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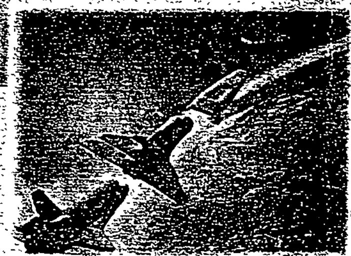

This artist's concept of evolving designs for reusable launch vehicles (RLVs) points the way to future space transportation.

For more information on the CICT Program, visit our web site at **http://www.cict.nasa.gov.**

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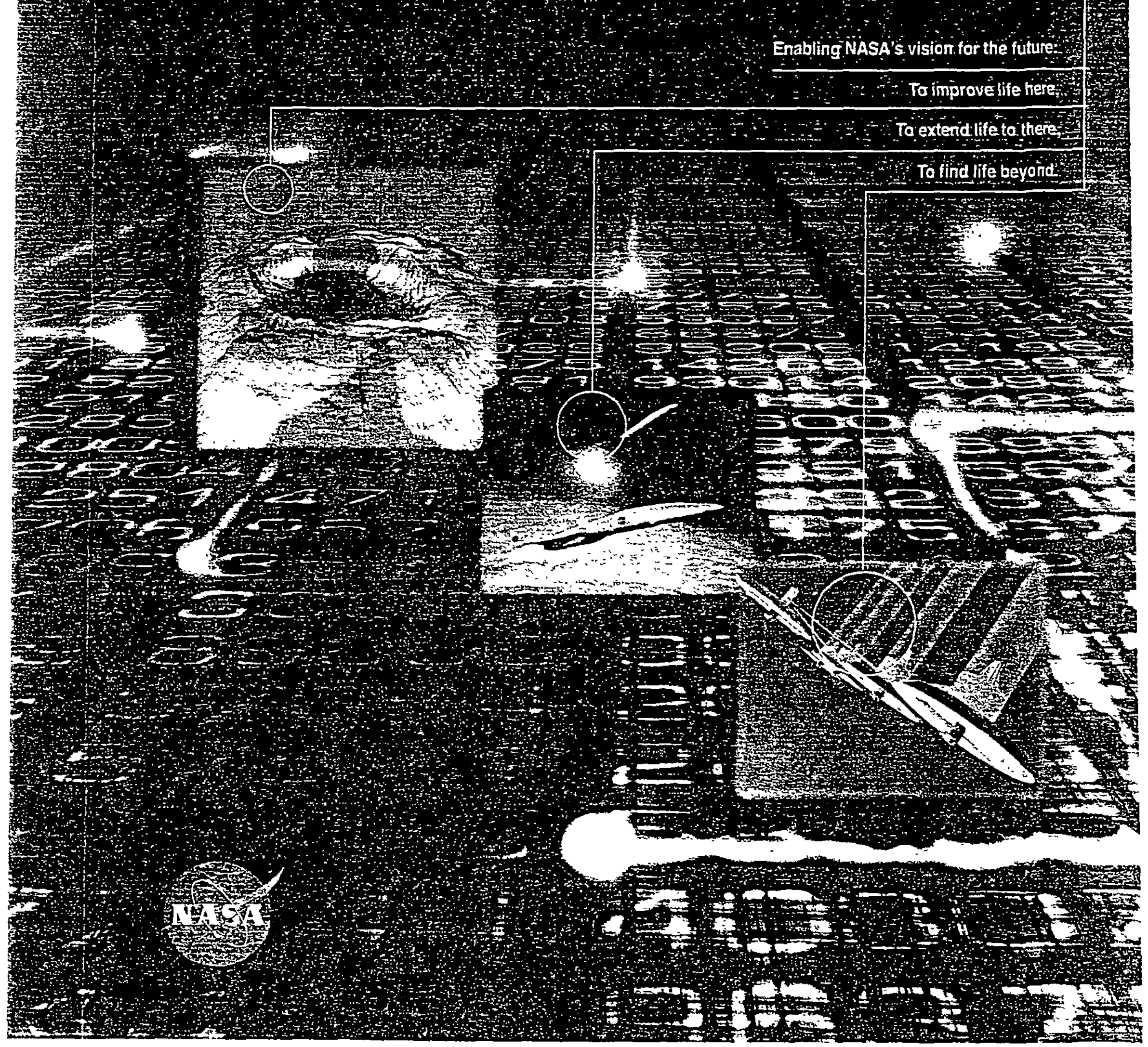

Eugene Tu
CICT Program Manager

Welcome to CICT

Our task is to enable NASA's scientific research, space exploration, and aerospace technology missions to achieve greater mission assurance, for less cost, with increased science return through the development and use of advanced computing, information, and communications technology. Our pioneering scientists and engineers are dedicated to developing and delivering innovative, fundamental technologies that achieve this goal.

Dr. Eugene Tu joined NASA in 1984. Prior to becoming CICT Program Manager in October 2001, he served as a research scientist and in several NASA management positions. Dr. Tu received his education at U.C. Berkeley (B.S. in Mechanical Engineering) and Stanford University (M.S. and Ph.D. in Aeronautics and Astronautics) and was awarded an Outstanding Leadership Medal by NASA in 2000.

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6 Delivering Data Quickly and Directly Between Earth and Space
CICT's Space Communications (SC) Project develops new distributed communication architectures, networks, and technologies to ensure continuous and rapid communication in space.

