HUMAN SPACE FLIGHT

FISCAL YEAR 2002 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT **SPACE OPERATIONS**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 2000 OPLAN REVISED	FY 2001 OPLAN REVISED	FY 2002 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Operations	[326,500]	(349,738)	258,900	HSF 6-4
Mission and Data Service Upgrades	[97,600]	(82,811)	62,400	HSF 6-10
Tracking and Data Relay Satellite System Replenishment Project	[31,700]	(50,879)	125,500	HSF 6-17
Technology	[40,200]	(38,316)	35,400	HSF 6-19
*[Budget Offsetting Reimbursements [non-add]]	[[43,000]]	[[43,000]]	[[43,000]]	
Total	[496,000]	[521,743]	482,200	
Distribution of Program Amount by Installation				
Johnson Space Center	[223,900]	(225,593)	139,000	
Kennedy Space Center	[15,100]	(37,111)	69,000	
Marshall Space Flight Center	[4,800]	(8,800)	9,000	
Dryden Space Flight Center	[12,800]	(12,743)	13,000	
Glenn Research Center	[10,100]	(8,990)	7,300	
Goddard Space Flight Center	[88,900]	(92,071)	109,300	
Jet Propulsion Laboratory	[134,400]	(113,016)	129,400	
Headquarters	[6,000]	(23,419)	6,200	
Total	[496,000]	[521,743]	482,200	

Note - FY 2000 data in this section are for comparison purposes only. See Mission Communication Services and Space Communications Services for more details on FY 2000 activity.

* – Budget offsetting reimbursements are that portion of total program reimbursable revenue that partially defray the fixed and variable costs of operating a NASA multi-mission facility as a service to a variety of NASA and non-NASA users.

PROGRAM GOALS

The program goal is to provide reliable, quality and cost-effective space operations services that enable Enterprise mission execution. Reliable electronic communications are essential to the success of every NASA flight mission, from planetary spacecraft to the Space Transportation System (STS) to aeronautical flight tests.

The Space Operations Management Office (SOMO), located at the Johnson Space Center in Houston, manages the program to ensure the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner. In line with the National Space Policy, the SOMO is committed to seeking and encouraging commercialization of NASA operations services and to participate with NASA's strategic enterprises in collaborative interagency, international, and commercial initiatives. As NASA's agent for operational communications and associated information handling services, the SOMO seeks opportunities for using technology in pursuit of more cost-effective solutions, highly optimized designs of mission systems, and advancement of NASA's and the nation's best technological and commercial interests.

STRATEGY FOR ACHIEVING PROGRAM GOALS

The Space Operations program provides command, tracking, and telemetry data services between the ground facilities and flight mission vehicles. This includes all the interconnecting telecommunications services to link tracking and data acquisition network facilities, mission control facilities, data capture and processing facilities, industry and university research and laboratory facilities, and the investigating scientists. The program provides scheduling, network management and engineering, pre-flight test and verification, flight system maneuver planning and analysis. The program provides integrated solutions to operational communications and information management needs common to all NASA strategic enterprises.

The Space Operations program provides the necessary research and development to adapt emerging technologies to NASA communications and operational requirements. New coding and modulation techniques, antenna and transponder development, and automation applications are explored and, based on merit, demonstrated for application to future communications needs. NASA's flight programs are supported through the evaluation and coordination of data standards and communication frequencies to be used in the future.

The Space Operations program provides spectrum management support for all missions across the NASA strategic enterprises. Future spectrum and orbit requirements are identified and integrated into National and international regulatory activities to assure near-term and far-term Agency requirements are met.

Many science and exploration goals are achieved through inter-agency or international cooperation. Services from NASA's Space Operations assets are provided through collaborative agreements with other U.S. Government agencies, commercial space enterprises, academia, and international cooperative programs. Consistent with the National Space Policy, NASA procures commercially available goods and services to the fullest extent feasible, NASA develops selected technologies which leverage commercial investments and enable the use of existing and emerging commercial telecommunications services to meet NASA's Space Operations needs. These are all parts of the strategic approach to providing the vital communications systems and services common to all NASA programs and to achieve compatibility with future commercial satellite systems and services.

The Consolidated Space Operations Contract (CSOC) was successfully implemented on January 1, 1999, under the direction of the Space Operations Management Office and Lockheed Martin Space Operations Company as the Prime Contractor. CSOC provides end-to-end space operations mission and data services to both NASA and non-NASA customers. CSOC is a $3.44B contract with a Basic Period of Performance from January 1999 through December 2003 and an option period though December 2008. CSOC is a Performance Based Cost Plus Award Fee (CPAF) contract. A total of nine contracts have been consolidated to date, and seven further contracts are to be consolidated in FY 2001 and FY 2002. CSOC reflects a significant change in NASA philosophy as accountability and day-to-day direction for providing space operations services shifts from NASA to the CSOC contractor.

Although FY 2001 activity is discussed in this section, the funding was appropriated in the Science, Aeronautics and Technology (SAT) appropriation. Budget data for that year is provided both here and in the Space Operations section in the SAT appropriation for completeness.

BASIS OF FY 2002 FUNDING REQUIREMENT

OPERATIONS

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Space Network	[2,500]	[40,619]	27,000
Deep Space Network	[81,700]	[149,870]	118,600
Ground Networks	[23,300]	[36,021]	24,500
Mission Control and Data Systems	[211,500]		
Wide Area Network	[7,500]	[97,715]	54,100
Mission Services		[8,581]	17,100
Western Aeronautical Test Range		[12,472]	13,000
Spectrum Management		[4,590]	4,300
Standards Management		[299]	300
Total	[326,500]	[349,748]	258,900

PROGRAM GOALS

Space operations functions are defined as those activities that provide "mission" and "data" services to customers to enable their utilization and exploration of space. The mission and data services goal is to provide high-quality, reliable, cost-effective operations that support planning, system engineering, design, development, and analysis to a large number of NASA missions including planetary and interplanetary missions; human space flight missions; near-Earth and Earth-orbiting missions; sub-orbital and aeronautical test flights.

