2000 (millions of then-year dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NASA Total	**445.0**	**451.9**	**572.5**	**692.5**	**1,056.9**	**1,099.3**	**1,111.9**	**1,152.0**	**1,134.0**	**1,114.7**
EOS	134.6	145.0	218.8	275.6	519.8	555.3	623.0	671.0	667.0	632.4
EOSDIS	36.0	77.7	130.7	182.7	316.7	360.8	329.4	370.6	368.7	381.8
Landsat		7.5	25.0	59.1	61.0	48.0	30.0	32.0	34.0	36.0
Other MTPE systems	274.4	221.7	198.0	175.1	159.4	135.2	129.5	78.4	64.3	64.5
NOAA Total	**251.0**	**305.8**	**319.5**	**444.8**	**387.6**	**418.9**	**411.6**	**431.0**	**448.1**	**466.0**
Total polar	50.3	130.3	153.9	203.5	184.3	252.3	270.3	261.8	272.3	283.2
Total geostationary	108.5	118.0	118.0	191.8	151.8	113.0	85.6	111.3	115.6	120.2
Observing services	57.6	55.5	47.6	49.5	51.5	53.6	55.7	57.9	60.2	62.6
Landsat	34.6	2.0								
DoD	**214.7**	**179.7**	**149.9**	**255.4**	**253.2**	**194.1**	**202.4**	**312.1**	**455.2**	**389.0**
Landsat 7		30.0	80.0	158.0	134.0	52.0	6.0	2.0	2.0	2.0
DMSP	214.7	149.7	69.9	97.4	119.2	142.1	160.4	213.1	262.2	225.0
Landsat 8							36.0	97.0	191.0	162.0
Total	**910.7**	**937.4**	**1,041.9**	**1,392.7**	**1,697.7**	**1,712.3**	**1,725.9**	**1,895.1**	**2,037.3**	**1,969.7**

NOTES: Funds for research use of data are not included.

All 1995-2000 figures are unofficial preliminary estimates.

NASA EOS budget reflects subtraction of "EOS Science" component.

NASA "Other MTPE Systems" reflects the subtraction of MTPE Science, Research Operations Support, ACTS, EOS, EOSDIS, and Landsat from the total MTPE Budget (represents all other MTPE space system development).

NOAA 1999-2000 polar & geostationary budgets are level-funding extrapolations based on 4% inflation adjustments to 1998 estimates.

NOAA Observing Services budget for 1994-2000 is a level-funding extrapolation based on 4% inflation adjustments to 1993 appropriation.

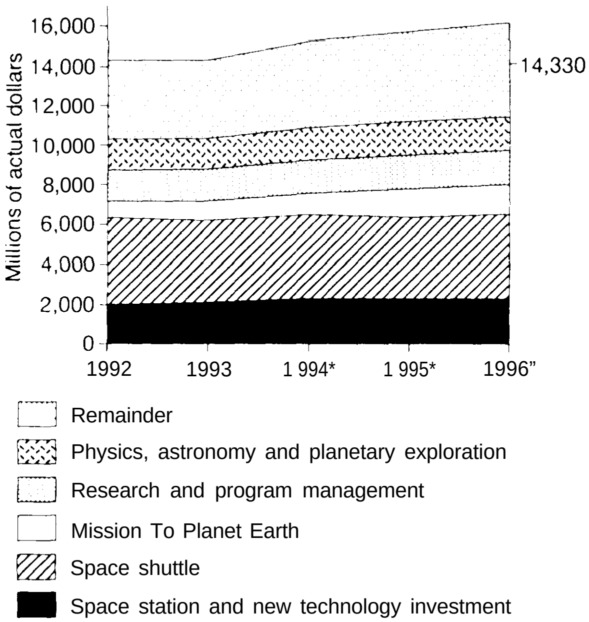
DoD Landsat budgets are from the National Land Remote Sensing Policy Act of 1992 Report 102-539.

Landsat 8 construction, according to present policy, will be performed by DoD, NASA, and/or NOAA. Landsat 8 funding is represented by the addition of then-year dollars, equivalent to the Landsat 7 development budget, to the "Landsat 8" line, beginning in 1997 (adjusted to 4% yearly inflation).

DMSP budget for 2000 is an OTA extrapolation.

SOURCE: National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, and Department of Defense, 1993.

Figure 2-6—NASA's Budget Projections Call for a 13 Percent Budget Increase Between 1993 and 1996



"Estimates

Large programs constitute most of NASA'S budget, leave littte flexibility, and require a 13 percent budget increase between FY93 and FY96.

SOURCE: NASA Budget Estimate, Fiscal Year 1994.

civilian space budget, should expect only modest annual increases in its overall budget.[19] Independent reviews of NASA's budget prospects also suggest that NASA may face lower future budgets.[20] NASA's budget in fiscal year 1992 was **$14.334 billion,** a **3.4** percent boost over the fiscal year 1991 budget (table 2-2).[21] For fiscal year 1993, however, NASA's budget is $14.330 billion. The Clinton Administration is requesting $15.265 billion for **NASA** for fiscal year 1994, a one billion dollar increase over the 1993 appropriation.[22]

Figure 2-6 illustrates the required budget increase for NASA's program plan. A level budget (in current year dollars-i.e., one that decreases as inflation rises), or a budget that is increased only slightly, would produce a significant gap between available funding and program needs.

