SCIENCE, AERONAUTICS, AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT — **SPACE OPERATIONS**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Operations	[333,500]	[326,500]	329,800	SAT 6-4
Mission and Data Service Upgrades	[92,000]	[97,600]	106,200	SAT 6-8
Tracking and Data Relay Satellite System Replenishment Project	[96,900]	[31,700]	55,000	SAT 6-16
Technology	[43,400]	[40,200]	38,400	SAT 6-18
[Reimbursements [non-add]]	[[45,900]]	[[43,000]]	[[43,000]]	
Total	[565,800]	[496,000]	529,400	

Distribution of Program Amount by Installation

	FY 1999	FY 2000	FY 2001
Johnson Space Center	[154,100]	[218,900]	222,300
Kennedy Space Center	[30,200]	[15,100]	41,700
Marshall Space Flight Center	[47,200]	[9,100]	11,900
Dryden Space Flight Center	[12,600]	[12,800]	12,600
Glenn Research Center	[10,100]	[10,100]	9,000
Goddard Space Flight Center	[169,300]	[89,300]	94,600
Jet Propulsion Laboratory	[136,200]	[134,700]	131,100
Headquarters	[6,100]	[6,000]	6,200
Total	[565,800]	[496,000]	529,400

Note - FY 1999 and FY 2000 data in this section are for comparison purposes only. See Mission Communication Services in the SAT section and Space Communications Services in the MS section for more details.

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.

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 1 January 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. The contract is a Performance Based Cost Plus Award Fee (CPAF) with possible conversion to Fixed Price Incentive Fee (FPIF) within 2 years. A total of nine contracts were consolidated at the inception of CSOC, a further four contracts have been consolidated in FY 2000 to date and two further contracts are to be consolidated in FY 2001. 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.

Space Operations is a new line in the SAT budget, beginning in FY 2001. Funding for these activities is consolidated from Space Communication Services, currently part of the Mission Support account, and Mission Communication Services, currently part of the SAT account. This is being done so as to link these activities more directly with the agency programs that constitute the principal users of these facilities and services. This will enable the Space Operations Management Office (SOMO) at Johnson Space Center to more effectively manage the Space Operations program. This will ensure that the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner. A set of budget crosswalk tables between the Space Communication Services and Mission Communications Service budget and the consolidated Space Operations program is described in the Special Issues section.

BASIS OF FY 2001 FUNDING REQUIREMENT

OPERATIONS

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Space Network	[6,900]	[2,500]	2,400
Deep Space Network	[86,800]	[81,700]	84,100
Ground Networks	[23,600]	[23,300]	22,500
Mission Control and Data Systems	[170,500]	[211,500]	210,500
NASA Integrated Services Network	[45,700]	[7,500]	10,300
Total	[333,500]	[326,500]	329,800

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.

SCHEDULE AND OUTPUTS

	FY 1999 Plan	FY 1999 Actual	FY 2000 Plan	FY 2000 Current	FY 2001 Plan
Deep Space Network					
Number of NASA missions	[52]	[46]	[51]	[45]	47
Number of hours of service	[92,000]	[93,000]	[84,000]	[84,000]	81,000
Ground Network					
Number of Space Shuttle launches	[6]	[4]	[8]	[6]	9
Number of NASA/Other ELV launches	[26]	[38]	[25]	[45]	54
Number of NASA Earth-Orbiting missions	[30]	[33]	[37]	[32]	32
Number of Sounding Rocket deployments	[30]	[25]	[25]	[27]	25
Number of Balloon deployments (scientific)	[26]	[26]	[26]	[26]	26
Number of hours of service (GN Orbital Tracking)	[23,750]	[26,000]	[25,200]	[23,000]	23,000
Western Aeronautical Test Range					
Number of hours mission control center			[1,450]	[1,450]	1,875
Mission and Control Data Services					
Number of NASA spacecraft supported by GSFC mission control facilities	[22]	[25]	[23]	[25]	25
Number of mission control hours of service (in thousands)	[66,000]	[57,300]	[67,000]	[62,000]	62,000
Number of NASA/Other missions provided flight dynamic services	[44]	[47]	[49]	[49]	49
Number of NASA/Other ELV launches supported by flight dynamic services	[34]	[37]	[22]	[22]	22
Other					
NASA Integrated Systems Network - number of locations connected	[410]	[410]	[420]	[420]	420
Number of hours of space network services in thousands	[54,100]	[57,800]	[62,000]	[61,000]	61,000