10 Enabling Systems That Think, Adapt, Evolve, and Work with Humans
CICT's Intelligent Systems (IS) Project explores new computational approaches to human and machine perception, reasoning, understanding, and interaction.

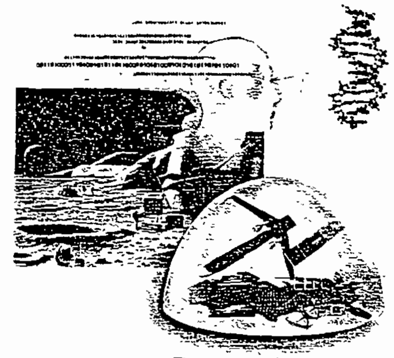
14 Seeding the Next Generation of Aerospace Technology
CICT's Information Technology Strategic Research (ITSR) Project researches, develops, and evaluates fundamental information and bio-nano technologies for infusion into NASA missions.

Cover images, from left to right, are a 3-D model of the hole in Earth's ozone layer high above Antarctica, an artist's depiction of spacecraft leaving Earth's atmosphere, and an artist's concept of the Terrestrial Planet Finder (interferometer version) which would use an array of mirrors flying in formation to block infrared light from the target star while amplifying reflected light from the star's planets.

NASA's CICT Program

Creating Innovative Technology for Mission Success

The CICT Program is part of the NASA Aerospace Technology Enterprise's fundamental technology thrust to develop tools, processes, and technologies that enable new aerospace system capabilities and missions.



This montage of artists' concepts represents some of the technologies and applications addressed by the CICT Program.

The CICT Program's four key objectives are:

Provide seamless access to NASA resources—including ground-, air-, and space-based distributed information technology resources—so that NASA scientists and engineers can more easily control missions, make new scientific discoveries, and design the next-generation space vehicles.

Provide high-rate data delivery from these assets directly to users for missions such as the Earth Science Enterprise's Digital Earth Vision, the Human Exploration and Development of Space, and Space Science.

Develop goal-oriented human-centered systems that will facilitate the observation and study of the Earth's climate, the combined human-robotic exploration of Mars, the safe and cost-effective operation of the Space Shuttle and subsequent launch vehicles, and the robotic exploration of deep space.

Research, develop and evaluate revolutionary technology that can make future aerospace systems smaller, lighter, and more reliable.

The CICT Program includes four projects:

The Computing, Networking, and Information Systems (CNIS) Project focuses on providing seamless access to NASA IT resources through the development and demonstration of grand challenge applications, information environments, grid common services, and advanced computing and networking testbeds.

The Space Communications (SC) Project focuses on intelligent communications architectures, high-rate backbone networks, flexible access networks, inter-spacecraft cooperative networks, and proximity wireless networks.

The Intelligent Systems (IS) Project focuses on automated reasoning, human-centered computing, and intelligent data understanding.

The Information Technology Strategic Research (ITSR) Project incubates technologies for other CICT projects and NASA programs. The ITSR Project's dynamic portfolio currently includes intelligent controls and diagnostics, automated software engineering technologies, bio-nano-technology, evolvable systems, and revolutionary computing algorithms.

Computing, Networking, and Information Systems (CNIS) Project

Providing Seamless Access to NASA IT Resources

CNIS Project Goal: *Provide seamless access to ground-based distributed information technology resources (both hardware and software) to enable NASA missions.*

To support the ambitious goals of NASA's Enterprises, CICT's Computing, Networking, and Information Systems (CNIS) Project researches new technologies that will provide NASA scientists and engineers with seamless access to distributed information technology resources regardless of location

The CNIS Project is developing an information architecture called the NASA Grid to provide a persistent, high-performance, networked environment that can be used by the NASA community for solving critical problems. The NASA Grid integrates geographically distributed resources, such as supercomputers, large databases, high-end instruments, laboratories, and training facilities

CNIS includes five subprojects 1) Grand Challenge Applications, 2) Information Environments, 3) Grid Common Services, 4) Advanced Networking Testbed Research, and 5) Advanced Computing Testbed Research.

Grand Challenge Applications (GCA)

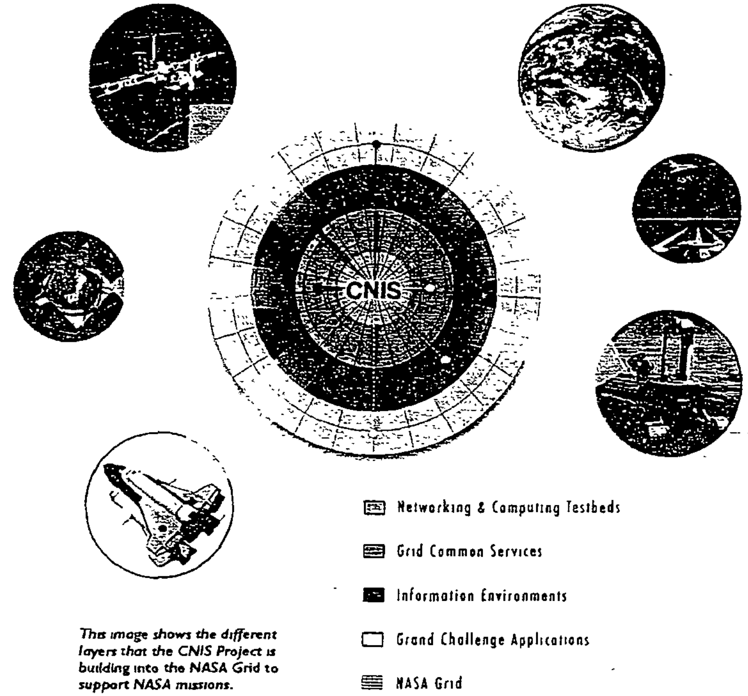
The GCA subproject focuses on NASA Grand Challenge Applications whose demanding requirements can drive development of the Grid and demonstrate how Grid capabilities can be used to improve science and engineering processes. The Grand Challenge Applications include. 1) Earth Systems Simulation, 2) International Space Station Systems Simulation, 3) the Collaborative Information Portal for the Mars Exploration Rover Mission, and 4) Space Flight Simulation.

