Spaceport News
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John F. Kennedy Space Center

From Origins to Destiny

U.S. Space Exploration in the Next Century

As explorers, pioneers, and innovators, we boldly expand frontiers in air and space to inspire and serve America and to benefit the quality of life on Earth.

— 1998 NASA Strategic Plan

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(Photos: Cover photo is Hubble Space Telescope image of the collision between two galaxies known as the Antennae galaxies. Photo above shows the Shuttle Endeavour prior to its maiden launch in May 1992. In the foreground is a full-sized replica of the sailing ship that carried Christopher Columbus and his crew to the New World 500 years before.)

Introduction

The theme for this special issue of *Spaceport News*, *From Origins to Destiny*, comes from the Space Science Strategic Enterprise Plan.

Space Science is one of four strategic enterprises in NASA's Strategic Plan. The other three enterprises are Mission to Planet Earth, Human Exploration and Development of Space, and Aeronautics and Space Transportation Technology.

The complete phrase, taken from the Space Science mission statement, reads: *From origins to destiny, chart the evolution of the universe and understand its galaxies, stars, planets and life*.

All four strategic enterprises encompass this concept in some way. Exploration of the solar system — through both crewed and uncrewed missions — allows us to better understand the evolution of our own planet and life forms as well as of the universe itself. Programs like Mission to Planet Earth also focus on our origins, allowing us to better understand and predict the global changes sweeping over the planet.

The impulse to send humans into space, be it to Earth's orbit, back to the moon, or onward to Mars, perpetuates a quest that has characterized the human race since our beginning.

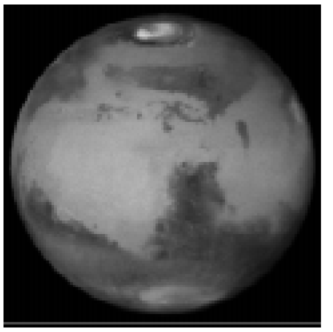
It is humanity's destiny to discover where boundaries lie and then surpass them.

In implementing all these enterprises, we continue to evolve as a nation and culture.

The articles and material presented in this special issue are not intended to be a comprehensive overview of U.S. space exploration in the next century.

Rather they represent a glimpse of some of the most intriguing aspects of what our nation hopes to achieve, as well as a recognition of some of our accomplishments to date.

Space Center sees future in trip to Mars



By Chuck Weirauch

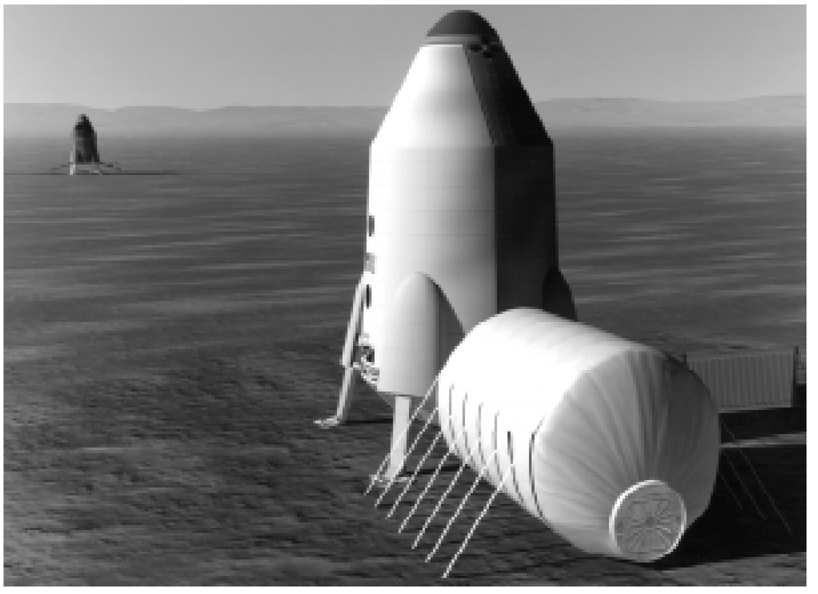
CAPE CANAVERAL — (AP) At 4:25 a.m. Dec. 15, 2013, the first human mission to Mars lifted off from Launch Pad 39B at Kennedy Space Center. The Magnum-1 launch vehicle performed flawlessly as it lofted the six-member international crew into a low-Earth orbit, where their spacecraft docked with the Mars propulsion module launched last month. After docking, the propulsion module engines will be ignited and the crew will begin its 180-day journey to the Red Planet. They will touch down near the Cargo Lander-1, already on the surface, to establish the first human outpost on an extraterrestrial planet. After inflating a habitation module already on Mars, the crew will begin preparations for the 550-day exploration phase of their mission. Orbiting overhead will be the Earth Return Vehicle that will bring them back to Earth when their mission is complete.

Although this quick look at a possible KSC future may seem like science fiction, work is now under way to make the Mars Reference Mission a part of the Space Center's long-range plans.

"We can make a substantial contribution to NASA's newest plan to send a human mission to Mars," said KSC Exploration Think Tank manager Mike O'Neal. "As a member of the agency's Integrated Mars Mission Team, we are now in the process of helping NASA determine what technologies need to be demonstrated for the Mars mission concept."