ACCOMPLISHMENTS AND PLANS

The Space Network is required to operate 24 hours per day, 7 days per week, providing data relay services to many flight missions. In FY 1999, the missions supported included four Space Shuttle flights and their attached payloads, observatory-class spacecraft in low-Earth orbit such as Hubble Space Telescope (HST) and the Compton Gamma Ray Observatory (CGRO), as well as other compatible missions such as Ocean Topography Experiment, Extreme Ultraviolet Explorer (EUVE), 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 and Lockheed Martin's commercial Atlas programs. In FY 2000 and FY 2001, 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 International Space Station and the Earth Observing System Terra mission.

The Deep Space Network (DSN) provided over 90,000 hours of tracking support to 46 missions during FY 1999. The year was unusually active with many critical events requiring support. These included 17 launches of NASA, NASA cooperative, and reimbursable spacecraft. The NASA support included the launches of DS1, MCO, MPL, Stardust, QuickSCAT, and the small explorers: SWAS, WIRE, and FUSE. The DSN also supported numerous encounters, including Galileo's continuing encounters with the moons of Jupiter, DS1's asteroid encounter, the Cassini Venus flyby and Earth swing-by, Planet-B Earth flyby, and the NEAR asteroid encounter. Special tracking coverage was provided more than 19 times in support of spacecraft emergencies and anomalies. Missions receiving this special support included DS1, MGS, Stardust, ACE, Galileo, NEAR, SOHO, TDRS, MPL, and GOES. During this busy year, DSN performance levels continued to exceed requirements, with delivery of scheduled telemetry data exceeding 98%.

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 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 2000 and FY 2001.

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.

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); the Compton Gamma Ray Observatory (CGRO); 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. Data processing support is provided for the ISTP/Geomagnetic Tail (Geotail) mission. Mission control of the Fast Auroral Snapshot (FAST) mission was operated under CSOC during FY 1999 and transitioned to the University of California-Berkley beginning in FY 2000. The pathfinder success of the earlier transition of EUVE mission operations was the basis for the FAST transition.

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.

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.

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.

BASIS OF FY 2001 FUNDING REQUIREMENT

MISSION AND DATA SERVICES UPGRADES

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Space Network	[5,500]	[1,700]	6,600
Deep Space Network	[34,000]	[39,500]	39,100
Ground Networks	[13,100]	[7,700]	7,400
Mission Control and Data Systems	[39,400]	[48,700]	53,100
Total	[92,000]	[97,600]	106,200

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 Space Network Upgrades, Deep Space Network Upgrades, Ground Network Upgrades, and Mission Control and Data Systems Upgrades. 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. New communications techniques and standards for the delivery of communication services to flight operations teams and scientific users are developed and applied. Data standards coordination for NASA is conducted under 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 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 task for the Space Network has been the recently completed Service Planning Segment Replacement for the Network Control Center (NCC). The NCC, located at the Goddard Space Flight Center in Maryland, provides the primary interface for all 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 develop 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 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 development of new technology and operational processes and the commercialization of ground based tracking systems. The goal of these efforts is to provide a low-cost ground tracking capability utilizing either the existing NASA resources or fostering the commercialization of ground tracking services. This concept will be validated by the NASA/CSOC polar tracking services contract recently awarded to the AlliedSignal Technical Services Corporation (ATSC) DataLYNX contractor in support of the EOS Program. Re-engineering efforts will be completed in early FY 2000 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 Control and Data Systems 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. The first launch of a Medium-class Explorer (MIDEX) is the Imager for Magnetopause-to-Aurora Global Exploration satellite (IMAGE) currently scheduled for February 2000. 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.

SCHEDULES AND OUTPUTS

Space Network - Control Center Communications and Control Segment Replacement Complete Plan: 4th Qtr FY 2000 Revised: Cancelled	The task was cancelled due to insufficient return on investment.