Information Environments (IE)

The IE subproject is researching new technologies to build distributed virtual environments and frameworks for management of applications and analysis, visualization, and integration of information using distributed heterogeneous resources.

Grid Common Services (GCS)

The GCS subproject is developing a layer of "middleware" that allows hardware resources to be accessed and shared in a secure and reliable fashion. GCS will develop services such as job execution management and runtime services, uniform access control and security, and Grid management and administration



This image shows the different layers that the CNIS Project is building into the NASA Grid to support NASA missions.

Advanced Networking Testbed Research (ANTR)

The ANTR group will infuse emerging networking technologies into NASA mission applications. ANTR will build a testbed to interconnect high-demand NASA computing and data resources, demonstrate the application of advanced networking technologies, and perform networking research to support integrated resource management, distributed collaborations, nomadic networking, and secure collaborative environments.

Advanced Computing Testbed Research (ACTR)

The ACTR group is investigating next-generation, high-end computing architectures and interconnects, programming paradigms to make programs portable and scalable, automated parallelization and performance optimization tools, and tools for modeling and optimizing application performance on different platforms for various sets of data

Selected Applications Addressed by the CNIS Project

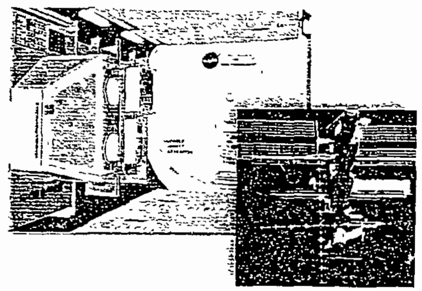
The "Chapman" supercomputer (front) is being used to run global climate model simulations (back).

Optimizing the Code for Global Climate Modeling on the Origin 3800

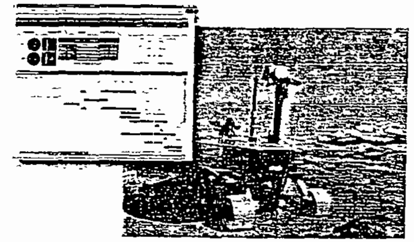
The CNIS Project is developing a high-end computing testbed to support applications requiring high-performance computing capabilities. For example, CNIS is working with the NASA Advanced Supercomputing Division and NASA's Earth Science Enterprise on global climate modeling, powered by NASA's high-performance 1,024-processor SGI Origin 3800 supercomputer called "Chapman." Accessible via the NASA Grid, Chapman is the first 1,024-processor computer with a single system image (SSI) architecture in which all processors share a common memory. This dramatically increases Chapman's performance over other cluster architectures. Chapman has increased the number of simulated climate days from 900 a day to more than 2,900 a day.

Developing an Intelligent Virtual Reality Model of the International Space Station

CNIS is collaborating with the Aerospace Technology Enterprise's Engineering for Complex Systems (ECS) Program to develop the Intelligent Virtual Station. The Intelligent Virtual Station's novel framework and architecture enable the integration of collaborative tools, advanced engineering tools, and intelligent tools to provide a single access point to distributed information regarding the International Space Station (ISS), along with intelligent analysis, search, and filtering capabilities. It also provides an interactive real-time simulation environment, with realistic astronaut avatars, to assist in ISS design, training, and operations. The IVS will help NASA monitor and operate the International Space Station, train astronauts, and support fault detection, isolation, and recovery.



This simulation of the International Space Station (ISS) centrifuge accommodation module (left) is an example of how the Intelligent Virtual Station will help NASA train astronauts to operate the ISS (right).



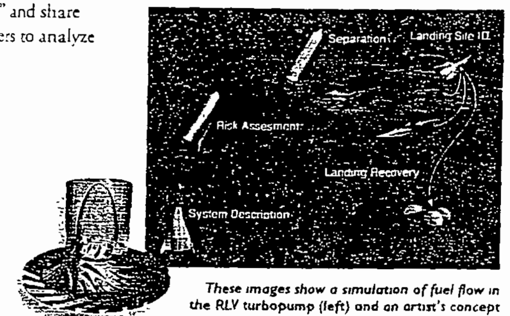
The Collaborative Information Portal (left) is a web-based tool that will be used to monitor the progress of the Mars Exploration Rover (right).

Increasing the Efficiency of the Mars Exploration Rover Mission

The Mars Exploration Rover Collaborative Information Portal (MER CIP) is a simple and customizable web-based tool that brings together information from multiple sources so that the user can quickly and easily determine the current status of mission operations. It is the "one-stop" place to which all team members go to determine "what's going on." Users can quickly orient themselves, monitor the progress of mission teams and key events, compare planned and executed sequences and results, and check the progress towards mission success. With technologies developed under CNIS, users can easily find the information they need to enhance their "situational awareness" and share information, collaborating with others to analyze data faster.