The Reference Mission, developed by the Mars/Lunar Exploration Office at Johnson Space Center, is not a final plan but a tool to help the agency determine what would be required to accomplish such a feat. Several NASA field centers have been asked to determine just how they could contribute to such a mission. The KSC Exploration Think Tank has the job of determining the areas of applicable KSC expertise and promoting their use by NASA in the development of hardware, new technologies and strategies that will be required for the human exploration of the Red Planet.

"One of KSC's primary areas of expertise that will be of enormous benefit to the Mars mission is more than 30 years of spacecraft ground processing and launch systems experience," O'Neal said. "KSC will be required to put together a plan to support the processing of spacecraft and payloads for the Mars mission, as well as the new heavy launch vehicle that would be required to lift them into space."

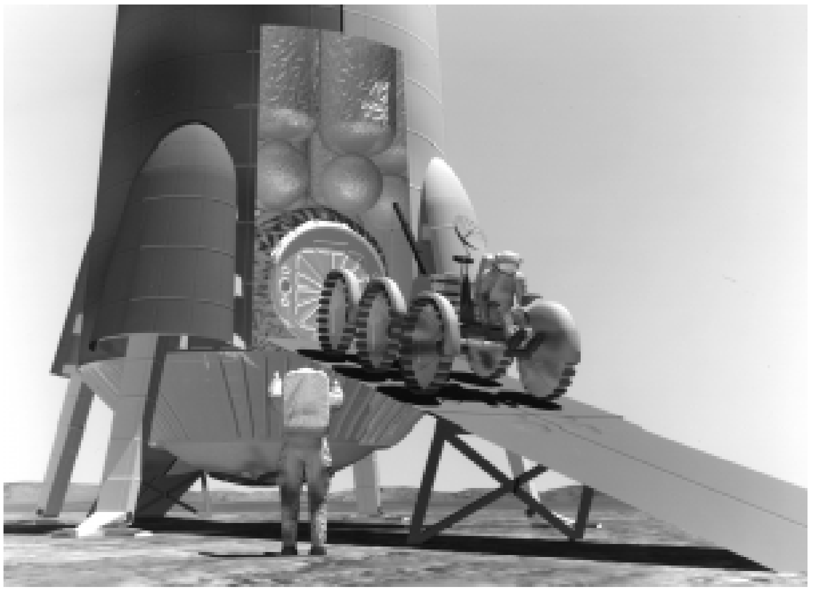


ABOVE RIGHT — Hubble Space Telescope image of Mars, March 1997. Above, artist's concept of crewed vehicle on the surface (in foreground) with inflated habitation module in front of it. The living quarters are transported to Mars in the Cargo Lander-1, shown in the distance, then destowed and inflated.

The Reference Mission, an element of NASA's Human Exploration and Development of Space (HEDS) enterprise, calls for a launch vehicle like the Magnum currently under consideration by NASA. This rocket would be designed to place payloads weighing up to 80 metric tons into low Earth orbit. This lift capacity would be sufficient to propel Mars cargo modules, human habitation modules and their respective propulsion modules into low-earth orbit. Once there, the cargo and habitation modules would dock with their propulsion modules and then set off to Mars with the crew on a fast-transit trajectory.

Instead of flying everything that would make up the Mars base along with the crew habitation module, two cargo missions to Mars would be launched well before the first human mission lifted off. The first Mars cargo mission, with an initial launch opportunity in September 2011, would send

(See MARS, Page 4)



AN unpressurized rover is unloaded from the Cargo Lander-1 by the first humans to land on the Red Planet's surface. The rover would be used to transport an inflatable habitation module from the lander to the transport vehicle that carried the crew to Mars. Visible inside the lander is an automated fuel manufacturing plant.

Mars . . .

(Continued from Page 3)

a fully fueled Earth Return Vehicle (ERV) into orbit around Mars. This first cargo mission would take a little more than two years to reach Mars. The second cargo mission, also slated to lift off in late 2011, would land the Cargo Lander-1 on the surface. Inside would be the Mars Ascent Vehicle (MAV). At the conclusion of the exporation phase of their mission, the crew will fly the MAV to the ERV, and return to Earth in the ERV.

Also stowed in the cargo lander: an unpressurized rover for traversing the Martian terrain and an inflatable habitat module. The crew would transfer the inflatable habitat to the spacecraft which brought them to Mars, attach it and then inflate it, establishing their living quarters on the Red Planet.

Also located in the lander would be an automated propellant plant, capable of manufacturing fuel and liquid oxygen (LOX) and storing it in cryogenic tanks prior to the arrival of the first crew. This unit, known as the In-Situ Propellant Production (ISPP) system, would carry liquid hydrogen (LH2) from Earth.

Prior to the crew's arrival, the plant would automatically manufacture methane fuel and LOX oxidizer for the Mars Ascent Vehicle using the on-board LH2 and carbon dioxide found in the Martian atmosphere. (Methane and LOX are leading candidates for propellants, but this is still under review.)