STRATEGY FOR ACHIEVING GOALS

Mission services provide for the launch and early orbit implementation, maintenance, and operations of the mission control and data processing facilities necessary to ensure the health and safety and the sustained level of high quality performance of NASA flight systems. Mission service operations are conducted in the facilities provided by NASA at multiple locations both in the United States and at overseas sites. Data Services provide command, tracking, and telemetry data services between the ground facilities and flight mission vehicles. This includes all the interconnecting telecommunications services to link tracking and data acquisition network facilities, mission control facilities, data capture and processing facilities, industry and university facilities, and the investigating scientists.

Data services are also provided to non-NASA customers on a reimbursable basis. A large share of the program that provides space network ground terminal complex operations and maintenance is funded with the receipts from reimbursable services.

SCHEDULE AND OUTPUTS

	FY 2000		FY 2001		FY 2002
	Plan	Actual	Plan	Current	Plan
Deep Space Network					
Number of NASA missions	[51]	[51]	[47]	[51]	51
Number of hours of service	[84,000]	[94,000]	[81,000]	[84,000]	84,000
Ground Network					
Number of Space Shuttle launches	[8]	[6]	[9]	[7]	7
Number of NASA/Other ELV launches	[25]	[22]	[54]	[25]	25
Number of NASA Earth-Orbiting missions	[37]	[32]	[32]	[37]	37
Number of Sounding Rocket deployments	[25]	[27]	[25]	[25]	25
Number of Balloon deployments (scientific)	[26]	[26]	[26]	[26]	26
Number of hours of service (GN Orbital Tracking)	[25,200]	[24,000]	[23,000]	[25,200]	25,200
Western Aeronautical Test Range					
Number of hours mission control center	[1,450]	[2,504]	[1,875]	[1,875]	1,875
Number of hours of data services support	[24,000]	[24,000]	[27,000]	[27,000]	30,000
Mission and Control Data Services					
Number of NASA spacecraft supported by GSFC mission control facilities	[23]	[16]	[25]	[22]	23
Number of mission control hours of service (in thousands)	[67,000]	[47,000]	[62,000]	[58,000]	58,000
Number of NASA/Other missions provided flight dynamic services	[49]	[54]	[49]	[45]	46
Number of NASA/Other ELV launches supported by flight dynamic services	[22]	[20]	[22]	[20]	30
Other					
NASA Integrated Systems Network - number of locations connected	[420]	[347]	[420]	[340]	323
Number of hours of space network services in thousands	[62,000]	[78,000]	[61,000]	[61,000]	61,000

ACCOMPLISHMENTS AND PLANS

The Space Network (SN) encompasses the White Sands Complex in New Mexico, the Guam Remote Ground Terminal and the Network Control Center at GSFC to operate the constellation of Tracking and Data Relay Satellites (TDRS). The SN is required to operate 24 hours per day, 7 days per week, providing data relay services to many flight missions. In FY 2001 and FY 2002, the missions to be supported include Space Shuttle flights and their attached payloads, observatory-class spacecraft in low-Earth orbit, such as Hubble Space Telescope (HST), as well as other compatible missions such as Ocean Topography Experiments, Department of Defense customers, the Rossi X-ray Timing Explorer (RXTE), the Starlink research aircraft, Engineering Test Satellite (ETS-VII), Tropical Rainfall Measurement Mission (TRMM), Landsat-7, and the Long Duration Balloon program. The Space Network extended service (on a reimbursable basis) to the expendable launch vehicle community, including agreements with US Air Force Titan, Lockheed Martin's commercial Atlas programs, Boeing's Delta program and Sealaunch program. In FY 2001 and FY 2002, the Space Network will continue to provide services to the Space Shuttle Flights and their attached payloads as well as the construction phase of the ISS

The Deep Space Network (DSN) includes the Goldstone Deep Space Communication Complex (GDSCC) in California, the Madrid Deep Space Communications Complex (MDSCC) in Spain, and the Canberra Deep Space Communications Complex (CDSCC) in Australia. The DSN plans to provide approximately 84,000 hours of tracking support to over 50 missions during FY 2001 and FY 2002. These included NASA, NASA cooperative and reimbursable spacecraft launches. Special tracking coverage was provided in support of spacecraft emergencies and anomalies. The number of missions serviced by the DSN facilities and the requirements of the individual missions will increase dramatically over the next several years. In anticipation of the increases, new antenna systems have been developed and obsolete systems will be phased out or converted for alternate uses. The DSN has been reconfigured with four new 34-meter antenna systems located at Goldstone, Canberra, and Madrid. These 34-meter antennae will satisfy expanded coverage requirements, and provide simultaneous coverage of deep space mission. In FY 2000, the 70-meter antenna located at Goldstone was upgraded to provide x-band capability. An 11-memer antenna system has been installed at each DSN complex to provide science support for the Institute of Space and Astronautical Science (ISAS) Japanese VLBI Space Operations Program (VSOP) spacecraft.

The Ground Network (GN) is comprised of tracking stations in Poker Flats Research Range near Fairbanks, Alaska, Bermuda, Merritt Island (MILA), Svalbard, Norway, McMurdo Ground Station in the Antarctic, and Wallops Island. The GN provides launch support, polar orbiting spacecraft support, and sounding rocket and atmospheric balloon mission support. The GN also supports critical Space Shuttle launch, emergency communications, and landing activities. The GN provides for the implementation, maintenance, and operation of the tracking and communications facilities necessary to fulfill program goals for flight projects in the NASA mission set. Missions supported also include NASA inter-agency collaborative programs, commercial enterprises, and other national, international, and commercial enterprises on a reimbursable basis. The Space Shuttle launches were successfully supported through dedicated facilities of the MILA station and the Ponce de Leon inlet annex. The continuation of this support, further enabled by the implementation of the re-engineered STDN system elements, is expected throughout FY 2001 and FY 2002. The University of Chile is providing southern hemisphere coverage for polar orbiting missions as well as planned early launch support to Mars Odyssey during FY 2001. Wallops Flight Facility (WFF) completed the installation of the 11-meter telemetry antenna systems at the Poker Flat Research Range near Fairbanks, Alaska and at Svalbard, Norway in preparation for support of the Terra, Quickscat, and Landsat-7 missions.