Improving the Safety and Survivability of Space Flight

To support NASA's long-term investment strategy under the Integrated Space Transportation Plan, CNIS is developing new processes and demonstrating collaborative software framework technologies for use by the Space Launch Initiative to improve simulations of ascent, abort, docking at the International Space Station, descent, landing, and other flight maneuvers. The collaborative design environment will enable rapid simulation and testing of various designs in a virtual environment. Engineers will be able to test performance, abort capabilities, and fly-ability—keys to understanding and improving the safety and survivability of space flight. The use of high-confidence simulation tools within the Grid environment will also improve the design, analysis, and risk assessment of re-usable launch vehicles (RLVs) and their subsystems (such as the liquid rocket subsystem) during the entire launch-to-orbit-and-return phase. Decreasing the time required to simulate the turbopump, a major component of the liquid rocket subsystem, is especially important for eliminating vibration and improving turbopump performance; this will enable an RLV to carry heavier payloads and make future missions more affordable.



These images show a simulation of fuel flow in the RLV turbopump (left) and an artist's concept of the RLV abort and recovery process (right).

Delivering Data Quickly and Directly Between Earth and Space

The Space Communications Project is designing the Space Internet.

SC Project Goal: *Enable broad, continuous presence and coverage for high-rate data delivery from ground-, air-, and space-based assets directly to the users.*

Working closely with CICT's CNIS Project, which provides seamless access to NASA data resources, the Space Communications (SC) Project provides high-rate delivery of data from those resources directly to users. The SC Project is looking for innovative ways to meet the needs of four NASA Enterprises. The Earth Science Enterprise needs a distributed network that enables all Earth-observing spacecraft to transfer real-time, multi-sensor information directly to users. The Human Exploration and Development of Space Enterprise requires multi-gigabit, Internet-based communications in near-Earth orbit. The Space Science Enterprise needs high-rate communications from scientific spacecraft traveling to our outer planets and beyond, as well as intra-planetary networks for surface exploration Finally, the SC Project helps meet the Aerospace Technology Enterprise's goals for a National Airspace system architecture to support safe and secure air travel in 2015.

SC includes five subprojects: 1) Intelligent Architectures, 2) Backbone Networks, 3) Access Networks, 4) Inter-Spacecraft Networks, and 5) Proximity Networks.

Intelligent Architectures (IA)

The IA subproject is developing the technology for intelligent, autonomous communication architectures that enable anytime/anywhere operations with end-to-end information delivery from space directly to users This task includes developing architectural design tools and emulation testbeds for space communication networks; intelligent architectures for formation flying and constellation missions; proximity network architectures and protocols for surface exploration; a space backbone for dynamic routing and transmission of large data sets, and architectures supporting direct-to-user applications for near-Earth missions In order to develop the next generation satellite network architecture, SC and CNIS are working together to develop a state-of-the-art satellite emulation testbed

Backbone Networks (BN)

The BN subproject is developing technologies for high-rate backbone networks, including microwave transmitter and receiver technologies for high-power, highly efficient, miniature systems; optical communications technologies for deep-space missions and inter-satellite cross-links; networking technologies to support interoperability; and standards for seamless communication networks

Access Networks (AN)

The AN subproject is developing technology for flexible, reconfigurable communication systems that enable mobile communications from infrastructure nodes to fixed and/or mobile assets in space or on the ground This includes low-cost and widespread ground terminals for direct-to-user applications; products and subsystems for connecting mission elements to both the near-Earth and deep-space backbone, and the protocol and mobile networking technologies for enabling greater coverage and accessibility to future NASA missions.

Inter-Spacecraft Networks (IN)

To enable future NASA spacecraft to communicate with each other while flying in formation, the IN subproject is investigating ways of extending the data and control bus across the cluster by using cross-link technologies for the physical and data layers, using standard protocols and media access control for the network and transport layers, and using system management technologies for the application and network layers.

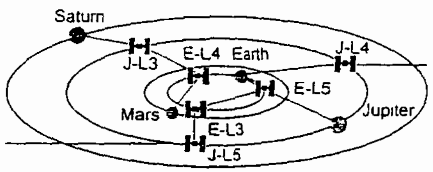
Proximity Networks (PN)

The PN subproject is developing short-range, short-lived, proximity wireless networks to enable small sensor packages to inter-communicate in space. This task includes developing smart high-speed, lower-power, fixed wireless micro-instrument sensor networks to enhance the quality and granularity of science data retrieved in extreme planetary environments. It also includes developing miniature wireless intranets with reconfigurable protocols and integrated navigation and communication systems to provide greater access and dissemination of exploration data.

Selected Applications Addressed by the SC Project

Designing the Earth's Sensor Web and Interplanetary Communications

SC's IA subproject is already designing an Interplanetary (or Solar System) Communications and Sensor Network to provide high-rate continuous coverage for space missions This end-to-end infor-mation delivery system will be a network of networks, with connecting nodes between near-Earth systems and deep-space systems across the Solar System. The high-bandwidth links established will enable evolvable, secure and transparent connectivity to the user.



This conceptual map of the Interplanetary Communications and Sensor Network shows the location of key relay stations.