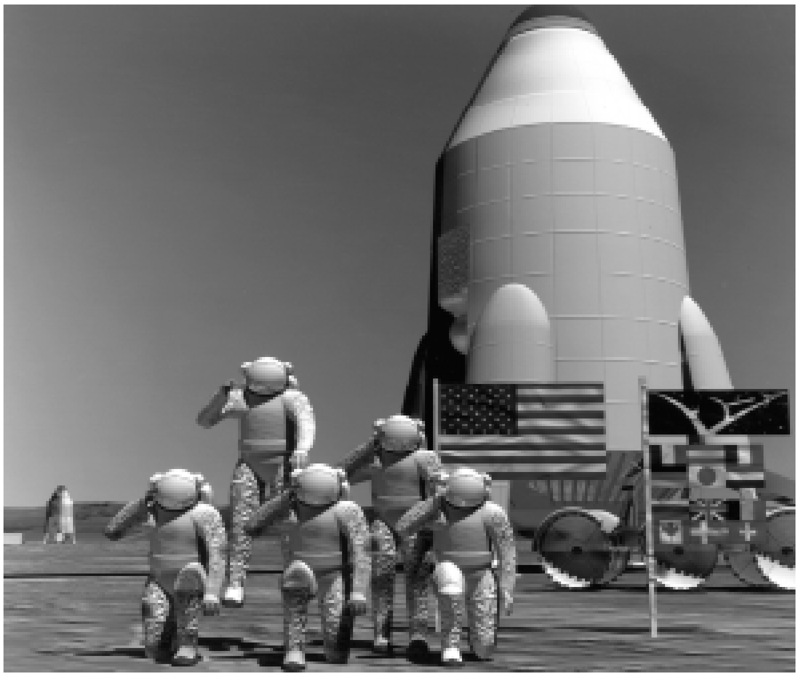
"KSC has the expertise in the cryogenics, autonomous systems and remote monitoring disciplines that would be required for the development of the ISPP," O'Neal said.

To sustain the crew in their habitat for an approximately one-and-a-half-year stay on the surface, an advanced type of life support system will have to be designed and developed. According to the latest version of the Mars Reference Mission, this system and its primary backup would be mostly based on a physical/chemical system such as the one on the Shuttle to scrub impurities from the crew supply of air and water, while the second backup system would rely on stored supplies.

"However, the Reference Mission also states that demonstrating the ability to produce food and revitalize the air in the Mars habitat is a mission-critical objective," O'Neal said. "We feel that KSC can also make a substantial technological impact on the bioregenerative part of the mission because of our considerable experience in this area."

Since 1985, KSC has been developing and conducting research on such a self-contained, plant growth-based life support system formerly known as the Controlled Ecological Life Support System (CELSS) Breadboard Project. This project is now called the Bioregenerative Research Lead of NASA's Advanced Life Support Systems.

"There are many other areas of expertise at KSC where we can have a major impact on NASA's Mars and other long-duration missions in the future," O'Neal said. "Our goal is to apply KSC operations know-how, resources and technical expertise to help enable the human exploration of the solar system while delivering world-class products."



NOT THAT FAR AWAY — This artist's concept shows five of the six crew members from the first human mission to Mars. The Mars Reference Mission timeline would be:

- 2011 – Fully fueled Earth Return Vehicle lifts off, arrives at Mars about six months later and begins orbiting planet;
- 2011 – Second mission, called Cargo Lander-1, lifts off, carrying Mars Ascent Vehicle that will land on surface. Also stowed inside are rover, propellant plant, and inflatable habitat module;
- 2013 — First human crew lifts off, lands on Mars 180 days later to begin 550-day exploration of Martian surface.

On matters of food ...

KSC scientists favor plant-based life support

If KSC Life Sciences researchers have their way, the science-fiction vision of greenhouse-grown plants sustaining a colony of Mars explorers just may become reality.

"We believe that on a Mars mission where the crew would be on the surface of the planet for more than 500 days, the life support system for the crew should be mostly bioregenerative," said Life Sciences agricultural engineer Dr. John Sager. "The most current version of the

(See FOOD, Page 13)

... and fuel.

Fuel supply will borrow from Earth and Mars

Just as early explorers of the North American continent learned to bring along only what was essential for survival and to live off the land for the rest, so too will the first Mars mission crews and future residents of a Mars colony.

"This philosophy of living off the land is the basis for NASA's new Mars Reference Mission and will provide the necessary resources required for the possible colonization of the planet," said KSC Exploration Think Tank member Robert Johnson. He is also the KSC lead for NASA's In-Situ Propellant Production (ISPP) Team at Johnson Space Center and chief of the Process Engineering Directorate's Main Propulsion/ Space Shuttle Main Engine (SSME) Branch. "The ISPP is a perfect example of how KSC's expertise can be used to support future NASA missions."

The ISPP is a critical element of the

(See FUEL, Page 13)