Yearly budgets for MTPE may reach more than 9 percent of NASA's total budget by 1995 (figure 2-7). If NASA neither receives large budget increases nor further reduces the content of its plans,[23] competition **for funds within NASA'S budget may force difficult choices among Mission to Planet Earth and other major projects, including those supporting the human presence in space.** For example, maintaining NASA's four largest programs at planned levels under a flat agency budget of $14.3 billion in fiscal year 1996 would require a 30 percent reduction in the rest of NASA's programs for that year.

The primary competition for funding within NASA is likely to be with programs supporting the human presence in space, which today consume more than 70 percent of NASA's budget for

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19 "The conferees concur in the Senate language enumerating a series of principles designed to adjust NASA's expectations and strategic plarming to leaner budget allocations in the coming years. ' Conference Report on the 1992 Appropriations for the Veteran's Administration Housing and Urban Development, and Independent Agencies, House of Representatives Report 102-226 (to accompany H.R. 25 19), Sept. 27, 1991, p. 54. The Senate language directs that "the agency should assume no more than 5 percent actual growth in fiscal year 1993:" Senate Report 102-107, July 11, 1991 (to accompany H.R. 2519), p. 130.

20 For example, the Electronic Industries Association forecasts that NASA's budget will drop by about 8 percent in real terms over the next 4 years. Electronics Industries Association, *Twenty-Eighth Annual EIA Ten-Year Forecast of DoD and NASA Budgets* (Washington DC: Electronics Industries Association October 1992).

21 Congress appropriated $14.352 billion for the NASA fiscal year budget but later rescinded $18.4 million from Climsat and other projects.

22 The amount of this request is similar t. the previous administration's request of $14.993 billion for fiscal year 1993, which Congress reduced substantially.

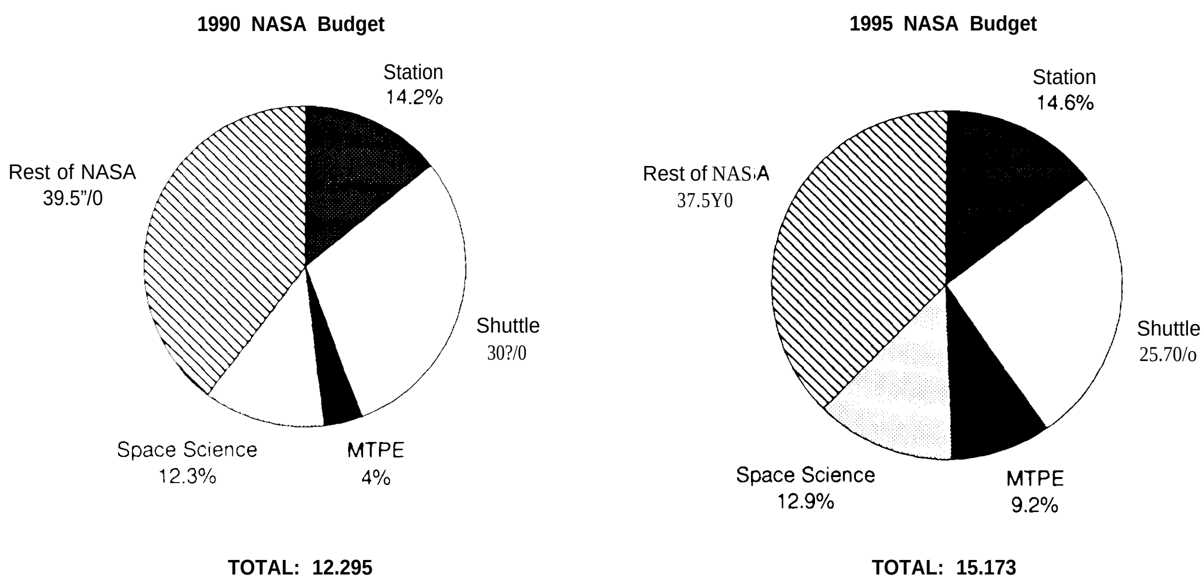
23 Schedule stretchouts that fail t. reduce program commitments only increase the total budget for a project and create a "bow wave' of future budget needs,

Table 2-2—NASA Budgets (millions of then-year dollars)

	1991	1992	1993 Estimate	1994 Request	1995 Estimate	1996 Estimate
Space Station (and new technology)	1,900.0	2,002.8	2,122.5	2,300.0	2,300.0	2,300.0
Space transportation capability development	602.5	739.7	649.2	649.2	643.3	639.0
Mission to Planet Earth..................	662.3	828.0	937.9	1,074.9	1,448.1	1,508.4
Physics and Astronomy & Planetary Expiration	1,442.9	1,570.9	1,577.5	1,631.9	1,709.1	1,676.0
Life Sciences and Space Applications......	325.9	314.7	350.6	351.0	320.7	282.0
Commerciai programs	88.0	147.6	164.4	172.0	141.4	132.7
Aeronautical, Transatmospheric, and Space research & technology ....:.....	893.9	1,101.5	1,138.3	1,398.9	1,528.1	1,650.9
Safety, QA, academic programs, tracking and data advanced systems	108.1	122.4	148.9	134.4	145.1	152.3
Shuttle production & operations...........	4,066.4	4,325.7	4,069.0	4,196.1	4,042.7	4,201.5
Expendable launch vehicle services	229.2	155,8	180.8	300.3	313.7	363.4
Space communications	828.8	903.3	836.2	820.5	1,014.6	1,093.3
Construction of facilities.................	497.9	531.4	525.0	545.3	387.2	375.0
Research & program management	2,211.6	1,575.8	1,615.0	1,675.0	1,703.0	1,752.0
Inspector general	10.5	13.9	15.1	15.5	16.0	16.5
Agency summary	13,868	14,334	14,330	15,265	15,713	16,143

SOURCE: National Aeronautics and Space Administration, 1992, 1993.