The Interplanetary system infrastructure will include a network of relay stations placed at the planetary Lagrangian points (where stations can remain in a fixed orbit relative to their respective planet and the sun). These relay stations will provide server and network routing services to support several missions simultaneously. In-space "lighthouse" services will support missions that require autonomous navigation and time synchro-nization. The Sensor Web architecture enables researchers to study the Earth as a global system, rather than as a series of individual observations. This will require revolutionary changes in the design of the communication network and the development of new communication technologies to effectively create a space and sub-space (land, air and sea) wide-area network.

High-Power Microwave Sources for Backbone Networks

High-power microwave sources will be critical components of the future high-data-rate space backbone. For the next Mars mission, the BN subproject will provide new high-power microwave sources that deliver 300% more power than current models. This will increase the effective data rate transmission by a factor of ten, providing a greater return of science data BN is also developing a miniaturized traveling wave tube that will be half the size and weight of current models and 20% more efficient.

The Mars Reconnaissance Orbiter (above) will use high-power microwave sources.

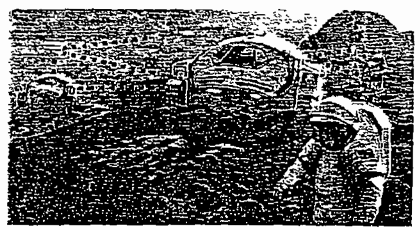
Scanning Reflectarray Antenna

To increase the coverage and throughput of transmissions from space, and reduce the cost of launching vibration-free antennas for small spacecraft, the AN subproject is developing electrically steered reflectarray antennas based on thin-film ferroelectric phase shifters Ferroelectric reflectarray antennas can be produced for only a tenth of the cost of MMIC (Microwave Monolithic Integrated Circuit) phased-array antennas, and consume much less power than gimbaled antennas Ferroelectric reflectarray antennas provide beam steering of greater than plus-or-minus thirty degrees, and deliver more than one-gigabyte-per-second throughput from space to Earth.

The ferroelectric reflectarray antenna (above) will enable cost-effective space communications.

Ad Hoc Networks for Mobile Space and Surface Systems

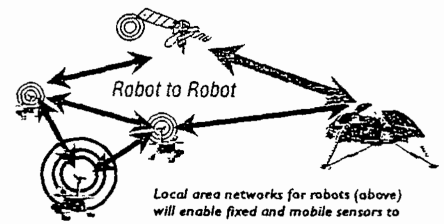
To improve communications performance, flexibility, manageability, and reliability, the IN subproject is creating multihop wireless ad-hoc networking protocols for use in NASA space and surface missions. The protocols are dynamic, self-organizing, and self-configuring to enable greater flexibility between nodes in a planetary environment. The nodes will cooperate to transmit data between nodes that are not within wireless range of each other.



This artist's concept shows an ad-hoc network on Mars.

A Local Area Network for Space-Based Instruments

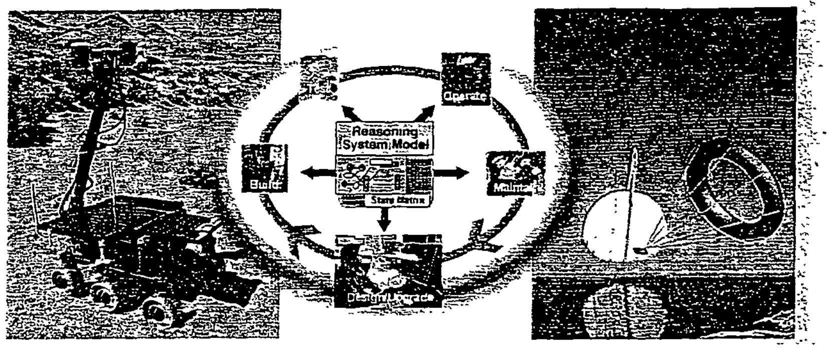
The PN subproject is creating a network architecture that will enable fixed and mobile sensors to communicate in space. Applications include planetary surface exploration using robot-to-robot and intra-robot communications, communications of sensors within vehicles, communications for astronaut activities outside the vehicle, and wireless control from the International Space Station. PN's research emphasizes low power draw, use of commercial off-the-shelf parts, and adequate bandwidth.



Local area networks for robots (above) will enable fixed and mobile sensors to communicate in space.

Intelligent Systems (IS) Project

Enabling Systems That Think, Adapt, Evolve, and Work with Humans



Representing some of the IS Project's research interests, these images (from left to right) are a planetary rover, a reasoning system model, and an artist's concept of an aerobot (balloon) for exploring the atmosphere of Saturn's largest moon, Titan.

IS Project Goal: *Develop smarter, adaptive systems and tools that work together with humans to achieve NASA's Space Science, Earth Science, Exploration, and Aerospace missions of the future.*

NASA's bold vision for the twenty-first century includes increasing the safety, security, and capacity of the U.S. air transportation system; ensuring the safe and cost-effective operation of the Space Shuttle and future space vehicles; using Earth-orbiting satellites to better understand climatic phenomena; deploying human-robotic systems to explore the planets; and sending intelligent robots into deep space to discover the origins of life. These goals require system (human plus machine) intelligence that does not exist today. IS is tasked with developing technologies to enable this system intelligence IS includes three subprojects: 1) Automated Reasoning, 2) Human-Centered Computing, and 3) Intelligent Data Understanding

Automated Reasoning (AR)

Because of the complexity of future NASA missions to Mars and beyond, and the communication restrictions and delays inherent in space, NASA needs smarter vehicles and processes that can respond with limited intervention to uncertain environments. NASA also needs more automated, cost-effective processes for designing, operating, and maintaining these vehicles. In addition, NASA needs highly reliable, cost-effective software to enable these systems and processes. To support these goals, the AR subproject is focusing on 1) system autonomy and automation, and 2) automated software synthesis, verification, and validation.