Space Station will lead the way

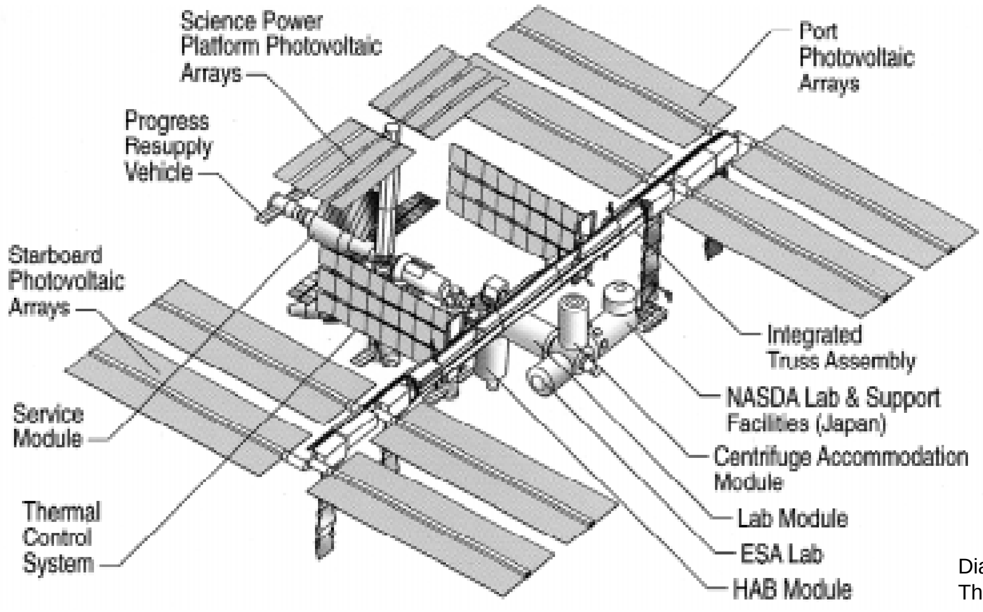


Diagram from Station prime contractor The Boeing Co.

By Bruce Buckingham

In the summer of 1998, NASA will inaugurate one of the greatest undertakings in the history of U.S. human space flight when the first element of the International Space Station (ISS) is carried into orbit aboard the Space Shuttle Endeavour. The launch will mark a major milestone in the on-orbit assembly phase of the station, culminating many years of dedicated work.

From the initial conception of the station to the final checkouts of the flight elements to major modifications to the orbiter fleet, the International Space Station will soon realize its ultimate goal of providing a long-term habitat for humans to work and live in space.

44 Shuttle flights

Assembling the station while orbiting the Earth at an average altitude of 220 miles and having it become operational will keep the Shuttle fleet and her multinational astronaut crews busy well into the next century. Forty-four Shuttle missions are currently earmarked to deliver key components to the on orbit construction site.

The Station will provide its crews with more than 46,000 cubic feet of living and working space – that's about the same as the combined passenger cabins of two Boeing 747s. The end-to-end wing span of the station will measure 356 feet and it will be 290 feet long. Its mass will total nearly one million pounds when complete.

The International Space Station is not only a great technological accomplishment. It also is a hugely successful international cooperative project, combining the efforts of 16 countries from all parts of the globe. In an effort to popularize the program and to share the expense of building a state-of-the-art orbiting platform, NASA sought and found interested partners who would share in the cost of station development and construction.

6 laboratories

The pressurized station will include six laboratories. The U.S. will provide one and others will be provided by Russia, Japan and the European Space Agency.

In October, representatives from the various nations building ISS gathered in Houston and confirmed that ground construction of the station remains on schedule.

The Russian Functional Cargo Block and the U.S. Node 1 are the first elements to be assembled on orbit; they both remain on track for launches next year. The third element, the Russian Service Module, is also set for launch late next year.

The European Space Agency's Columbus Orbital Facility will be carried aloft in October 2002.

4 ISS crews

The first four International Space Station crews have been announced in anticipation of flying the first flights to the station. Astronaut William Shepherd will be the first ISS commander. He will travel there on a Soyuz vehicle, along with Russian cosmonauts Yuri Gidzenko and Sergei Krikalev. All three are training for an early 1999 launch and will remain in orbit five months.

Also announced is the first relief crew which will replace Shepherd, Gidzenko and Krikalev. The second incremental crew will arrive at ISS via Shuttle Atlantis. Russian cosmonaut Yuri Usachev will command this crew which includes American astronauts James Voss and Susan Helms.

The third crew named will journey to ISS in a Soyuz for a two-month mission beginning in late 1999. That crew will be commanded by veteran astronaut Kenneth Bowersox and include the first rookie space flyer to journey to Station, cosmonaut Mikhail Turin. Cosmonaut Vladimir Dezhurov will act as flight engineer. These three are now training as backups for the first crew.

The fourth crew named to date will be commanded by cosmonaut Yuri Onufrienko. Joining him on this four-month mission will be astronauts Carl Walz and Daniel Bursch. They are scheduled to arrive at the station in the year 2000 via the Shuttle Discovery.

The first astronauts to work on the station on-orbit, however, won't be the first to inhabit it. Astronauts Robert Cabana, Frederick Sturckow, Nancy Currie, Jerry Ross and Jim Newman have the task of beginning the station assembly process in July 1998, when they attach Node-1 to the already on-orbit Russian Functional Cargo Block delivered just weeks earlier.

The node arrived at KSC earlier this year and continues to undergo preflight processing in the Space Station Processing Facility.

Links between Earth and space are spiritual, practical and economical

By Susan Maurer

"The visions we offer our children shape the future. It matters what those visions are. Often they become self-fulfilling prophecies. Dreams are maps."

— Carl Sagan, *Pale Blue Dot*

The exploration of space is one of the greatest adventures of humanity.

Discovering distant planets using crewed and robotic spacecraft has been an achievement almost in the realm of fantasy, and yet, these dreams also have real-world implications benefiting humankind in the here and now.

Down-to-Earth Benefits

NASA's Mission to Planet Earth is a long-term program to study the Earth as a total system. For example, the weather phenomenon called El Niño, highly publicized this year, has been under study by NASA for several years.