Figure 2-7-Composition of NASA's Budget, 1990 and 1995



Note the growth of NASA's major programs, including Mission to Planet Earth, which increase to neariy 9 percent of total budget.

SOURCE: NASA Budget Estimate, Fiscal Year 1994; Fiscal Year 1992.

space activities,[24] primarily though the space shuttle and space station *Freedom* programs.[25] Hence, if NASA'S overall budget remains flat or includes **only modest growth, unexpected future increases in either of these two large programs could squeeze MTPE to the point that its effectiveness to support global change research would be severely reduced.** Extremely stringent budget conditions would put Congress and the Clinton administration in the position of having to choose between a robust program that tracks global change and manages Earth resources and a program that supports human presence in space.

The risk of budget surprises related to the support of humans in space is relatively high. As noted in an earlier OTA report, ''The United States should expect the partial or total loss of one or more shuttle orbiters some time in the next decade [i.e., the 1990s]."[26] As experienced after the failure of *Challenger in 1986, the* costs of such a loss could reach several billion dollars, even neglecting the costs of repairing or replacing the damaged orbiter.[27] Losing an orbiter would almost certainly delay construction of a space station, causing much higher costs to that program.

Additional budget pressures on MTPE could lead to the use of fewer advanced sensors and other subsystems, or to technology choices that would raise system operating costs. They could also lead to smaller investments than planned in the distribution and analysis of MTPE data. Furthermore, satellite research and development (R&D) projects, like most other efforts that involve signficant technology R&D, tend to grow in cost beyond initial estimates as engineers and scientists face the complexities of design and production, and delays that are beyond the control of the project directors.[28] Cost growth *within the* MTPE satellite development and/or operations programs also would probably reduce the quality or quantity of scientific observations NASA is able to accomplish.

Figure 2-8 indicates cost performance in the major recent remote sensing ''New Starts. ' Four of the five programs have encountered significant cost increases over the original estimates presented to Congress at the time of program approval (New Start).[29] Some cost growth in these programs is the result of additions or changes in program content, while the majority of cost growth is the result of cost increases at contractors. The GOES-Next program has encountered the most substantial cost growth of recent remote sensing programs, with development costs increasing more than two and one half times original cost estimates since program approval by Congress. UARS, on the other hand, was built and flown with no cost growth between

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24 That is, excluding $911 million for aeronautics.

24 That is, excluding $911 million for aeronautics.

25 Direct spending on space station *Freedom* and space shuttle alone consume nearly half of the total budget (table 1-2).

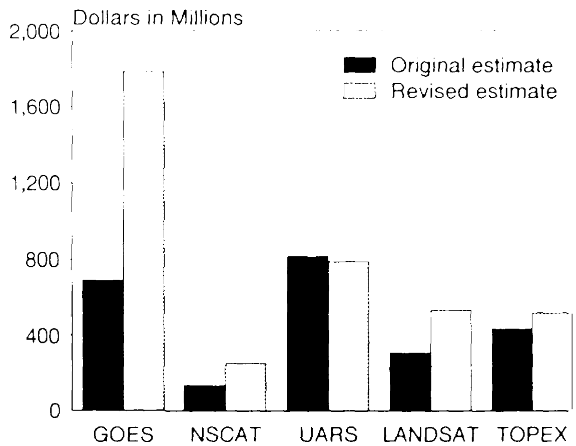
26 Office of Technology Assessment, *Access to Space: The Future of U.S. Space Transportation Systems* (Washington, DC: U.S. Government Printing Office, May 1990), p. 7. This is based on an assumption of shuttle launch reliability of between 97 and 99 percent (p. 45).

27 Office of Technology Assessment, *Access to Space: The Future of U.S. Space Transportation Systems* (Washington, DC: U.S. Government Printing Office, May 1990), p. 21.

28 Notable recent exceptions include the Upper Atmosphere Research Satellite, which was built within budget and on schedule.

29 Figures include launch and operation estimates, except GOES, which does not include operations. TRMM and EOS are not included, as these programs have been in development a relatively short time.

Figure 2-8-Cost Performance of Recent Remote **Sensing Programs**



SOURCE: General Accounting Office

post-Challenger reprogramming in 1986 and spacecraft flight.[30]

Among these five recent remote sensing programs, cost increases average 55 percent. In total dollars for all five programs, cost increase is 61 percent. Similar cost growth among EOS and the planned remote sensing New Starts in the future would have a significant adverse impact on the future of remote sensing.

In order to reduce the risk to MTPE, NASA will need to find ways to build in resilience to possible future unforeseen circumstances that would cause budget growth. **In overseeing NASA's allocation of funding for MTPE, Congress may wish to examine how NASA plans to provide contingency funds and other means of ensuring resilience for the program.**

In attempting to find room in NASA's budget to retain EOS activities at a level at or near $8 billion between 1991 and 2000, Congress could reduce funding for other individual programs, including space shuttle, the advanced solid rocket motor, space station, and space science.