The NASA Dryden Flight Research Center (DFRC) Western Aeronautical Test Range (WATR) provides communications, tracking, data acquisition, and mission control for a wide variety of aeronautic and aerospace vehicles. The WATR meets widely diverse research project requirements with tracking, telemetry, and communication systems and control room complexes. Due to the nature of the aeronautical research mission, it is essential to respond to new project requirements within days or weeks rather than months or years, and to do so safely, efficiently, and economically. To accomplish this, WATR facilities, systems, and processes are designed to support a wide range of requirements, be easily reconfigured (less than one hour for control rooms), to be shared between multiple projects, and to readily interface with specialized equipment brought in by our customers. This approach provides the needed agility to be responsive while reducing costs to individual customers by increasing utilization rates. Customers of the WATR facilities include other NASA Centers, the U.S. Army, U.S. Air Force, U.S. Navy, Federal Aviation Administration, and the aerospace industry. In addition to providing over 2500 hours of Mission Control Center support to a variety of programs, the WATR also provided on-orbit support to the MIR and ISS as well as the Space Shuttle. Two Shuttle landings have been supported in FY01 to date. Significant FY 2000 and FY 2001 activities include the build-up of a Mission Control Center and data processing system to support unique X-40A, and X-43 (Hyper-X) requirements. A work-around was developed to support classified data on a limited basis. The test range was also extended to the West Coast to support the X-43 launch over the Pacific Ocean late in FY 2001.

Mission control facilities operated and sustained under this program are Mission Operation Centers (MOC) for the Hubble Space Telescope (HST) program; the International Solar Terrestrial Physics (ISTP) Wind, Polar, and Solar Observatory for Heliospheric Observation (SOHO); Rossi X-ray Timing Explorer (RXTE), Total Ozone Mapping Satellite-Earth Probe (EP), Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX); Transport Region and Coronal Explorer (TRACE); and Submillimeter Wave Astronomy Satellite (SWAS) missions, and the Multi-satellite Operations Control Center (MSOCC) which supports Upper Atmosphere Research Satellite (UARS) and Earth Radiation Budget Satellite (ERBS) missions. The Advanced Composition Explorer (ACE), Tropical Rainfall Measurement Mission (TRMM), the International Monitoring Platform (IMP-8), and Land Satellite (Landsat-7) are also operated out of GSFC MOCs. Science data processing support is provided for the ISTP/Geomagnetic Tail (Geotail) mission. Microwave Anisotropy Probe (MAP), the second Medium-class Explorer (MIDEX), is scheduled to be launched in June 2001.

The data processing function captures spacecraft data received on the ground, verifies the quantity and quality of the data and prepares data sets ready for scientific analysis. The data processing facilities perform the first order of processing of spacecraft data (Level 0) prior to its distribution to science operations centers and to individual instrument managers and research teams. The Earth Observation System (EOS) Data and Operations System (EDOS) began supporting the EOS Terra (AM-1) mission and is preparing for the second mission of the EOS series, Aqua (PM-1) currently planned for July 2001. EDOS provides the science data processing capability and product generation and delivery for the EOS missions. In addition, the Terra mission is supported via the SN and transmits telemetry to the EDOS Ground System Interface Facility (GSIF) located at the WSC for storage and delivery to the EDOS Level Zero Processing Facility (LZPF) located at GSFC.

Flight dynamics services were provided to all NASA space flight missions that utilize NASA's Space Network and to selected elements of the Ground Network, including the Space Shuttle, Expendable Launch Vehicles, and satellite systems. Attitude software and simulator development was provided for the TRACE, ACE, and TRMM flight systems. Flight dynamics ground systems for routine support was provided for MAP and the EOS Aqua (PM-1) during FY 2001. MAP will be launched in June 2001 and two Small Explorer missions (SMEX) are expected to launch in FY 2001 and FY 2002: the High Energy Spectroscopic Imager (HESSI) is to launch in FY 2001; the Galaxy Evolution Explorer (GALEX) will launch in FY 2002. These missions emphasize reduced mission costs and accelerated launch schedules.

NASA Integrated Services Network (NISN) provides for the implementation, maintenance, and operation of the telecommunications services, control centers, switching systems, and other equipment necessary to provide an integrated approach to NASA communications requirements. NISN completed the transition of the NISN Video Teleconferencing Service to the General Services Administration's Federal Telecommunications Services (FTS) 2000 Switched Compressed Video Transmission Service (SCVTS). This video service is shared by several government agencies, provides connectivity to commercial video services such as those provided by Sprint and MCI, and is also compatible to desktop video systems. This transition standardizes NASA video teleconferencing service on the industry standard of voice activated switching, and provides greater access to non-NASA video systems. In FY 2001, NISN will continue to analyze commercial services for potential use in meeting NASA's expanding Mission Requirements. NASA will be adding services to support continued implementation of IFMP, the Consolidated Supercomputing Management Office (CoSMO), ISS Phase II, National Oceanic and Atmospheric Administration (NOAA)-K, Earth Observation System, Advanced Composition Explorer (ACE), Advanced Earth Observing Satellite (ADEOS) and TRMM.

In FY 2002, the mission services asynchronous transfer mode (ATM) infrastructure will be completed. This new infrastructure will allow for improved technology and performance in providing mission services to both human and robotic space programs. The induction of voice over Internet protocol will be introduced into the mission infrastructure allowing a low cost solution to NASA's principal investigators participating in NASA's missions. In conjunction with NASA Research and Education Network (NREN), NISN has entered into formal agreements with other Government Agencies and Organizations to pass data over their networks, both research and operations. These agreements prove to be cost-effective for the Agency in that it reduces the need to install dedicated circuits to partnering universities and principal investigators. Such agreements also assures that NASA's remote users have advance network capabilities in more timely matter. NASA's peering agreements includes Commercial Internet Service Providers, Federal & Academic Research Networks (Abilene, DREN, Esnet, Argonne National Labs, vBNS+), and International Research Networks (Canada, Japan/Korea, Singapore, Germany, England, Israel). NASA's peering agreements will continue to be improved to provide NASA greater connectivity to the university and research networks without expensive dedicated circuits to those locations. In the fourth quarter of FY 2002, NISN plans to implement web caching at the peering locations, off loading outside traffic to popular NASA web sites from the NASA internal network allowing improved throughput between NASA centers. Improvements in voice and video teleconferencing will be implemented as technology matures.