Deep Space Network - Configuration Control Group Upgrade Complete Plan: 4th Qtr FY 2002 Actual: 4th Qtr FY 1999	Replace existing microwave controller hardware used to control the high-powered transmitters in the 34M and 70M antennas to improve safety. Year 2000 compliance for hardware required earlier completion date.
Deep Space Network - Frequency and Timing Monitor and Control Upgrade Complete Plan: 4th Qtr FY 2001 Actual: 4th Qtr FY 1999	Replace existing frequency and timing subsystem control hardware and software to retire non-maintainable equipment and reduce operations costs. Year 2000 compliance for hardware required earlier completion date.
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.

ACCOMPLISHEMENTS AND PLANS

Space Network Upgrades

Implementation was completed on an improved, distributed architecture for the NCC, which is Year 2000 (Y2K) compliant. This Service Planning Segment Replacement (SPSR), provides more efficient use of the network capabilities, improved ability to resolve scheduling conflicts among customer missions, and provides standard commercial protocols for both internal and customer interfaces. The NCC modifications to the scheduling system also incorporated the Request Oriented Scheduling Engine (ROSE) which provides special features for conflict-free spacecraft scheduling, such as goal-directed scheduling and repetitive activities with variable start times and duration. This architectural change was undertaken over several years and accomplished segment by segment. The Communication and Control Segment Replacement (CCSR) development effort, planned as a follow on to the SPSR, was cancelled when analysis indicated that it would not be cost-effective in the current environment. Work will be initiated in FY 2000 on various components of the DAS, including Space Network Web-based scheduling; this effort is expected to continue through FY 2001 and become fully operational in FY 2002.

The Ka-Band Ground Terminal Development activity will begin 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).

In FY 1999, work began on the TDRS low power transceiver (LPT) development. This initiative seeks to provide a lower cost, lighter weight and lower power-demanding alternative to today's expensive transponder options for spacecraft telemetry, command, and orbit determination requirements. The multiple-mode nature of the LPT allows for flexible multiple-frequency implementations that also provide for Global Positioning System (GPS) position processing including time determination. Suggested applications include use on smaller satellites, satellite crosslinks and NASA/DOD network interoperability. This effort will continue into FY 2000 with the delivery of a prototype unit and the initiation of flight unit development; completed flight units are planned to be delivered in FY 2001.

Work will begin in FY 2000 on various components of the DAS, including the Third Generation Beam Forming System (TGBFS). The TGBFS development activity was initiated 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 TGBFS component is planned to be completed in FY 2001. The DAS will be installed at White Sands, New Mexico, and is expected to be operational and available for customer use in FY 2002.

Deep Space Network Upgrades

JPL engineers worked with SOMO and its industry contract partners to ensure that the integrated operations architecture design will meet the needs of deep space missions while reducing life cycle costs. In particular, a new high-level control architecture was defined for the DSN. This new service-oriented Deep Space Missions System architecture was successfully applied to DS1, MGS, and Stardust.

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 Y2K certification, improved network control, network simplification, upgrades to the 26-meter antenna subnet, replacement of aging electronics systems, and decommissioning of obsolete antennas.

During FY 1999, over 400 program elements associated with the DSN were subjected to a rigorous Y2K certification process involving the examination of 8 million source lines of code within the DSN itself and another 8 million lines of code in the advanced multi-mission operations system.

Development of the Network Control Project (NCP) was mostly completed in FY 1999 with deployment scheduled to start during the first quarter of FY 2000. Deployment of NCP will facilitate workload reductions at the antenna stations and establish the infrastructure for modernization, automation, and reduction in operations cost.

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 a 34-meter beam wave-guide antenna at Goldstone for operational testing during FY 2002.

Major elements of the effort to replace aging DSN electronics include accelerated deployment of the Block V Exciters and the microwave controller. The new exciters replace 20-to-30 year old suites of uplink processing equipment -- increasing reliability, decreasing maintenance, and accommodating the pursuit of higher frequency, Ka-band communications. The microwave controller provides for computer control, allowing automation and reducing operations costs.

Implementation has begun 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 2001.

Additional upgrades of the unique 70 meter antennas were made to avoid obsolescence issues and develop an improved transmit capability. The 70 meter X-band Uplink task will implement a higher power transmit capability to better communicate with spacecraft in the outer solar system. The 34-meter antenna-arraying task is also nearing completion. This task has already demonstrated the improved performance achievable through the use of an array of multiple antennas and will be operational in early FY 2000.