However, in order to retain the existing budget for Earth sciences research by cutting other programs, NASA would either have to stretch out some programs by a significant amount, thereby increasing total program costs,[31] find savings by increasing efficiencies, or cancel some programs.

NOAA'S REMOTE SENSING BUDGET

NOAA will remain the primary collector of satellite remote sensing data for both meteorological and climate monitoring efforts through the decade of the 1990s. Thus, NOAA could play a strong role in the satellite remote-sensing portion of the USGCRP, while also maintaining g and improving its traditional role.[32]

Yet many observers question NOAA's capability and commitment to broader global change research, as well as its ability to secure the funding to support that research. Indeed, NOAA's yearly budgets experience strong competition with other priorities within the Department of Commerce and within Congress' Appropriations Subcommittee on Commerce, Justice, State, and Judiciary.

Table 2-1 provides unofficial planning estimates for NOAA satellite remote sensing. NOAA remote sensing budgets are currently expected to remain in the range of $400 to $450 million per year through the rest of the decade, with no major

30 Reasons attributed to UARS cost performance success include: The UARS project had well-defined scientific requirements, and used the multimission modular spacecraft employed earlier for the Solar Maximum Mission. It also used "plug-in" modules for propulsion, communications, and navigation. Scientists and engineers in the UARS project were well aware of standard interfaces, and apparently no exceptions were allowed by UARS management. The UARS project was also able to depend on steady, full funding from the administration and Congress, which in turn is essential for budget, capability, and schedule performance.

31 Projects tend to have an optimum pace at which to proceed in order to keep costs at a minimum. Stretching projects as a result of yearly budget limitations requires putting off parts of the project. Because NASA and its contractors must retain much of their experienced workforce on a project, despite the stretched schedule many overhead costs continue, increasing the overall cost of a program.

32 NOAA has long series of continuous records for important climate variables such as snow cover, ice analysis, sea surface temperature, Earth radiation budget, vegetation index, and ozone. Some of these observations date back to 1%6.

funding increases expected. This is in marked contrast to the expansive satellite research efforts underway at NASA. NOAA's smaller increases in yearly remote sensing funding would allow for some relatively minor planned improvements in POES satellites and instruments, and the completion and launch of improved GOES satellites (see ch. 3: Weather and Climate Observations).

Highly constrained NOAA satellite remote sensing budget requests have historically been the norm, as illustrated by Administration attempts to cut the POES program to one satellite, and the termination of the Operational Satellite Improvement Program at NASA in the early 1980s (see ch. 3: Weather and Climate Observations). A more recent example of the effects of limited funding in NOAA is Congress' $5.3 million cut in the "environmental observing services' line of the 1993 NESDIS budget request.

Recent efforts within NOAA to strengthen advanced sensor research, oceanic remote sensing, and climate observations have been largely unsuccessful. Continuing budget pressures have hampered NOAA's efforts to participate meaningfully in sensor design, mission planning, or data analysis in U.S. and international efforts to develop new satellite remote sensing spacecraft and instruments in the 1990s. Yet these endeavors could build on the substantial investment of other agencies and countries for satellite system hardware to provide additional global change information. For example, NOAA has still not succeeded in securing the relatively small resources (approximately $6 million) required to assure direct receipt of vector wind data from the NASA scatterometer instrument aboard the Japanese ADEOS satellite,[33] a potentially important enhancement of NOAA's forecast capability.

Observers note that the outcomes of the yearly budget process have caused NOAA's operational remote sensing program to ''limp along from year to year. Over the past decade, NOAA has reportedly lost much expertise in remote sensing, and lost some credibility among the user community. In sum, NOAA satellite remote sensing funding appears to constrain NOAA's ability to serve U.S. needs for remotely sensed data, especially considering the continued importance to the United States of meteorological and long-term climate **change data.**

THE COSTS AND BENEFITS OF SATELLITE REMOTE SENSING

Between fiscal years 1993 and 2000, the United States plans to spend about $14 billion to supply remotely sensed data form several systems, or an average of $1.75 billion per year. Such data serve the U.S. economy by producing information useful for predicting weather, managing natural and cultural resources, economic planning, and monitoring the environment (table 2-3). They will also help scientists detect and understand global change. Multiple systems are needed to provide different kinds of information. Although a systematic study of how costs and benefits compare has not been conducted, costs are likely to be small compared to the benefits that could be obtained with better information generated from remotely sensed data. For example, as noted above, knowing many hours in advance which path a hurricane is likely to take has allowed coastal dwellers to prepare their houses, businesses, and public buildings for the onslaught, and has saved numerous lives as well as millions of dollars in costly repairs. The management of rangeland, forest, and wetlands can also benefit from the large-scale, synoptic information that data form satellite systems can supply.

In the near future, global change research will likely consume the largest share of the satellite remote sensing budget. Here again, the gains in increased knowledge about the effects of harmful change could far outweigh the average yearly costs for space-based global change research (about $1 billion annually beginning in 1995).

[33] ADEOS is scheduled for a 1996 launch.