The Spectrum Management program achieved significant success in FY 2000 at the 2000 World Radiocommunications Conference held May 8 – June 2, 2000 in Istanbul, Turkey. Allocations were achieved that will protect spaceborne navigation for NASA missions, including the International Space Station and Space Shuttle, using the Global Positioning System (GPS). In addition, NASA's efforts helped to ensure that the GPS remain the preeminent navigational aid for commercial aviation and other important applications. A complete realignment of the Table of Frequency Allocations in the range 71 – 275 Ghz was accomplished that will enable enhanced spaceborne sensing of the Earth's environment. In addition, existing allocations used in support of critical NASA operations were safeguarded from intrusion by incompatible services. For FY2001, the Spectrum Management program has begun preparations for the 2003 World Radiocommunications Conference (WRC-2003). Study efforts are being conducted to prepare the technical bases for Agency proposals to WRC-2003. These efforts include enhancement of frequency allocations for spaceborne radars, protection of vital tracking and data relay capabilities and ensuring the protection of sensitive signals from deep space scientific research. The program will leverage its activities through coordination with other civil space agencies throughout the World by participation in the Space Frequency Coordination Group. The program is also helping to foster NASA's commercialization goals by working with the National regulatory agencies to solve the associated regulatory challenges. The program will continue to support NASA missions in obtaining national and international authority to operate in a protected and properly allocated manner.

BASIS OF FY 2002 FUNDING REQUIREMENT

MISSION AND DATA SERVICES UPGRADES

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Space Network	[1,700]		
Deep Space Network	[39,500]		
Ground Networks	[7,700]		
Mission Control and Data Systems	[48,700]		
Mission Services		[32,129]	28,900
Data Services		[50,682]	33,500
Total	[97,600]	(82,811)	62,400

PROGRAM GOALS

The goal of Mission and Data Services Upgrades Project is to enable the conduct of the NASA strategic enterprises by implementing required upgrades to space operations systems and services. Reliable electronic communications and mission control systems are essential to the success of every NASA flight mission, from planetary spacecraft to the Space Transportation System (STS) to aeronautical flight tests.

The Mission and Data Services Upgrades Project, one part of NASA's Space Communications program, is composed of Data Services Upgrades and Mission Services Upgrades. Data Services Upgrades are made to the Space Network, Deep Space Network, and Ground Network. Mission Services Upgrades are made to mission control and data processing systems. These areas establish, operate, and maintain NASA ground networks, mission control, and data processing systems and facilities to provide communications service to a variety of flight programs. These include deep space, Earth-orbital, research aircraft, and sub-orbital missions. Mission support service facilities that perform functions such as orbit and attitude determination, spacecraft navigation and maneuver support, mission planning and analysis and several other mission services are also upgraded as part of this project.

STRATEGY FOR ACHIEVING GOALS

Upgrade tasks are being conducted on the Space Network, the Deep Space Network, the Ground Network, and the mission control and data processing systems to enable the conduct of on going and new missions by the NASA strategic enterprises. These upgrades are implemented by the Goddard Space Flight Center, the Jet Propulsion Laboratory, and their respective industry partners.

A major upgrade effort is underway to reduce operations costs for the Space Network and Ground Network through the implementation of the Data Services Management Center at the White Sands, New Mexico. This effort involves consolidating scheduling, management, and control of operations for the Space Network and Ground Network, including relocating the Network Control Center (NCC). The NCC, currently located at the Goddard Space Flight Center in Maryland, provides the primary interface for all Space Network customer missions. The primary function of the NCC is to provide scheduling for customer mission services. In addition, the NCC generates and transmits configuration control messages to the network's ground terminals and TDRS satellites and provides fault isolation services for the network. The Mission and Data Services Upgrades Project provides comprehensive mission planning, user communications systems analysis, mission analysis, network loading analysis, and other customer services and tests to ensure network readiness and technical compatibility for in-flight communications.

In the Deep Space Network (DSN) area, JPL is working with its industry contract partners to transform the DSN and associated mission operations system architecture into a service provision system known as the Deep Space Mission System (DSMS). The DSMS will provide a customer-oriented, turnkey service system which seamlessly integrates the facilities of the DSN and the Advanced Multi-Mission Operations System (AMMOS). This system will enable more efficient provision of currently available services as well as the creation of entirely new services.

Beyond efficiency improvements to existing assets, NASA is exploring ways to enhance the amount of deep space communications capability that can be applied to servicing the growing exploration fleet. NASA efforts along these lines include international cooperation and technology upgrades to existing assets.

In the international cooperation arena, NASA, through JPL, is working with other space-faring nations to implement a standardized set of communications protocols that will allow spacecraft interoperability with U.S. and foreign ground communications assets. NASA is also working to establish the agreements necessary to utilizing such interoperability – one example under discussion is the possible application of Italy's planned 64 meter Sardinia antenna to the support of some U.S. deep space missions.

In NASA's other effort for supporting the growing exploration fleet, applying technology improvements to existing DSN communications assets, JPL is working to improve capacity through data processing and antenna feed enhancements at current radio frequencies and through the application of higher radio, and even optical, frequencies. This will enable significant leaps in the data rates available for future missions. The first major new radio frequency improvements involve the addition of Ka-band reception capability on all of the DSN's 34-meter beam wave-guide antennas. NASA is also working to develop the corresponding Ka-band transmission hardware needed for the flight elements.

The Ground Networks upgrades area, in conjunction with other NASA and commercial elements, is demonstrating and implementing automated ground station control software systems to allow for increased reliability and lower overall operating costs. The completion of the implementation of the autonomous polar ground stations in Alaska and Norway will demonstrate these new capabilities using commercial and in-house developed software systems as the primary source of this function.

Efforts to reduce the cost of operations for low-Earth orbit spacecraft will continue with the commercialization of ground based tracking systems. The goal of these efforts is to provide a low-cost ground tracking capability utilizing commercial ground tracking services in lieu of building additional government assets. This concept is being validated by the NASA/CSOC polar tracking services contracts with the Honeywell DataLYNX and Konsberg Lockheed Martin contractors in support of the EOS Program. Re-engineering efforts will be completed in early FY 2001 on the Ground Network facilities, resulting in reduced operation and maintenance costs. The UHF air-to-ground voice service at the Bermuda station remains available for Space Shuttle launch operations.