AR's goals are to provide robotic explorers with capabilities such as autonomous guidance and control, on-board science interpretation, and intelligent vehicle health maintenance, to find new ways to cost-effectively develop and test software; and to develop new methods to reduce the manpower required for ground support activities.

Human-Centered Computing (HCC)

The HCC subproject is researching ways to integrate the performance of systems that receive mixed input and responses from experts, intelligent software agents, and/or robots. Viewing humans and technological systems as inextricably linked, HCC looks at not only "the computer," but also cognitive/social systems and physical facilities and environments. HCC is focusing its research on three areas 1) multi-modal interface technology, 2) human-system modeling, and 3) agent-based decision systems.

The multi-modal interface technology addresses areas such as distributed collaborative science, dialogue systems between humans and robots, and biologically based human-computer interfaces The human-system modeling technology addresses areas such as work systems, learning complex dynamic tasks, and human-centered software development.

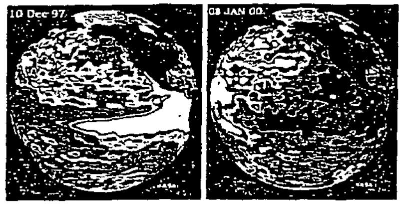
The agent-based decision systems address areas such as the Mars Exploration Rover, intelligent launch and range operations, and integrated mission operations for the International Space Station.

Intelligent Data Understanding (IDU)

NASA scientists and engineers collect more data each day than they can effectively analyze. The IDU subproject is looking for new ways for scientists to extract meaningful information from large, diverse databases, such as those generated by space-based observatories. NASA engineers and operations staff also need help analyzing the massive maintenance data available for systems such as the Space Shuttle and the International Space Station.

To meet these challenges, IDU is conducting research in three main areas: 1) data mining, for processing and combining raw data and detecting patterns and regularities within the data set. 2) knowledge discovery, for helping a scientist or engineer understand underlying causal relationships and processes; and 3) machine learning, for using knowledge extracted from data to perform a specific task that assists a human or system in taking decisive action.

Selected Applications Addressed by the IS Project



Scientists have discovered pattern relationships between the recurring weather phenomena, "El Niño" (left) and "La Niña" (right).

Forecasting Events on Earth

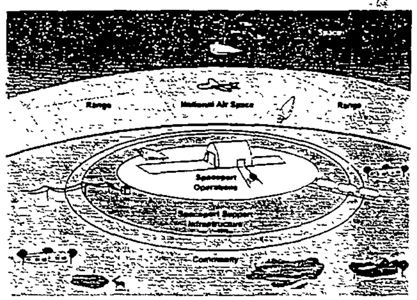
Accurate forecasting of climatic and biological events on Earth is an interagency and international goal. NASA leads the world in the use of space-based observing sensors and complex computer models to help understand and forecast future events in the Earth's biosphere. IS's IDU subproject is developing a system called the Terrestrial Observation and Prediction System (TOPS) to rapidly and accurately understand data from NASA's Earth Observing System and discover useful connections between the complex components of the Earth system. TOPS will quickly assimilate web-based climate and satellite data into NASA models of hydro-ecological processes to forecast the impact of changes in climate and weather on hydrological and biological systems.

IDU technology helps scientists explore large sets of climatic data, find association patterns, and analyze anomalies to discover and understand the impacts of weather phenomena such as "El Niño."

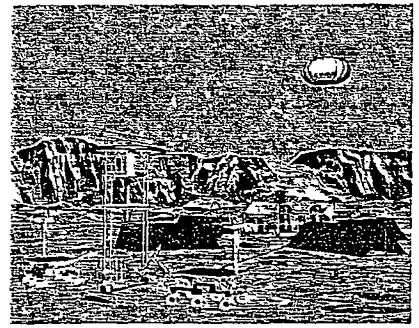
Designing Spaceport Systems

The HCC subproject is working with Kennedy Space Center to create a Spaceport Operations Testbed that will enable researchers to safely test new information and decision support systems for launch, range, and flight operations. The goal is to replace today's space flight procedures and systems with safer and more responsive intelligent systems that can handle more flights and mixed operations at lower cost with fewer human controllers.

The testbed researchers will use collaboration techniques, teamwork-cognition models, expertise-capture systems, and new human-machine interfaces to find new ways to enhance human performance and operations. Spaceport designers and operations planners will be able to test their ideas against a variety of simulated missions, vehicles, flight anomalies, human controller scenarios, and range operations.



Pictured is an artist's concept of a future spaceport.



The IS Project is developing technology to manage multiple types of robots.