Table 2-3—Potential Benefits of Investment in Selected Remote Sensing Systems

Investment / Expected benefit
Landsat
Improved mapping; better land-use planning, including urban planning, location of dams, waste sites, other public and commercial facilities; more effective management of natural resources; quicker environmental impact assessments; military terrain analysis
GOES-Next
More accurate storm prediction, rainfall measurement resulting in improved ability to warn, prepare, and evacuate affected populations; expanded monitoring of atmospheric humidity
POES K-M
More accurate global precipitation measurements; better global vegetation analyses, resulting in better prediction of drought, crop forecasts, environmental assessments
EOS-AM instruments
Better determination of: role clouds play regulating climate; role of oceans in global warming; carbon cycle
SeaWiFS
Monitor ocean productivity; map ocean production for research, and fishing, shipping, recreational industries; monitor ocean-atmospheric interaction

SOURCE: Office of Technology Assessment, 1993.

Although estimates of the potential costs to sectors of the world's economy from global change are uncertain, they do indicate that such costs could range to tens of billions of dollars per year for the United States alone (box 2-A). Analysts predict, however, that *some* of the costs to the U.S. economy from global warming, taken alone, might be offset by the potential benefits.[34]

The Federal Government may wish to fund programs to mitigate the effects of global change or to adapt to it. The choices of how to respond to the effects of global change, in large part, will be determined by scientists' ability to predict these effects. Satellite remote sensing data *alone* will not necessarily enable the United States to avoid potential costs, but some fraction of the costs might be saved with improved information derived from satellite data. **Given the large investment the United States and other nations are making in the provision of data from satellite systems, Congress may want to request a systematic study that would compare costs of providing satellite data for monitoring the environment and for global change research with the expected savings better environmental information would provide.** Such an assessment could help allocate resources based on the type of data and utility of their information content.

DATA CONTINUITY, LONG-TERM RESEARCH, AND RESOURCE MANAGEMENT

To be effective in monitoring global change or in supporting resource management, the delivery of high-quality, well-calibrated, remotely sensed data must be sustained over long periods. Certain data sets, such as those related to Earth's radiation budget, should be acquired continuously over decades. In some cases, data must also be delivered with few or no gaps in the operation of the satellites. For example, losing a Landsat satellite more than a few months before a replacement can be launched would force resource managers to find sources of other, possibly less efficacious, data. Such a data gap would also reduce the ability of global change researchers to follow large-scale changes in the rain forests and other elements of the biosphere.

The need for continuity of data collection and use is recognized in the Land Remote Sensing Policy Act of 1992, which states:

> The continuous collection and utilization of land remote sensing data from space are of major benefit in studying and understanding *human*

[34] For example, one effect of global warming could be to lengthen the growing season in areas that are now marginal, thus improving the income from agriculture and other seasonal industries. See William D. Nordhouse, "Economic Approached to Greenhouse Warming," in Rudiger Dornbusch and James M. Poterlan, eds., *Global Warming: Economic Policy Responses* (Cambridge, MA: The MIT Press, 1991), ch. 2.

Box 2-A–Estimated Costs Resulting From Global Change

Determining the expected costs resulting from various scenarios of climate change is challenging. The economic effects of climate change can be divided into two broad categories. If climate change does occur, every country will endure costs of remediation and costs associated with coping with a changing environment. Costs of remediation involve expenses incurred adapting to change and preventing further harmful emissions. For example, included in remediation costs would be the expenses incurred for developing less polluting technologies. Adapting to a changing environment might include the expense of developing new agricultural practices and seeds needed to cope with changing climate and weather patterns. Costs are influenced by technology development, ability of consumers to afford new technologies, government regulations, population growth, demographic trends, and effectiveness of international treaties. Potential costs in several areas could be quite high:

- costs to agriculture could increase by $5.9 to $33.6 billion annually (1992 dollars);
- forests, a $13 billion industry whose costs could increase by $4 billion annually;
- species loss could lead to damages ranging from a few billion to an order of magnitude higher;[1]
- for the costs of sea-level rise, estimates range from $73 to$111 billion (1965 dollars-cumulative through 2100), to $373 billion associated with a one-meter rise, an additional $10.6 billion annually to cover associated economic losses;[2]
- loss of wetlands, biological diversity, and water resources; and
- increased fuel and power requirements, $200-300 billion (1986 dollars)[3]

These and all cost estimates associated with climate change should be regarded with extreme skepticism. The art of estimating the costs o f global change is still in its infancy. Most published estimates are predicting future events that are not clearly defined and may not even occur. However, what is clear is that should our climate change, the costs of change both in real and in opportunity costs could be enormous.

1 William R. Cline, The Economics of Global Warming, Washington, DC: Institute for international Economics, 1992.

2 See U.S. Environmental Protection Agency, "The Potential Effects of Global Climate Change on the United States," December, 1989, and U.S. Environmental Protection Agency, "Changing Climate and the Coast," 1980.

3 U.S. Environmental protection Agency, "The Potential Effects of Global Climate Change on the United States," December, 1989.

impacts on the global environment, in managing the Earth's resources, in carrying out national security functions, and in planning and conducting many other activities of scientific, economic, and social irnportance.[35]

If **Congress wishes to sustain U.S. efforts to understand and plan for the effects of global change, prepare for more effective management of Earth's resources, and support national** security uses of remotely **sensed data, it** will have to give attention to funding programs that would maintain the continuity of data **collection and use over decades. In order to be** fully exploited, these calibrated data sets will have to be archived, maintained in good condition, and made readily available to users.