The Mission Services Upgrades area, primarily managed by the GSFC, is comprised of a diverse set of facilities, systems and services necessary to support NASA flight projects. The mission control function consists of planning scientific observations and preparing command sequences for transmission to spacecraft to control all spacecraft activities. Mission Operation Centers (MOC's) interface with flight dynamics, communications network, and science operations facilities in preparation of command sequences, perform the real-time uplink of command sequences to the spacecraft systems, and monitor the spacecraft and instrument telemetry for health, safety, and system performance. Real-time management of information from spacecraft systems is crucial for rapid determination of the condition of the spacecraft and scientific instruments and to prepare commands in response to emergencies and other unplanned events, such as targets of opportunity. The data processing function captures spacecraft data received on the ground, verifies the quantity and quality of the data and prepares data sets ready for scientific analysis. The data processing facilities perform the first order of processing of spacecraft data prior to its distribution to science operations centers and to individual instrument managers and research teams.

A major effort within the mission control and data systems is the development of more cost-effective mission operations systems to support the Explorers Program. Approximately one spacecraft per year will be launched, with potentially every other MIDEX mission operated from GSFC, dependent on successful Principal Investigator teaming arrangements. To minimize operations costs, plans for the MIDEX missions include consolidating the spacecraft operations, flight dynamics and science data processing all into a single multi-mission control center. Many of the functions will be automated using a commercial expert system product. The control center system will be used for spacecraft integration and test, thereby eliminating the need and cost of unique spacecraft manufacturers integration and test systems.

The Office of Space Science Mars Exploration Program has initiated funding beginning in FY 2001 to implement an additional 34-meter beam wave guide antenna in Spain to meet DSN mission loading requirements in FY 2003/FY 2004.

SCHEDULES AND OUTPUTS

Deep Space Network - DSN 26M Electronics Development Complete Plan: 4th Qtr FY 2001	Automate and upgrade the existing electronics in the 26M antennas to support unattended operations (i.e., no operations staff is nominally required).
Ground Network - McMurdo Ground Station Upgrades Complete Plan: 2nd Qtr FY 2001	Upgrade the existing facility (joint with the USAF) to improve operability during inclement weather and support future cooperation with the USAF.
Mission Services – PACOR Automation Complete Plan: 3rd Qtr FY 2001	Automate and upgrade existing data processing systems to reduce operations costs.
KA-Band Ground Terminal Development Complete Plan: 4th Qtr FY 2001	Implement a Ka-Band ground terminal to test and demonstrate high rate ground data acquisition at this higher frequency.
Space Network Demand Access System Complete Plan: 1st Qtr FY 2002	Implement an improved Space Network multiple access system to provide increased capacity to support new operational uses of the TDRSS.

ACCOMPLISHMENTS AND PLANS

Data Services Upgrades

The Ka-Band Ground Terminal Development activity began in FY 2000. This effort will seek to demonstrate the commercial viability of providing high rate ground data acquisition in the Ka-Band area. This activity will include participation by members from various NASA centers and commercial vendors. The successful demonstration of this capability is scheduled for late FY 2001. Capabilities to be demonstrated are far beyond what is in operation today. Success will allow NASA and its commercial partners to take advantage of the new frequency allocations for space and earth science and to alleviate issues regarding radio frequency spectrum interference that exist today.

The requested funding also provides for continuation of mission planning, customer requirements definition and documentation, mission and network operational integration, analyses, customer communications systems analyses, test coordination and conduct, and other customer support services in support of Space Shuttle and the International Space Station (ISS).

Work will continue in FY 2001 on various components of the Space Network Demand Access System (DAS). The Third Generation Beam Forming System (TGBFS) development activity was completed to augment the TDRSS multiple-access (MA) capability and to permit customers to implement new operations concepts incorporating continuous return link communications. The DAS will expand existing Multiple Access (MA) return service capabilities by allowing customers to directly obtain services from the Space Network without scheduling through the Network Control Center (NCC). The DAS will be installed at White Sands, New Mexico, and is expected to be operational and available for customer use in FY 2002.

JPL has also been working to decrease the Deep Space Network's complexity and improve equipment reliability, thereby enabling substantial DSN operations and maintenance cost savings. Efforts along these lines include improved network control, network simplification, upgrades to the 26-meter antenna subnet, and the replacement of aging electronics systems.

The Network Simplification Project (NSP) has continued on schedule. NSP consolidates or replaces all the telemetry and radiometric DSN equipment with new technology and COTS solutions that enable advanced capabilities and remote operations. The objectives include replacing failure-prone aging assemblies, reducing system interfaces, reducing manual switches, replacing old NASA-unique protocols with industry standards, and providing new deep space mission command services to eliminate labor-intensive controller functions. The final installations are planned for mid-2002 through 2003. The first-of-a-kind uplink and downlink replacement systems will be installed on the DSS-26 34-meter beam wave-guide antenna at Goldstone for operational testing during FY 2002.

Implementation continues on the telecommunications roadmap that was developed in FY 1998. The roadmap laid out a plan for using new technologies to increase the DSN's deep space communications capabilities to accommodate a growing exploration fleet while maximizing the utility of the existing DSN antennas. The first major goal of this implementation will be the addition of Ka-band reception capability on all of the DSN's 34-meter beam wave-guide antennas. An implementation plan was developed in FY 1999 that has successfully passed a preliminary definition and cost review, and has moved on to prototyping activities for certain key technologies. One of these technologies currently under test is a single microwave feed horn and associated cryogenic low-noise amplifiers that can receive both X-band (8 GHz) and Ka-band (32 GHz) simultaneously. The other significant effort undertaken as part of the telecommunications roadmap is the completion of the DSS-26 34-meter antenna at Goldstone. The electronics for this antenna are being developed and installed to make this antenna operational in FY 2002.

The 70 meter X-band Uplink task is implementing a higher power transmit capability to better communicate with spacecraft in the outer solar system. The upgrade to the antenna at Goldstone, California was completed in FY2000 The upgrade to the antenna at Canberra, Australia will be completed in FY2001. The remaining antenna at Madrid, Spain will be upgraded in FY2002. The 34-meter antenna-arraying task has been completed. This task has already demonstrated the improved performance achievable through the use of an array of multiple antennas.