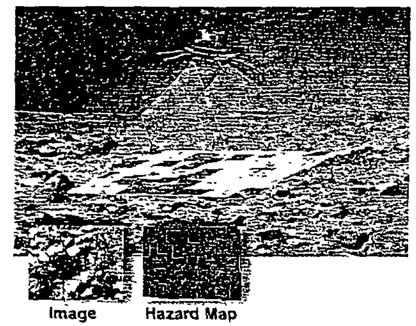
Managing Multiple Robots Efficiently

NASA faces significant challenges in sending different types of robots to a planet such as Mars to gather scientific data. NASA robots must learn how to work together to achieve complex tasks—surveying sites of scientific interest, coordinating their use of instruments to analyze rocks, intelligently forming networks for communication, evaluating one another's health and progress, and assisting each other in diagnosis and repair. To develop an overall architecture for dynamic team formation, the AR subproject is researching autonomous robot architectures, multi-robot coordination, planning and scheduling; task execution; distributed control; probabilistic reasoning; machine learning, and monitoring and fault diagnosis. The team will evaluate both distributed and global approaches to see which offer the most computational efficiency.

Landing Safely on New Planets

Another challenge is to land a spacecraft, especially one without a human pilot, on an unknown planetary surface. In the face of unexpected circumstances, the craft must decide quickly how to best preserve its safety while still executing its mission. To solve this problem, the AR subproject is exploring intelligent sensing and reflexive behavior. The team will develop software systems that provide spacecraft with real-time situational information, or "awareness," so that they can quickly and intelligently decide what to do next. Autonomous on-board data analysis systems can offset the effects of sudden and unexpected winds and enable the craft to land precisely and safely. The reward is a greater return of scientific data.

This artist's concept of the Mars Smart Lander shows it detecting hazards before landing.



Information Technology Strategic Research (ITSR) Project

Seeding the Next Generation of Aerospace Technology

This artist's concept represents some of the revolutionary technologies that the ITSR Project is developing

ITSR Project Goal: *Research, develop and evaluate a broad portfolio of fundamental information technology and biologically inspired nanotechnology for infusion into NASA missions.*

Future NASA missions will require new and dramatically different technologies, including new materials; smaller, lighter devices that consume less power, highly reliable software; and reconfigurable computing and information technologies. In ITSR's technology "incubator," high-risk, high-payoff, and long-range technologies are identified, explored, developed, verified, and transferred to NASA missions. ITSR's dynamic research portfolio currently includes development and assembly of nanoscale components; intelligent, adaptive, immersive, multi-modal control of aerospace vehicles; automated development and verification of high-confidence software; adaptive and fault-tolerant systems; and new models of computing ITSR currently includes five subprojects: 1) Intelligent Controls and Diagnostics, 2) Evolvable Systems, 3) Automated Software Engineering Technologies, 4) Bio-Nanotechnology, and 5) Revolutionary Computing Algorithms.

Intelligent Controls and Diagnostics (ICD)

The ICD subproject researches adaptive vehicle control systems that automatically compensate for unanticipated failures or damage which might otherwise cause a catastrophe; outer-loop technologies that intelligently maneuver a vehicle; health management and diagnostics technologies that detect, isolate, and take steps to rectify imminent system and/or component malfunctions; and machine-learning algorithms that augment control and enable new interfaces for immersive virtual human-machine environments. These technologies are designed for aircraft and spacecraft applications (piloted, remotely piloted, and autonomous), and for robotic vehicles/devices used for atmospheric and space-based science and exploration.

Evolvable Systems (ES)

The ES subproject seeks to ensure mission success and increase science return by developing biologically inspired, adaptive, hardware and software systems. These systems will respond to, and recover from, component faults and failures by adapting, repairing, and reconfiguring themselves, effectively marshalling healthy resources and reconfiguring them for mission success. ES is developing advanced algorithms for three functional areas: (1) reconfiguration and re-use, (2) optimization and design, and (3) adaptation and learning.

Automated Software Engineering Technologies (ASET)

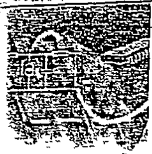
NASA's 1977 Voyager mission contained 3,000 lines of software code, whereas the International Space Station contains nearly two million. The ASET subproject is advancing technologies and tools for cost-effectively developing highly reliable, complex software systems that increase mission safety and the probability of success. ASET is applying formal methods for specifying software requirements and design, developing high-assurance design techniques, and improving program synthesis Researchers will look at mathematical specification and verification of software requirements and design, explore ways to automate and scale-up analytical methods of verifying and debugging software across its life cycle, and develop efficient algorithms for automatically generating high-assurance software designs and code.

Bio-Nanotechnology (BN)

Nanotechnology is the science of creating functional materials, devices, and systems by controlling matter and exploiting its novel phenomena and properties (physical, chemical, and biological) at the nanometric (atomic) scale. With nanotechnology, NASA scientists can take the notion of "small but powerful" to the extreme, while using biology to provide the models and processes. We can expect remarkable results: biologically-inspired sensors will be sensitive to a single photon; data storage based on DNA will be a trillion times more compact than current media; and supercomputers modeled after the brain will use only a billionth of the power used by today's supercomputers. The BN subproject's research will enable NASA to develop smaller and lighter spacecraft, smaller and more efficient and powerful computers, radiation-resistant nanoelectronics, biosensors, in-vivo medical devices, artificial neural systems, robots, and nanoelectromechanical systems

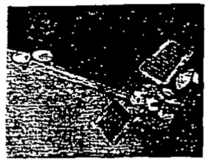
Revolutionary Computing Algorithms (RCA)

The RCA subproject researches new computational models and algorithms for future space missions. Quantum computing, for example, exploits recently discovered quantum effects—such as superposition and interference—to solve computationally hard problems. Biological systems inspire new computational models and problem-solving methods that can be applied to automated reasoning, human-centered computing, and intelligent data understanding Current efforts in neural networks, genetic algorithms, cognitive science, and gene sequencing are expected to generate new approaches for computing and storing information. For example, RCA is investigating new algorithms that enable remote sensory systems to compress data by selecting only the novel and unpredictable input, application of this technology will enable landing craft to dynamically estimate trajectory, closure rate, and flight attitude in relation to the surface.