DEVELOPING AND EXECUTING A STRATEGIC PLAN FOR SPACE-BASED REMOTE SENSING

The expected constraints on NASA's budget for MTPE speak to another important theme that has emerged during the continuing debate over U.S. space policy — how to accomplish the goals

35 Public Law 102-555.

for U.S. space activities more efficiently and with greater return on investment. Decisions will be made in an environment in which several U.S. agencies, private companies, and foreign entities pursue remote sensing activities. Greater **program integration, both domestically and internationally, has the potential for reducing costs and redundancy, but risks program delays, compromises on goals, and increased cost. In the** past, the development of new or improved satellite sensors and systems has proceeded according to the specific needs of the funding agency. However, recent experience with data from Landsat and from NOAA and DoD environmental satellites, as well as foreign satellites, demonstrates that the utility of data from these systems extends far beyond the interests of any single agency. Responding to a broader set of needs would likely increase the cost of any single satellite system or sensor because it would put more demands on the instruments and satellite bus. However, increased capability might in time increase the overall benefit of satellite remote sensing to the U.S. taxpayer.

On the domestic level, **the need to maximize the return on investments in remote sensing, particularly for global change research, which dominates expected future spending on civilian remote sensing systems, suggests that NASA, NOAA, DoD, and DOE should combine efforts to develop a single, flexible strategic plan that would:**

- guarantee the routine collection of high-quality measurements of weather, climate, and Earth's surface over decades;
- develop a balanced, integrated, long-term program to gather data on global change that includes scientifically critical observations from aircraft and groundbased platforms, as well as space-based platforms;
- develop appropriate mechanisms for archiving, integrating, and distributing data from many different sources for research and other purposes; and
- ensure cost savings to the extent possible through incorporating new technologies in system design developed in either the private or public sectors.

Developing a single, flexible plan would require an assessment of whether and where programs of these agencies might conflict, and if so, how they might be harmonized.

9 Collecting Routine Earth Observations

Operational, long-term remote sensing programs such as NOAA's environmental satellite programs and Landsat have generally suffered budget neglect, while the Nation directs attention instead toward new spaceflight missions supported through NASA's budget. An integrated plan would improve the incorporation of data from DMSP, GOES, POES, and Landsat into operational government programs, as well as into global change research.

The recent shift of operational control of the Landsat system from NOAA to DoD and NASA, as stipulated in the *Land Remote Sensing Policy Act of 1992*,[36] appears to support the routine, long-tern provision of Landsat data for the operational use of government, the private sector, and international users. From now into the next century, these data will serve as one of the primary sources for information on the condition of the land and coastal environments. Landsat data will also enable the tracing of long-term, gradual changes to Earth's surface as a result of climate change and/or anthropogenic environmental effects. However, **if Congress and the Administration wish to ensure continuity of data delivery and the continued improvement of Landsat sensors and system components, they will have to maintain a more supportive policy and funding environment for land**

[36] Ibid.

remote sensing than they have during the past decade.

The private sector has developed a growing market for remotely sensed data products, both as buyer and seller, and is a major force in setting standards for remotely sensed data and analytic software. It has also created new data applications, and developed innovative sensors. In the past, many private sector users of remotely sensed data have complained that the government has not taken their needs and interests into account when designing new remote sensing programs. **In order to ensure that Landsat meets the needs of private sector as well as government users, Congress might wish to encourage DoD and NASA to establish an advisory committee to gather input from private industry and academia for building and operating remote sensing satellites.**[37]

For the United States to assure the continual improvement of operational satellite systems, it will need a new approach to developing new sensors. In the past, NASA has generally developed remote sensing systems in response to a set of research interests. As its interests change, NASA's focus on sensors and satellites change with them.[38] In the 1960s and 1970s, some research instruments developed by NASA were incorporated into NOAA's environmental satellites and the Landsat satellites, all of which serve abroad clientele from government and the private sector. However, in recent years, as exemplified by the experience with the development of NOAA's GOES-Next geostationary satellite (see ch. 3: Weather and Climate Observations), the previous arrangement for close cooperation between NASA and NOAA has broken down .39

1 Global Change Research

In order to be effective in fully understanding Earth systems, global change research requires detailed data about chemical and physical processes in the atmosphere, oceans, and land. Some research problems, particularly those that involve modeling Earth's atmosphere, also require data taken over decades. In order to make the most efficient use of funding resources, the long-term research goals of U.S. global change research must be well coordinated across agencies and with academia. There should also be appropriate means to allocate funding among agencies. The USGCRP has served an important function in focusing the activities of the different agencies toward global change research, but it has relatively little power to adjudicate differences among agencies or to bring discipline to funding decisions. National Space Policy Directive (NSPD) 7, issued on June 1, 1992, established the Space-based Global Change Observation System (S-GCOS), under the aegis of USGCRP, to coordinate the satellite-based global change studies of U.S. agencies.

"In support of the USGCRP the S-GCOS shall:

- Improve our ability to detect and document changes in the global climate system to determine, as soon as possible, whether there is global warming or other potentially adverse global environmental changes; and, if changes are detected, determine the magnitude of these changes and identify their causes.
- Provide data to help identify and understand the complex interactions that characterize the Earth system in order to anticipate

37 For ~.pie, the Land Remote Sensing Policy Act of 1992 mandates the solicitation of advice from "a broad range of perspectives . . . [including] the full spectrum of users of Landsat data including representatives from United States Government agencies, academic institutions, nonprofit organizations, value-added companies, the agricultural, mineral extraction, and other user industries, and the public; Section 101 (c) Landsat Advisory Process.