The Ground Network consists of the Merritt Island Launch Area (MILA) station and the Ponce de Leon (PDL) inlet annex in support of Shuttle launch and landing activities. The potential for the long-term replacement of aging 9-meter hydraulic antennas at MILA by a commercial ground station is being studied. Infusion of technology developed in support of receiver, exciter, and ranging subsystems will be introduced in a phased manner to replace aging subsystems at MILA and Ponce de Leon. This effort will continue throughout FY 2001.

NASA is planning for the future of the McMurdo Ground Station (MGS) in Antarctica. The drivers for this station are the need to provide for predictable performance of MGS in support of Launch and Early Orbit Operations, to provide for supplemental telemetry support, and to pursue a mutually beneficial relationship with the U. S. Air Force with regard to improved service and cost sharing. Concept definition, project plans, and approval to proceed were granted in FY 1999. Upcoming plans for MGS in FY 2001 include the implementation of a Joint Operations Center (JOC) with the U. S. Air Force and subsystem upgrades in support of the EOS missions.

Mission Services Upgrades

The Mission Services Upgrades area has pursued proactive measures to consolidate functions, close marginal facilities, and reduce overall contractor workforce to reflect the Agency's goals. Examples include the automation of flight dynamics tasks and the automation of data packet processing tasks at GSFC.

Transfer of data systems technologies to flight project use occurred in the areas of software reuse, expert system monitoring and command of spacecraft functions, and packet data processing systems. Software reuse, expert systems, workstation environments, and object-oriented language applications continued. The Mission Control and Data Systems upgrades areas will continue to integrate modern technology into mission operations support systems through the use of systems like the Generic Spacecraft Analyst Assistant (GenSAA) for automation, software-based telemetry front-end processing systems and the Mission Operations Planning and Scheduling System, case-based and model-based reasoning tools, and commercial orbit planning systems.

Significant development, test, and pre-launch support associated with the MIDEX and SMEX missions are part of the Mission Control and Data Systems activity. Emphasis upon commercial products, artificial intelligence applications and advanced graphical displays will be continued in FY 2001 for application in MIDEX and future SMEX missions. Evolution of systems to a single integrated mission control, command management, flight dynamics, and first-level science processing system will continue. New flight dynamics technology development and infusion for autonomous space and/or ground spacecraft navigation and control will be major efforts.

The Mission Services Upgrades efforts will continue to focus efforts on operations automation beyond the Flight Dynamics COTS Infusion and PACOR Automation tasks. The Flight Dynamics COTS Infusion task completed in FY2000 and utilized commercial software tools to automate orbit determination functions at GSFC and reduce operations costs. The PACOR Automation task is automating data processing functions at GSFC to reduce operations costs. PACOR Automation will be completed to support the Hubble Space Telescope and Tropical Rainfall Measuring Mission (TRMM) in FY2001 and the Earth Radiation Budget Satellite (ERBS) mission in FY2002.

Mission Services Upgrades area will continue the lead in scoping and prototyping innovative architectures. This includes: the use of Transmission Control Protocol/Internet Protocol or Space Communications Protocol Standards for ground and flight communications; the use of knowledge-based control languages; ground and space autonomy; and active endorsement and collaboration in formulating a Space Objects technology for adoption and implementation of plug-and-play components for mission operations. Exploration of the promise of advanced communications technologies and the challenges of satellite constellation operations will continue throughout FY 2001 and FY 2002.

Development for Triana and MAP will be completed in FY 2001; developments will continue for the MIDEX and SMEX series as well as for the HST Servicing Mission 3B. Development efforts on Triana, MAP, EO-1, and similar missions will realize benefits from modern technology, commercial products, and more cost-effective processes (for example, a single system to perform spacecraft integration and test and mission operations; skunkworks development teams; concurrent engineering). The flight dynamics work will continue to be provided in the areas of ground support system development, analysis, and automation tools.

BASIS OF FY 2002 FUNDING REQUIREMENT

TRACKING AND DATA RELAY SATELLITE REPLENISHMENT PROJECT

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Spacecraft Development	[17,700]	[14,468]	57,700
Launch Services	[14,000]	[36,411]	67,800
Total	[31,700]	[50,879]	125,500

PROGRAM GOALS

The objective of the TDRS Replenishment Project (TDRS H, I, J Spacecraft) is to provide three spacecraft to continue Space Network tracking, data, voice, and video services to NASA scientific satellites, the Space Shuttle, International Space Station, and to other NASA customers. The spacecraft are replacements to the current constellation of geosynchronous TDRS satellites as they begin to exceed their lifetimes. The functional and technical performance requirements for the satellites will be virtually identical to those of the current satellites except for improved multiple access and S-band single access performance, addition of Ka-band, and spacecraft collocation. The three spacecraft will be placed in orbit by expendable launch vehicles (ELV).

STRATEGY FOR ACHIEVING GOALS

The Goddard Space Flight Center manages the development of the TDRS Replenishment Project, and the systems modification of the ground facilities and equipment as necessary to sustain network operations for current and future missions. The three TDRS spacecraft, procured under a fixed-price contract, were awarded to the Hughes Space and Communications Company (now Boeing) in 1995. Lockheed Martin Corporation is the prime contractor for launch services for the TDRS Replenishment Spacecraft.

SCHEDULE AND OUTPUTS

Complete Testing of TDRS-I Plan: June 2001	Complete environmental and functional testing.
Ship TDRS-I to launch site Plan: August 2001	Shipment of TDRS-I to KSC for completion of launch activities

Launch TDRS-I Plan: November 2002	Launch within five years of contract award will be performed, ensuring the continuity of TDRSS services to user space flight systems. This will be the second of three TDRS Replenishment Spacecraft.

ACCOMPLISHMENTS AND PLANS

In FY 2000, the TDRS-H spacecraft was launched successfully. On-orbit checkout of the spacecraft was conducted in July-September 2000. The spacecraft is working well and meets most user service telecommunications performance requirements, except for a minor Multiple Access (MA) anomaly shortfall in performance. An investigation of the MA anomaly began in September 2000. TDRS-I and ¬J integration and test activities continued to progress.

The TDRS-H MA anomaly is planned to be resolved in FY 2001. Changes to the TDRS-I and ¬J spacecraft flight hardware and test program as a result of the MA investigation will be completed prior to the completion of environmental and final functional testing of the spacecraft. The TDRS-I spacecraft will undergo a Pre-Ship Review.