El Niño is a climatic event that can bring devastating weather to parts of the world. Prediction of its conditions has both regional and global implications. El Niño events, which take place on average once every two to seven years, are marked by an increase in ocean surface temperature and a higher-than-normal sea level in the Eastern equatorial Pacific Ocean. The 1982-1983 El Niño yielded catastrophic effects. It was blamed for between 1,300 and 2,000 deaths and more than $13 billion in damage to property and livelihoods.

As part of Mission to Planet Earth (MTPE), NASA and the Centre Nationale d'Etudes Spatiales (CNES), the French space agency, joined in TOPEX/Poseidon, a program that gathers data essential to understanding the role oceans play in regulating global climate, one of the least understood areas of climate research.

The five years of global ocean topography observations made by TOPEX/Poseidon have been a boon for El Niño researchers, who have been able to track three El Niño events since the satellite's launch in August 1992 and another strong one occurred this year.

Spin-Offs

The use of space for economic activities is no longer a subject of debate. Communications satellites are an important part of our industrial growth, and the processing of pharmaceuticals and biological compounds in microgravity is on the verge of becoming another commercial activity.

For more than 30 years, the secondary use of NASA technology has been facilitated through NASA's Commercial Development and Technology Transfer Program. Its outreach activities result in private industry's application of NASA-generated technology, which frequently leads to the development of commercially available products and services known as "spin-offs."

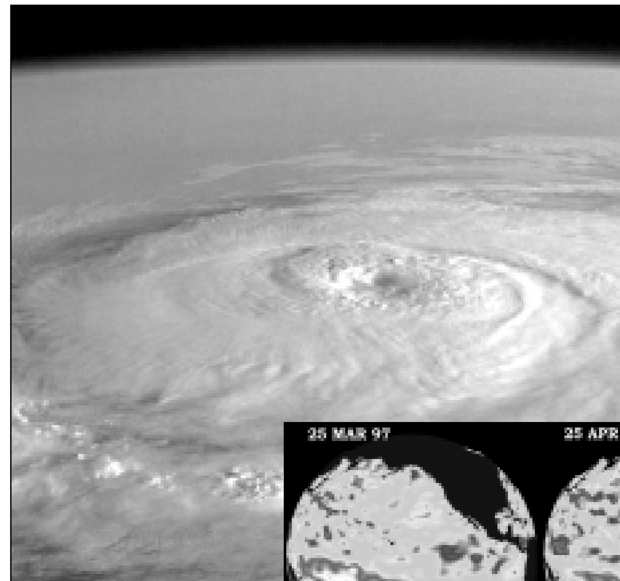
A spin-off example includes lightweight rechargeable batteries developed for space use that also made possible the creation of many cordless appliances and tools. Paints developed to keep spacecraft cool by reflecting the sun's rays could help us keep cooler on Earth in our cars, homes, and planes. Indeed, more than a thousand spin-off products and processes have emerged from reapplication of technology developed for NASA mission programs.

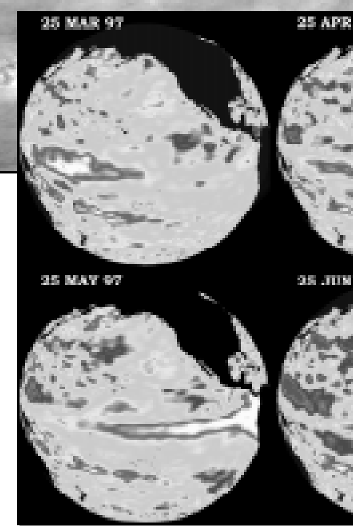
The Road Ahead

"Columbus sailed west to reach the Indies, an impossible mission with the ships and provisions under his command ... His voyage succeeded because he ran into something new, an unknown continent. ... Space exploration is similar: its value resides less in confirming what we already know than in exposing us to something new."

— Timothy Ferris, professor of journalism, University of California, Berkeley, *Where Next Columbus?*

The dream of human exploration of Mars is intimately tied to the belief that new lands create new opportunities and prosperity. In human history, migrations of people have been stimulated by overcrowding, exhaustion of resources,





FOUR TOPEX/Poseidon views at right show displaced warm water (white area outlined in darker shade) moving eastward over time. The displacement of so much warm water affects evaporation, rain cloud formation and consequently alters jet stream patterns.

search for religious or economic freedom, and competitive advantage. Rarely have humans entered new territory and then completely abandoned it.

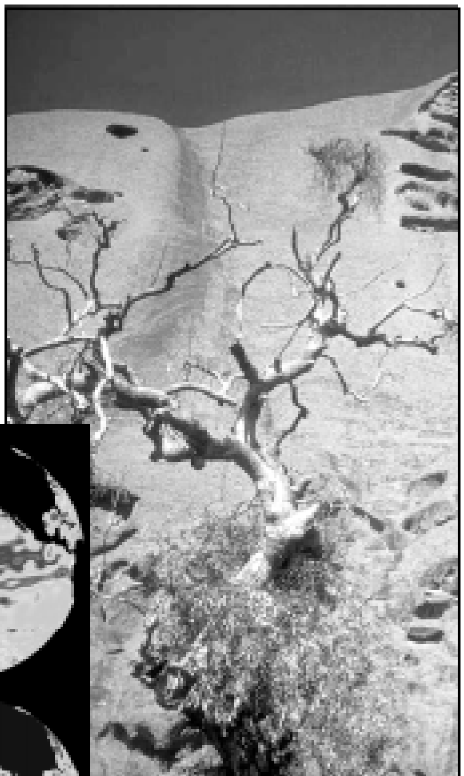
A human settlement on Mars, which would have to be self-sufficient to be sustainable, would satisfy human urges to challenge the limits of human capability, create the potential for saving human civilization from an ecological disaster on Earth (e.g., a giant asteroid impact or a nuclear incident), and potentially lead to a new range of human endeavors not attainable on Earth.