38 When NASA was developing the Landsat series of surface remote sensing satellites in the 1970s, some data users complained that NASA's shift of data formats made it difficult for tbem to plan on routine use of the data.

39 Department of Commerce, Office of the Inspector General, *National Strategy for Satellite Remote Sensing is Needed*, unpublished report, February 1991.

changes and differentiate between human-induced and natural processes.

. Provide for a data system to manage the information collected by S-GCOS as an integral part of the Global Change Data and Information System, consistent with the USGCRP data policy.

. Provide for the development and demonstration of new space-based remote sensing technologies for global change observation and identify candidate technologies for future operational use. ' [40]

NASA was assigned the lead role in S-GCOS. NSPD7 directs other agencies—including the Departments of Defense, Energy, and Commerce to cooperate in the development and operation of spacecraft and data systems. Because S-GCOS is a recent creation, and because of the recent change of executive branch administration, it is too early to judge its effectiveness in guiding the direction of global change research and other aspects of U.S. satellite remote sensing programs. However, because S-GCOS creates a forum where agencies can share information about existing and future plans for space-based global change research, it has the potential to reduce redundancy and lead to greater sharing of limited resources.

I Improving the Use of Data

The need to be more efficient in using resources dictates greater attention to the ground portions of these programs, which are historically relatively inexpensive compared to procuring new spacecraft and instruments. **Although NASA has demonstrated the ability to collect data from a variety of instruments, it has been less successful in making effective use of them. Historically, data from remote sensing systems have been underutilized, while funds that might be used for data analysis are instead funneled toward the next generation of spacecraft.**

NOAA and NASA have not made sufficient use of NOAA's rich data archives for global change research. The Landsat archives held at the U.S. Geological Survey's EROS Data Center are also underutilized for global change research. Such inattention to effective data management and use could undermine global change research efforts, particularly NASA's Earth Observing System (EOS), the largest component in its MTPE program.

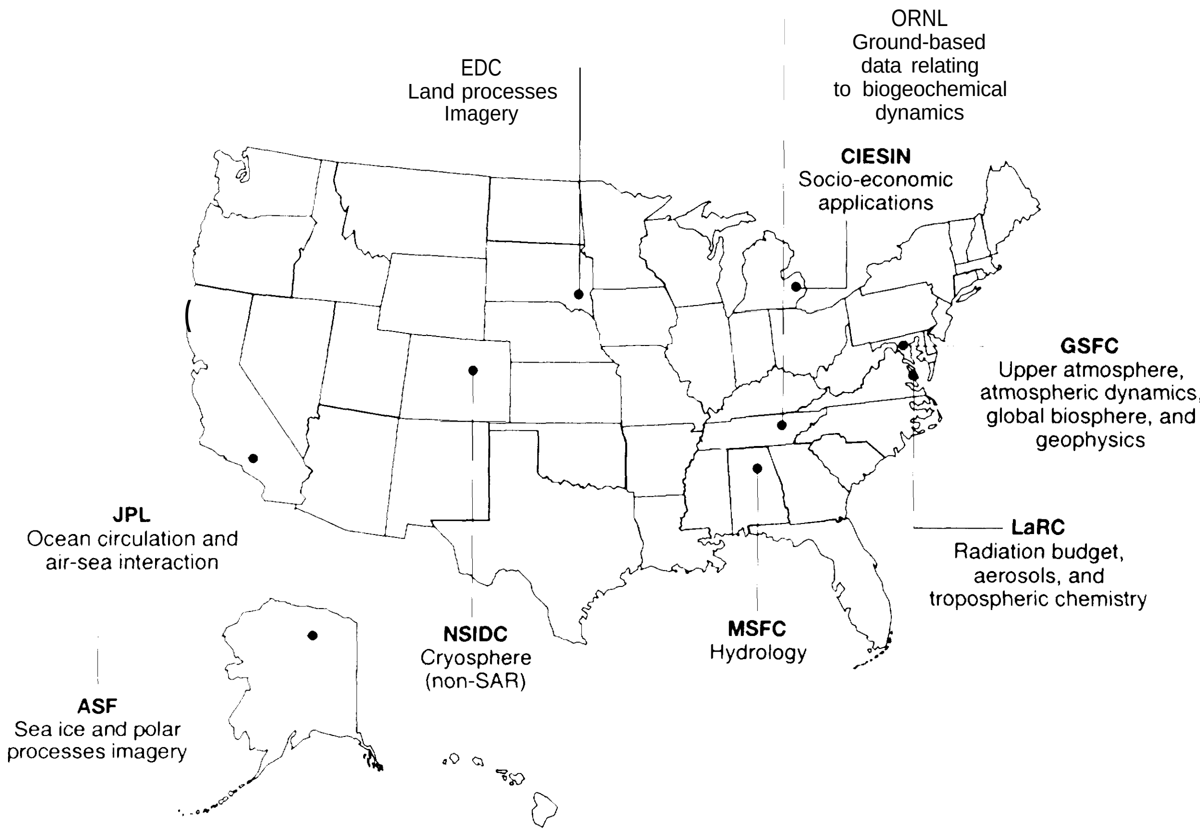
Scientists participating in the MTPE have pressed for close attention to the development of a powerful system to store, distribute, and analyze data collected from the various U.S. and international sensors that will contribute to global change research. As a result, NASA is developing the Earth Observing System Data and Information System (EOSDIS), which will be composed of several interconnected data archives distributed around the country (figure 2-9).[41] As part of its EOSDIS efforts, NASA has funded the development of data sets composed of data gathered over the past two decades from sensors aboard the Landsat satellites and form the NOAA operational environmental satellites. NASA's early experience in developing these 'pathfinder' data sets illustrates the difficulties NASA may encounter in dealing with the massive amounts of data from the EOS satellites.[42] It also helps NASA resolve many difficulties before EOS becomes operational. Scientists working on the project are finding it much more difficult than they anticipated to process the data to make them useful to global change researchers. NASA's and NOAA's