In FY 2002, the TDRS-J spacecraft will have completed environmental and final functional test activities. TDRS-I is scheduled for launch in November 2002. The TDRS-J spacecraft will undergo a Pre-Ship Review and the contractual option to store the spacecraft will be exercised.

BASIS OF FY 2002 FUNDING REQUIREMENT

TECHNOLOGY

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Advanced Communications	[21,300]	[13,371]	10,900
Space Internet	[4,100]	[4,989]	5,300
Virtual Space Presence	[5,300]	[5,288]	5,600
Autonomous Mission Operations	[5,400]	[6,585]	5,000
Advanced Guidance, Navigation, and Control	[4,100]	[5,288]	5,600
Standards		[1,297]	1,400
Technology Program Support		[1,497]	1,600
Total	[40,200]	[38,316]	35,400

PROGRAM GOALS

The objective of the Communications Technology Project (CTP) is to identify, develop, integrate, validate, and transfer/infuse advanced technologies that will increase the performance, provide new capabilities, and reduce the costs of providing data and mission services to the Space Operations customers. Additionally, the CTP infuses new capabilities into commercial practice for the benefit of both NASA and the Nation. Essentially all tasks serve to improve and/or reduce the cost of space operation services, or provide the technology advancement to allow the introduction of new services to the overall Space Communications Architecture.

STRATEGY FOR ACHIEVING GOALS

The SOMO strategy for achieving technology goals is to define five specific campaigns that address unique technology needs across the NASA Enterprises. In defining the activities in each of these campaigns, SOMO works closely with the relevant enterprises to understand their needs and focus on those activities of greatest potential for enabling or enhancing future missions and science. The five campaigns are described below. In addition, funds are requested for Agency standards activities. This provides infusion of new protocols and information system standards to meet space communications and mission operations of NASA and international partners. This budget program support provides funds to cover field center institutional assessments.

Advanced Communication

The focus of this campaign is development of telecommunications technologies to increase data return and decrease costs for support of NASA's missions. The Advanced Communication Campaign is committed to the development of high performance communication technologies for use in future NASA spacecraft and the ground and space assets that support them. The new communication technologies and more efficient implementation schemes will enable or augment future NASA missions with enhanced, lower cost communication services and allow the scientific community to perform more and better research by providing them with access to greater overall communication system bandwidth. The mission of the Advanced Communication Campaign is to identify, develop, and infuse high performance communications technologies necessary to enable or enhance mission data services and to achieve seamless interoperability among NASA, commercial satellite, and terrestrial communications systems.

This campaign has focused work areas supporting the unique low signal levels of Deep Space, high data rates for Near Earth, and low size, weight, power, and cost components for all missions. Activities related to the development and validation of a wide variety of radio frequencies (RF) and optical devices (antennas, receivers, transmitters, modems, and codes) are part of this campaign.

Space Internet

Supporting the Space Communications Architecture vision for transparent operations, the Space Internet Campaign seeks to provide users direct access to tools, payloads, and data. The mission of the Space Internet Campaign is to identify, develop, and infuse Internet and supporting communications infrastructure technologies necessary to achieve seamless interoperability between satellite and terrestrial networks. For Near Earth and near planetary missions, the Space Internet Campaign is committed to the extension of commercially available, terrestrial-based Internet technologies into future NASA spacecraft to enhance the capabilities for remote access and control of space-based assets. Deep Space missions will require new communications protocols and new relay telecommunications. The long round-trip light times, intermittent link availability, and extremely low signal-to-noise ratio (SNR) of deep space links demand carefully tailored protocols to achieve the kinds of high-level file transfer capabilities that we take for granted in today's terrestrial Internet. Within this campaign, we will develop new deep space protocols, test and validate them in protocol testbeds, and infuse them into new radios that provide high-level communication and navigation functionality in low-mass, power-efficient, highly interoperable systems. This campaign also includes activities related to development and validation of space qualifiable code, local area network (LAN), routing, and switching hardware and software.

Virtual Space Presence

As we gather more detailed science information in remote locations, and rely more heavily on robotic exploration and autonomous operations, we must shift how we plan, operate, and visualize these activities. These technologies provide improved science return through several means:

- Advanced data compression techniques and buffer management strategies,
- Advances in on-board processing including feature identification, data mining, fusion, and synthesis operations,

- Other onboard techniques that are coupled with intelligent approaches for information transfer prioritization and management of the limited return link resources.

Advanced tools for high fidelity 3-D visualization of planned and executed spacecraft activities, and the ability to remotely plan activities and display the results, enable distributed team operations and broad outreach by providing secure access to science and mission information resources. This campaign also develops techniques for merging diverse but related data types, and technologies that will allow scientists, and thence the public, to fully visualize and appreciate the value of the returned science products.

Autonomous Mission Operations

This campaign will enable the planning, design, development, and operation of missions with challenging observational or exploration scenarios. These include autonomous decision-making and control for complex navigation and guidance scenarios, collaborative robotic exploration of remote bodies or terrain, autonomous observation planning and optimization of information return, and hazard avoidance and autonomous maintenance of spacecraft operational safety. Model-based system design and operation, goal-oriented planning, and related advanced testing techniques for autonomous systems are essential elements of these approaches. System automation to increase information handling and effective science return, automate system responsiveness to operational activities and spacecraft driven service requests, and automated detection and response to unplanned events are elements of this campaign.

Advanced Guidance, Navigation and Control (GN&C)

Enabling the planning, design, development, and operation of missions with challenging navigation scenarios is the Advanced GN&C Campaign. Scenarios include autonomous navigation and guidance for entry, descent, precision landing, and rendezvous & docking, autonomous formation flying and constellation operations, and operation in complex gravitational fields such as small body or Europa orbits, and Libration points. Many of these mission scenarios require highly responsive guidance approaches with control loops closed on the spacecraft rather than between spacecraft and ground. Autonomous maneuver decision-making, planning, and execution techniques are being extended to enable distributed networks of individual vehicles to interact with one another and act collaboratively as a single functional unit. The activities in this campaign include the techniques and subsystems to enable the relative positions and orientations of vehicles to be determined; formation flying control architectures, strategies, and management approaches; inter-spacecraft communication techniques for constellation coordination; and assess ground/flight operations concepts, trades, and accommodation requirements. Global positioning system (GPS) technologies that have been utilized for applications at the Earth are being evaluated and extended to support autonomous navigation for non-low earth orbit (LEO) missions.