Mars could also serve as a base for our exploration of the outer solar system. With its low gravity, it would be easier to launch crafts into space from Mars than from Earth.

What can insight into the origins and evolution of the early solar system tell us? The study of Jupiter, Saturn, Uranus, and Neptune — which contain 99 percent of the planetary mass in the solar system and which, far from the vaporizing effects of the sun, remain largely unchanged since their formation — can tell us much about the composition and evolution of the protoplanetary masses from which planets form.

Wild Cards

Wild cards are technological discoveries or conceptual breakthroughs that



EL NIÑO leads to unusual and extreme weather conditions, such as drought (above) or hurricanes (above left).

fundamentally change the way we think and act, altering the course of human events. For someone living in the year 1900, wild cards included airplanes, the atom bomb, genetic engineering, space travel, artificial organs, and communications satellites.

What will be the wild cards during the next 50 to 100 years? According to *Where Next, Columbus?*, they might include:

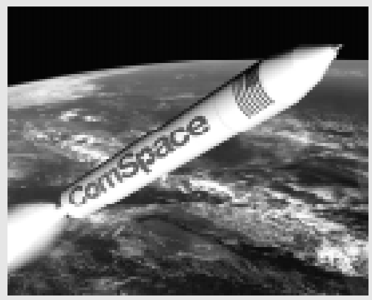
1. Economical and practical fusion energy;
2. Sentient, artificially intelligent computers;
3. Indisputable evidence of extraterrestrial life;
4. Communication or contact with extraterrestrials;
5. Discovery of gravity control;
6. Indefinite extension of life;
7. Creation of new life forms by humans;
8. Near- or even faster-than-light travel;
9. Harnessing antimatter as an energy source;
10. Terraforming, the process of making a planet more capable of supporting life forms from Earth.

These and other wild cards will all have the direct effect of accelerating the inevitable — advancing the human race through exploration of the cosmos.

NASA Strategic Plan is agency's roadmap to future

The 1998 NASA Strategic plan outlines four strategic enterprises representing the framework through which the agency implements its mission. The articles in this special issue touch upon all four in varying detail. The Strategic Plan appears on the agency Web site at http://www.hq.nasa.gov/office/nsp/NSPTOC.html

Aeronautics and Space Transportation Technology



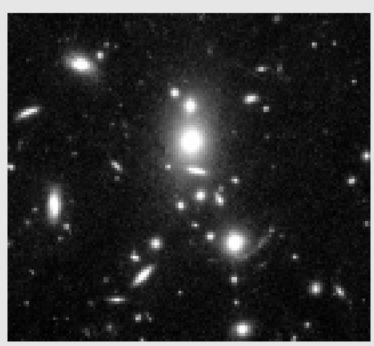
Low-cost launch vehicle

Mission: Pioneer the identification, development, verification, transfer, application and commercialization of high-payoff aeronautics and space transportation technologies.

Technology goals: Enable U.S. leadership in global civil aviation through safer, cleaner, quieter and more affordable air travel; revolutionize air travel and the way in which aircraft are designed, built and operated; enable the full commercial potential of space and expansion of space research and exploration.

Service goals: Enable, and as appropriate provide, on a national basis, world-class aerospace research and development services, including facilities and expertise, and proactively transfer cutting-edge technologies.

Space Science

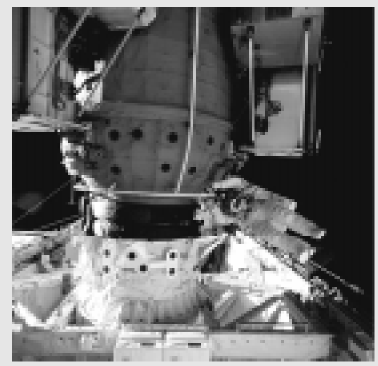


Most distant galaxy, Hubble deep space image, July 1997

Mission: Solve the mysteries of the universe, explore the solar system; discover planets around other stars; search for life beyond Earth.

Goals: Establish a virtual presence throughout the solar system; probe deeper into the mysteries of universe and life on Earth and beyond; pursue space science programs that enable and are enabled by future human exploration beyond low Earth orbit; develop and utilize revolutionary technologies for missions impossible in prior decades; contribute measurably to achieving the science, mathematics and technology goals of our nation, and share widely the excitement and inspiration of our missions and discoveries.

Human Exploration and Development of Space



STS-76 spacewalk

Mission: To bring the frontier of space fully within the sphere of human activity to build a better future for all humankind.

Goals: Prepare to conduct human missions of exploration to planetary and other bodies in the solar system; use the environment of space to expand scientific knowledge; provide safe and affordable human access to space, establish a human presence in space and share the human experience of being in space; enable the commercial development of space.