@ Nation~ Space Policy Directive 7: Space-based Global Change Observations. The White House, signed by Resident Bush, I June 1992. This NSDD, which attempts to improve coordination and collaboration in global change research, originated in the National Space Council.

41 Hughes Applied Information Services, Inc. won the contract to develop EOSDIS.

42 U.S. Congress, General Accounting Office, GAO/IMTEC-92-79, *Earth Observing System: Information on NASA's Incorporation Of Existing Data Into EOSDIS* (Washington, DC: General Accounting Office, September 1992).

Figure 2-9—The EOSDIS Network



EOSDIS will connect research sites around the country, from Goddard Space Flight Center to the Alaska SAR Facility, via a high-capacity telecommunication link.

KEY: ASF = Alaska Synthetic Aperture Radar Facility; CIESIN = Consortium for International Earth Science Information Network; EDC = Earth Resources Observing System Data Center; GSFC = Goddard Space Flight Center; JPL = Jet Propulsion Laboratory; LaRC = Langley Research Center; MSFC = Marshall Space Flight Center; NSIDC = National Snow and Ice Data Center; ORNL = Oak Ridge National Laboratory.

SOURCE: National Aeronautics and Space Administration.

efforts on the pathfinder data sets also make clear that these data have been underutilized for global change research.

A future report in this assessment will treat data issues in detail. Improving the return on investment in U.S. remote sensing systems will require **more efficient use of existing remote sensing data acquired by satellite. It will also require making more efficient use of data acquired by other means, such as data that could be taken by aircraft, balloons, UAVS, or from groundbased installations. These data are important for remote sensing instrument calibration and validation.**

9 Institutional Issues

U.S. research and operational remote sensing activities cut across disciplinary and institutional boundaries. Although existing institutional mechanisms are likely to improve the coordination of U.S. research and operational remote sensing activities, they are unlikely to be sufficient **to develop a long-term integrated plan that allocates resources among the agencies.** Because funding and resource decisions rest largely with each individual agency and its respective congressional committees, no mechanism exists to enforce collaboration among agencies or adjudicate differences that are likely to arise. **Congress may wish to establish an institutional mechanism to make resource allocation recommendations about remote sensing that extend across agency boundaries. The** Office of Science and Technology Policy, might be given this role. However, as presently constituted, the Office lacks the staff and the mandate to resolve differences among agencies. OMB might be able to assume such a task, but it suffers from a lack of staff and expertise. In addition, it is highly departmentalized. OTA will examine this and other organizational and institutional issues in a future report, which will develop a set of options for Congress to consider.

Greater international coordination and collaboration on sensors and systems, as well as data types and formats, will eventually be needed in order to reap the greatest benefit from the worldwide investment in remote sensing technologies (see ch. 8: International Cooperation and Competition. Sensors on existing satellites provide considerable overlap in capability. Although some redundancy is appropriate in order to give engineers and scientists in different countries experience in designing, operating, and using remote sensing technology, eventually the international community as a whole would be best served by reducing overlap[43] as much as possible and by using the available funds to improve the application of the data or to provide additional capability. The United States and Europe, which are now headed toward the goal of building and operating a single system of two polar orbiting satellites (see ch. 3: Weather and Climate Observations), might consider including Russia in their plans. The United States and Russia now operate polar orbiting satellites. Closer cooperation between the United States, Europe, and Russia could lead to the development and operation of a single, more capable polar orbiting system. Because of the precarious state of the Russian economy, this might initially require supportive funding from the United States and other countries.

The countries that operate Earth observation satellites have established two mechanisms to foster greater cooperation-the Committee on Earth Observations Systems (CEOS) and the Earth Observation-International Coordination Working Group (EO-ICWG). Both were deliberately created as informal organizations in order to avoid confronting administrative hurdles within each country that a more formal cooperative structure might engender. Countries use CEOS and EO-ICWG to inform members about their plans and to coordinate Earth observations. There is no exchange of funds.

In the future, the United States may wish to consider leading a broadbased cooperative program to collect, archive, and distribute long-term environmental data sets using sensors and satellites systems similar to those now operated by NOAA.[44] If properly structured, such an international system could involve the funding and talents of many more nations in building and operating a system. It would also increase our capability to gather and process environmental data sets over the long term. The final report of this assessment will examine the benefits and drawbacks of a broadbased international polar-orbiting system, as well as the related issue of closer cooperation on NOAA's geostationary satellite system.

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43 Some overlap in the form of redundancy is useful in order to provide appropriate backups for failed spacecraft or to provide additional coverage. The use of the European Meteosat-3 spacecraft to provide backup for the aging U. S. geostationary environmental satellite, GOES-7, is a case in point.

44 John McElroy, "The Future of Earth Observations in the USA,' *Space Policy,* November 1987, pp. 313-325.