Ground Network Upgrades

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 aging 9-meter hydraulic antennas at MILA are being replaced with electric drive systems, capable of functioning without an operator. Efforts in support of this initiative will begin in FY 2000 and be completed in FY 2001. 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 2000 with completion expected in FY 2001.

The 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 QuikSCAT and Landsat-

7 missions in FY 1999. Ground station and network integration and certification testing was completed in FY 1999. The systems are scheduled to be officially transitioned to CSOC for operations, maintenance, logistics, and sustaining engineering in FY 2000. 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 Earth Observing System (EOS) Polar Ground Network (EPGN) 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 2000 include the implementation of a Joint Operations Center (JOC) with the U. S. Air Force and subsystem upgrades in support of the EOS missions.

Work will continue on the replacement of the Wallops Range Data Acquisition and Computational System; this system is a range safety tool and is obsolete and expensive to maintain. Work on the 11-meter antenna system enhancements required to support the Advanced Earth Orbiting Satellite (ADEOS) II mission will be completed in FY 2001.

The Ka-Band Ground Terminal Development activity will begin 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.

Mission Control and Data Processing Upgrades

The Mission Control and Data Processing 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 transition of both the SAMPEX and FAST MOC operations to ITOS workstation systems and the outsourcing of FAST mission operations to the UCB, the completion of the ISTP Reengineering consolidation of Wind and Polar operations with SOHO to be completed in FY 2000, and the use of automation to monitor routine spacecraft health and safety functions to enable smaller flight operations teams and reduced operations schedules (RXTE, CGRO, Landsat-7, etc.).

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 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 2000 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. The Flight Dynamics Facility (FDF) operations concept to perform routine operations as integral functions within mission control centers will also continue into FY 2000. New flight dynamics technology development and infusion for autonomous space and/or ground spacecraft navigation and control will be major efforts.

Preparations for the HST Third Servicing Mission in FY 2000 will continue, including the delivery of the Vision 2000 ground system, delivery of the new flight control computer flight software, and the payload computer ACS support system. Development efforts will continue in preparation for the MIDEX MAP mission that is scheduled to launch in FY 2001.

The Mission Operations and Data Systems upgrades efforts will continue to focus efforts on operations automation beyond the RXTE Automated Mission Operations System (AMOS), the CGRO Reduced Operations by Optimizing Tasks and Technologies (ROBOTT), and the automation provided for TRACE to promote single shift staffing for operations. Mission Control and Data Systems will actively lead and participate in establishing new architecture directions and rapid prototyping, exploring system autonomy concepts, and use of commercial-off-the-shelf products.

Mission Control and Data Systems upgrades area will continue the lead in scoping and prototyping innovative architectures such as: 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 will continue throughout this period.

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 2001 FUNDING REQUIREMENT

TRACKING AND DATA RELAY SATELLITE REPLENISHMENT PROJECT

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Spacecraft Development	[66,700]	[17,700]	14,500
Launch Services	[30,200]	[14,000]	40,500
Total	[96,900]	[31,700]	55,000

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 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 in 1995. The first spacecraft's launch readiness is scheduled for June 2000. Lockheed Martin Corporation is the prime contractor for launch services for the TDRS Replenishment Spacecraft.

SCHEDULE AND OUTPUTS

Launch TDRS-I Plan: 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 2001, the TDRS-I spacecraft will continue ground storage. The TDRS J Spacecraft will complete final functional testing. TDRS J spacecraft will undergo a pre-storage review and the contractual option to store the spacecraft will be exercised.

BASIS OF FY 2001 FUNDING REQUIREMENT

TECHNOLOGY

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Advanced Communications	[22,800]	[21,300]	14,000
Space Internet	[4,300]	[4,100]	5,100
Virtual Space Presence	[5,900]	[5,300]	6,400
Autonomous Mission Operations	[5,700]	[5,400]	7,700
Advanced Guidance, Navigation, and Control	[4,700]	[4,100]	5,200
Total	[43,400]	[40,200]	38,400

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 Integrated Operations Architecture.

STRATEGY FOR ACHIEVING GOALS

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 frequency (RF) and optical devices (antennas, receivers, transmitters, modems, and codes) are part of this campaign.

Space Internet

Supporting the IOA 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

Optical Communications Technology Laboratory (OCTL) First Light Plan: 1st Qtr FY 2001	OCTL development completed and installed at Table Mountain. Performance Validation initiated.
Autonomous formation flyer unit complete Plan: 4th Qtr FY 2001	Iteration of sensor technology hardware and software system required for multiple spacecraft flying in formation.
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.