Mission to Planet Earth

Earth from space

Mission: Dedicated to understanding the total Earth system and the effects of natural and human-induced changes on the global environment.

Goals: Expand our scientific knowledge of the Earth system; disseminate information about the Earth system; and enable the productive use of Mission to Planet Earth science and technology in the public and private sectors.

From 1999 to 2081 and beyond

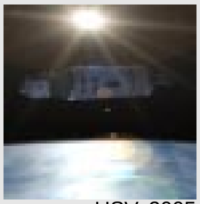
Joe Dean, Quality Assurance, Boeing

The mid-'90s has seen much change in the way the United States explores space, and those changes are just now becoming evident, particularly in the unmanned planetary programs such as Mars Pathfinder. Gone are the mega-budget unmanned probes and the U.S. going it alone. Space exploration, especially by humans, is still a difficult and expensive venture, however. Let's take a look at what could lie ahead:

• **1999** – First direct visual image of an ExtraSolar Planet (ESP) is recorded by the Keck telescope complex. Actually the size of Jupiter, the distant planet shows up as only a tiny dot. The planet orbits the yellow dwarf star, 47 Ursae Majoris, approximately 44 light years from our own Sun.

• **2002** – A strong ExtraTerrestrial (ET) signal is detected that is virtually certain to be artificial in nature. The signal emanates from Delta Pavonis, another Sun-like star only 19 light years away. This captures public imagination, resulting in a resurgence of interest in space exploration.

• **2003** – International Space Station (ISS) is completed and operational.



USV, 2005

• **2004** – The Powerlifter launcher makes its debut. The heavy-lift vehicle is similar to the canceled Shuttle-C, except it becomes an operational spacecraft upon reaching orbit. Also, Cassini enters Saturn orbit.

• **2005** – The single-stage-to-orbit vehicle becomes operational. Access to space is routine at last! Crewed Utility Service Vehicles (USV) become operational around an expanding ISS.

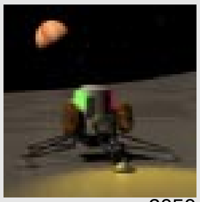
• **2006** – Larger version of the Powerlifter launch vehicle debuts. A robotic mission to Mars returns the first samples of Martian soil to Earth.

Lunar Telescope, 2007

• **2007** – First element of a Mars direct-type mission is launched using the Powerlifter. Two successive launches carry crew and the Nuclear Thermal Rocket (NTR) needed to get them to Mars and back.

• **2007-11** – Lunar base construction is under way, including establishment of an optical/radio array known as the Farside telescope. Construction is supported by Powerlifters and single-stage-to-orbit vehicles.

• **2012** – The first humans land on Mars, touching down some 250 miles east of the solar system's largest known volcano, Olympus Mons. Evidence of past life on Mars is confirmed.



2050

• **2014** – The Farside lunar telescope images ExtraSolar Planet (ESP) first sighted in 1999 as a disc rather than a dot. Space-based industry matures.

• **2020-40** – Advances in computers and robotics usher in the age of

Ask.

Ram accelerator is the way to go

Bill Notardonato, Fluid Systems Division, Process Engineering

Development of an inexpensive method of launching insensitive bulk cargo to orbit will create a revolution in space operations. This system, called a ram accelerator, has a projectile shaped like the centerbody of a ramjet that can be fired at high speed into a stationary tube filled with a premixed fuel and oxidizer, and the shock wave reflected off the tube wall will create an oblique detonation wave that combusts the propellant and expands the hot, high-pressure products past the aft end of the projectile, creating thrust.

Using this simple system, which does not need mixing tubes, igniters, or propellant tanks to carry fuel, a 2,000-kilogram-projectile with a 40 percent payload mass fraction can be launched to orbit from a one-meter-diameter, four -kilometer-long tube positioned on the side of a mountain near the equator. This inexpensive system will be used to launch fuels and oxidizers, foods, raw materials, and emergency supplies to orbit, and possibly create a new class of hardened orbital satellites built specifically to be able to withstand the high G forces associated with a ram accelerator launch. Preliminary price estimates predict a cost of $100-500 per pound to orbit.

The simplicity of this system offers the opportunity for a commercial company to create a market for low-cost space cargo, possibly leading to an orbiting fuel depot where satellites and manned space vehicles could dock, refuel and continue their missions.

This would allow for a reusable orbital transfer vehicle to ferry satellites from low-Earth to geotransfer orbit, or return them for refurbishment. This would eliminate heavy upper stages,

Commercial rocket-based, combined-cycle Space Express vehicle.

and would allow large geosynchronous satellites to be launched on smaller boosters. Refueling capability would be built into commercial satellites, and this capability would drive manufacturers to design them for longer life and upgradability. This will make their applications cheaper.

The potential exists for orbital plane changes, now prohibitively expensive due to high fuel usage. Surveillance satellites would have more maneuvering capability and hence be more robust. A human mission to the moon or Mars can be accomplished using boosters no more powerful than current systems, and nuclear thermal engines will not be needed since the fuel needed for chemical engines would be plentiful on-orbit. Space Station resupply can be accomplished more cheaply, and parts and supplies would be able to be launched immediately in case of emergency. The presence of inexpen-sive fuel and raw materials on-orbit is the key needed to create the next-generation-in-space capability. A ram accelerator can provide that service.