Selected Applications Addressed by the ITSR Project

Using Evolution to Repair Spacecraft Electronics



Genetic algorithms could lead to self-repairing electronics for spacecraft such as the Mars Odyssey.

Genetic algorithms are computational search procedures that simulate the evolutionary processes of natural selection and genetics to find the optimal solution to a problem. They have been used to solve many problems, from jet engine optimization to factory scheduling. ITSR's ES subproject is investigating genetic algorithms to see if they can make spacecraft electronics more tolerant of faults caused by extreme temperature, radiation, or manufacturing Today's fault-tolerance strategy of deploying redundant systems is effective but adds to the size, weight, and power requirements of the spacecraft Self-repairing electronics might be more efficient while adding little to these requirements Challenges remain, however. Genetic algorithms must scale to repair increasingly complex functionality and be able to reconfigure chips in real time. If they can meet these challenges, ES will investigate their use in fault tolerance for sensors and planetary rovers.

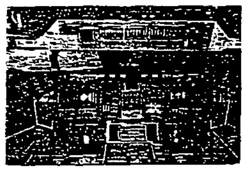
Designing Spacecraft with Smart Whisker Technology

Many creatures have distributed sensor arrays that, in combination with their neural processing, enable them to safely explore unknown environments. The RCA subproject is studying aspects of these sensory systems to discover new approaches to sensor fusion and new algorithms for representing spatio-temporal data to spacecraft and other devices. Research includes studying how rats use their whiskers to identify an object's position, orientation, size, shape, and texture; how monkeys store "programs" for coordinated movement in theirbrain's cerebellum; and how electric fish detect and locate objects via electrolocation and fluid flow estimation. From this research, RCA will develop algorithms for use in designing artificial sensing and exploratory systems for spacecraft.

Rats use their whiskers to identify objects.

Developing and Verifying Software for Aerospace

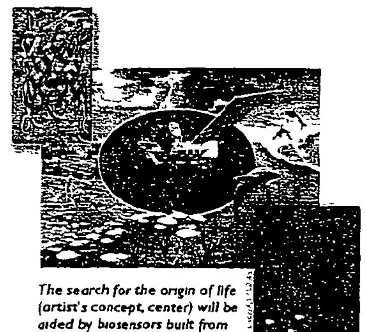
The ASET subproject is developing formal verification tools and technologies to enhance and assure the reliability of a new commercial avionics technology—Integrated Modular Avionics (IMA). IMA can reduce the size weight, power, and recurring cost of commercial avionics systems by enabling shared computing resources to simultaneously host functions of differing criticality, but the risk is that a less critical task could affect a more critical task. The ASET technology would verify the safety of the IMA operating system, ensuring that tasks do not negatively affect each other. ASET is also exploring automated approaches to certifying software generated by a program synthesis system, such as the one used to generate state estimation code for parts of a deep-space mission's attitude control system ASET will demonstrate that automated certification tools can be used to reliably check these synthesized programs, leading to faster and more reliable software development



The Shuttle's cockpit reveals a web of avionics devices.

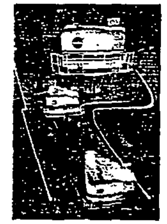
Searching for the Origin of Life with Nanotechnology

The BN subproject is analyzing the structure and function of genetically engineered protein-based systems and nanowire-based systems to see if they can be used to create biosensors for future NASA missions. The nanostructures could be used to produce smaller, stronger, and "smarter" probes These probes could search for extraterrestrial life forms, and detect life-threatening atmospheric elements both in space and on Earth. For example, BN is developing a solid-state "nanopore"—an ultra-sensitive device that can rapidly detect single molecules of nucleic acids (RNA and DNA), identifying them by their nucleotide sequence The nanoprobe could be used to detect life on other planets, and to decode virtually all DNA genetic variations among organisms on Earth. This and other BN research will have useful applications in the fields of electronics and medicine, as well as space science.



The search for the origin of life (artist's concept, center) will be aided by biosensors built from proteins (left). The carbon nanotube (modeled on right with attached functionalized module) offers another versatile material for nanotechnology.

Designing Intelligence for the Human and the Machine



Flight simulators are used to test intelligent flight control systems.

When an aircraft or spacecraft loses a crucial flight control effector, catastrophe often results. The ICD subproject is dedicated to improving the safety of aerospace vehicles with more intelligent vehicle control systems, such as the Intelligent Flight Control System. The system automatically compensates for flight control failures by using the remaining effectors to replace the failed function. For example, in aircraft applications it compensates for a failed rudder by deploying differential engine thrust, and a failure of the elevators by initiating a symmetric up-or-down movement of the ailerons. This system has enabled pilots to handle severe control failures that would have otherwise led to a crash ICD is also exploring new modalities of human-machine interaction, such as connecting pilots and astronauts directly to computers via the human electrical nervous system. Researchers are developing brain-computer interfaces using electroencephalographic (EEG) pattern recognition and prostheses control using electromyographic (EMG) pattern recognition Applications include "wearable cockpits" with virtual instruments, keyless workstation interfaces, direct communication with autonomous reasoning systems, and more