SCHEDULE AND OUTPUTS

Autonomous formation flyer unit complete Plan: 4th Qtr FY 2001 Revised: 1st Qtr FY 2001	Iteration of sensor technology hardware and software system required for multiple spacecraft flying in formation. The Autonomous formation flyer development has been infused into the New Millennium Program's Space Technology 3 (ST-3) program.
Disseminate ACTS experiment results and complete data and record archiving Plan: 4th Qtr FY 2001	Overall experiment results will be catalogued and made available through the ACTS Web Page (http://acts.grc.nasa.gov).
Common Planning and Scheduling System (COMPASS) design review for distributed constellation planning Plan: 4th Qtr FY 2001	COMPASS capability extended to provide flight planning and scheduling in addition to science planning. COMPASS has been incorporated into the Advanced Visual Tools and Architecture Project Build 1 prototype. COMPASS is expected to reduce the cost of mission planning while enabling planning for distributed, independent and/or cooperative observatories (constellations).
Advanced Visual Tools and Architectures (AVATAR) project TAR Build 1 prototype release Plan: 2nd Qtr FY 2001	Zoomable Unit Interface, Data Carousel implemented, and Health Modeling design complete.
Demonstration of Deep Space Station Controller (DSSC) prototype Plan: 4th Qtr FY 2001	Includes model-based health monitoring and diagnosis
Reconfigurable Radio Testbed Demo Plan: 4th Qtr FY 2001	Radio metric navigation and telecommunications between multiple vehicles at Mars.
Optical Communications Technology Laboratory (OCTL) First Light Plan: 1st Qtr FY 2001 Revised: 1st Qtr FY 2002	OCTL development completed and delivery and installation of 1M-diameter telescope at Table Mountain. Performance Validation initiated. The slip for this milestone can be attributed to a delay in the actual placement of the contract, and difficulties in telescope development. No budget growth or customer impact.
Disseminate ACTS experiment results Ka-band TWTA Protoflight model delivery Plan: 3rd Qtr FY 2002	24W EOL Traveling Wave Tube Amplifier with greater than 40% efficiency. A key technology in enabling Ka-band communications.

ACCOMPLISHMENTS AND PLANS

A low power transceiver is being developed for near earth missions which will allow the unit to process up to 12 channels allowing simultaneous Tracking and Data Relay Satellite System (TDRSS) and Global Positioning System (GPS) signal reception. In FY 2000, the Field Programmable Gate Array (FPGA)-based transceiver completed ground-based demonstration of a prototype and is currently scheduled for a Shuttle-based demonstration in FY 2001.

The Advanced Visual Tools and Architectures (AVATAR) project applies visualization technology to spacecraft engineering data analysis in order to increase operator performance in multi-mission, constellation, and lights-out (autonomous operations) environments. The current challenge being addressed by the project is the ability to cost-effectively operate constellations of up to 100 spacecraft.

Key technologies needed to enable utilization of Ka-band communications on future deep space missions will continue. A contract has been awarded for the development of a 27 Watt (24 Watt at end-of-life) space-qualified Ka-band Traveling Wave Tube Amplifier (TWTA) which is more than 40% efficient. Delivery is expected in the third quarter of FY02. The 3m Ka-band reflector array antenna demonstrated last year will be redesigned to enhance its rigidizability and reduce its mass, and a dynamic structural analysis will be performed to assess its expected performance under space flight conditions. A small profile rigid X/Ka-band antenna with high illumination efficiency is also under development. For the ground-receiving end, development of a Ka-band multi-cavity maser low noise amplifier will be demonstrated. Additionally, a combination deformable plate mirror and array feed compensation system will be developed and demonstrated to compensate for large DSN antenna distortions due to gravity and wind buffeting.

Development of the Optical Communications Telescope Laboratory (OCTL) will continue. The 1m-diameter telescope will be delivered and "first light" is planned for first quarter of FY02. The OCTL facility on Table Mountain in California will be used to demonstrate and validate optical communications techniques, components and systems level performance for application to NASA's future high capacity near-Earth and deep-space communications needs. The network of three Atmospheric Visibility Monitoring (AVM) telescopes will continue to collect data, which will be used to assess statistics of optical signal propagation through the atmosphere. Models from these data will be used to evaluate optical link performance for future mission applications.

A software system was developed in FY00 to make real-time position determination anywhere on the Earth to 20 cm resolution. The software uses the Internet to transfer data from multiple GPS receiving sites in real time and to calibrate out error sources in the final position determination. The software was selected by NASA for the FY2000 "Software of the Year" Award.

The Autonomous Formation Flyer development has been infused into the New Millennium Program's Space Technology 3 (ST-3) program. A derivative of the AFF, a software reconfigurable spacecraft transceiver processor prototype, is being developed to provide radio metric navigation and telecommunications between multiple vehicles at Mars. The design will be capable of reconfiguration from the ground through uploads of new software or Field Programmable Gate Array (FPGA) code.

Development of the Deep Space Station Controller (DSSC) prototype will continue and will lead to a demonstration of automated downlink operations in an actual DSN environment. The DSSC is developing an architecture and prototype for achieving station-centric automated control and employs AI-based methods for system health monitoring, diagnosis, and recovery. The monitoring and diagnosis portion of the prototype will employ the BEAM technology, which utilizes a combination of deterministic and stochastic models to monitor system health. Automation of recovery actions is achieved through the Closed-loop Execution and Recovery (CLEaR) technology, which employs continuous planning and execution capabilities. A prototype of the Deep Space Station Controller (DSSC) will be demonstrated in the fourth quarter of FY01.

The ACTS experiments program officially concluded with the ACTS Conference held in conjunction with the 6th International Ka-band Utilization Conference in May 2000. Instead of ceasing all operations and rendering the spacecraft inert, NASA began the process of transferring ACTS to a university-based consortium in early-FY 2001. The intent is to maximize the use of this National asset and benefit space communications education, research and outreach. The consortium is expected to fully fund operations and is to be in place by mid-FY2001. NASA will maintain the operating license and provide minimal oversight of spacecraft operations in exchange for experimental access to the payload to support the communications technology project.