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. Development began in FY 1999 with implementation of a digital matched filter/correlator in an FPGA as a first step, prior to a lower power implementation. In FY 2000, the FPGA-based transceiver development will be focused on a prototype capable of use for ground-based demonstrations as well as a possible short duration Shuttle flight targeted for FY 2001.

The Scientist's Expert Assistant (SEA) will be used as the front end of a planning tool. The SEA includes a Visual Target Tuner which allows Principle Investigator's to visually specify what they want to observe. This will feed directly into a planning tool to schedule and execute the specified observation. In this way the SEA will be able to support other observatories including HST, Chandra, GRO and XTE. SEA will be developing a simulation feedback loop, to improve the accuracy of observation specifications. (The PI will request an observation, the SEA will simulate the results, the PI will assess the simulation and adjust his/her request, and then the observation will be executed. As a result, fewer mistakes will be made and resources will be used more efficiently.) Other observatories such as HST, Chandra, GRO and XTE can also use this enhancement.

NASA will continue propagation data measurement and analysis at Ka-Band begun under the ACTS project, and extend the propagation models to include V-Band frequency data collection and analysis. The unique ACTS propagation terminals will be modified to include V-band capability, and will be used to obtain the propagation data required for model validation. The end of FY 2000 will complete modification of two terminals. The French Ministry of Defense is providing the Ka-Band and V-Band satellite beacons at no cost to NASA. However, the beacons are only measurable in the U.S. from Puerto Rico. NASA's propagation measurement activities will rely on the successful operation of the French STENTOR satellite, scheduled for launch in the first quarter of FY 2001. Ka-band and V-band propagation data will be collected and analyzed beginning in FY 2001.

Key technologies needed to enable utilization of Ka-band communications on future deep space missions will continue. A new Ka-band reflector array membrane will be designed, fabricated and integrated with the 3-m inflatable antenna structure developed last year. Additionally, mechanical mounting and stability analyses will be completed to assess the expected performance of such antennas under space flight conditions. A contract will be let for the development of a 30 Watt (24 Watt at end-of-life) output, Ka-band Traveling Wave Tube Amplifier which is more than 40% efficient. Additionally, a miniature Ka-band Opto-electronic oscillator (OEO) with 1 Hz phase noise sidebands 32 dB below the carrier will be demonstrated. The OEO uses fiber delay line technology to permit the direct generation of a Ka-band signal source. Previous techniques generated lower-frequency signals and then multiplied the frequency (and the phase noise distortions) up to the Ka-band carrier frequency. Low 1 Hz phase noise is necessary for weak signal detection and synchronization of Ka-band deep space communication signals. These developments will provide the remaining major ingredients (complementing the STM technology that was infused into follow-on development programs last year) needed to enable high capacity Ka-band communications on future deep space missions

Development of the Optical Communications Telescope Laboratory (OCTL) will continue with the completion of the building modifications for the OCTL, and the issuance of the OCTL telescope contract. The OCTL facility will be used to demonstrate and validate optical communications techniques, components and systems-level demonstrations links for applications to NASA future high capacity near Earth and deep space communications needs. In FY 2001, we will complete the development of the OCTL Telescope, install it in the telescope facility completed on Table Mountain, California begin “first-light” validations of the telescope performance, and begin preparations for systems-level demonstrations of optical communications and component technology validations.

Work is continuing in using Global Positioning System Derived Navigation in planetary rendezvous and formation flying environments. Several flight programs are assessing the Autonomous formation Flyer (AFF) sensor. This work area continues to develop a general AFF sensor with multi-mission capability.

Technology verification experiments over the ACTS will continue through to the end of spacecraft operations in June 2000. The technology verification experiments are coordinated by GRC and are being conducted by a team of investigators to study various propagation and link performance at Ka-band, to characterize system availability, and to perform statistical system analysis of the ACTS technologies. All spacecraft data received from ACTS technology verification experiments will be archived for future use. Final data analysis of the spacecraft data and experiments will be completed in early FY 2001. The overall experiments program results will be catalogued and made as accessible as possible through the ACTS Web page (http://acts.grc.nasa.gov). Completion of all data archiving and results dissemination will occur by September 2001.