Make space travel as accessible as air travel

Edgar Zapata, Fluid Systems Division, Process Engineering

Having worked for some years on future space transportation initiatives, I have formed a vision of our future in space: One in which we have achieved, within my lifetime, affordable, reliable, and safe space transportation. That means accessible to the average person.

Air travel, once the domain of a few daredevils and the wealthy, eventually opened up to the average individual who just wanted a quick, affordable way to get from A to B.

Colonies on the moons of Jupiter or low-Earth-orbit theme parks will come about once cheap access to space is possible. Also, within our lifetime we should be seeing the first human exploration beyond the solar system, perhaps also the first space experiments showing the potential to overcome the chasm between our and other solar systems.

Jupiter

Let's go to the Moon first

Dian Hardison, Safety, Reliability and Space Vehicle Safety Division

We should certainly already be working on definitive plans for crewed exploration of Mars — but we could be sending small robots to the moon RIGHT NOW to prepare caverns (shielded from radiation by rock) for permanent habitation. Luna is close enough for quick transit of supplies and workers from Earth, has plenty of raw solar power available, and so little gravitational penalty that many future missions could be launched from there. Oxygen can be liberated from lunar soil, construction materials mined from it, and plants grown in it. Radio telescopes would work best on the far side. Risky experiments could be safely conducted in the closed environment. And once a colony is up and running, the Earth-bound public would come to understand that humans are in space to stay.

Earth's moon

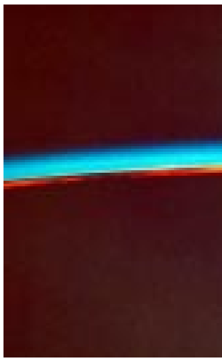
Convert the S missions

Richard W[illegible]roth, Orbiter Processing Facility, United Space Alliance

Take one of the Shuttle orbiters and connect an extended-duration consumables and fuel package into the payload bay. Design a lander similar to the one used in the Apollo missions that could dock with the Shuttle for crew transfers, and use the orbiter as a ferry ship to the moon. The orbiter would not be able to land on the moon, but neither could the Apollo command ship. With a payload bay 60 feet long,and 15 feet wide, it would be a good way to travel to and from lunar orbit.

Where do from here?

KSC workers of



spacecraft design and construction almost entirely by semi-intelligent machines. Human exploration and in some cases, exploitation, of the asteroid belt is under way. Fusion propulsion becomes a reality.

• **2040s** – Numerous ESPs are cataloged, some by now found to be similar in appearance to Earth.

• **2050s** – Human exploration of Jupiter and Saturn systems is under way. Molecular-level manufacturing is commonplace.

Beyond 2081

• **2081** – 100th anniversary of the first Shuttle launch and 120th anniversary of first human in space. The first starship departs for Alpha Centauri system at 98 percent the speed of light. After a 10-year round trip, humanity reaches its first star.

Shuttle for lunar-orbiting

Other than using a little extra fuel for the Orbital Maneuvering System engines, the flight requirements would be the same as going to Mir. A four-person crew would be more than ample for these flights to start with. More crew members could be added on later flights after a pattern of safety and reliability is developed.

With Administrator Goldin's declaration Sept. 29, 1997, regarding the American explorer's spirit and attitude toward new challenges, this would be a good time to go back to the moon — only this time, on a more permanent basis.

The early settlers accepted the challenge to try new things and explore risky ideas, sometimes risking life and limb. Can we do any less?

we go

?

fer their visions.

Over the horizon

Lagoon Nebula, Hubble Space Telescope image, January 1997

Shuttle will lead the way

Michael Ciannilli, Test Project Engineering, United Space Alliance

In regard to the long-range direction the United States should take, I see two primary choices. First, there is a human mission to Mars. Undoubtedly, this would ignite worldwide excitement and an "Apollo-like" atmosphere. The new heavy-lift launch vehicle needed to perform the mission would most likely be derived from a Saturn V-based concept.

Political and budgetary concerns pose the greatest obstacle to this program, and relatively short stays on Mars would be typical for some time.

The second choice would be for America to return to the moon. Again, a new heavy-lift vehicle would be employed to start construction of a lunar base. Returning to the moon perhaps represents the best option to gain the most knowledge in the near-term, as well as survive a tight budgetary atmosphere. Either way we go, it is essential for the United States, and KSC in particular, to continue early planning for those options today.

An array of unmanned spacecraft should also be developed to continue planetary exploration, focusing on sample return missions when possible. Continuous research, along with constant upgrades, should be the mainstay of the space station program throughout the next century.

The vehicle that will lead us into the 21st century for a decade or two is the same one that will close out the 20th: the Space Shuttle.

With a commitment to upgrading the fleet and streamlining its processing, the Space Shuttle will continue to be the hallmark of America's space program.It should be remembered, the initial concept of the program was to fly a fleet of reusable vehicles, many times for many years.

Seek.

Moon should be next

Frank Merceret, KSC Weather Office

Immediate: Work with the private sector and other governments to build a permanent mining, manufacturing and research colony on the moon. First human return trip no later than 2002, with full operation by 2005. The private sector component should be for profit, with tax incentives to encourage participation. Similar for-profit commercial activity aboard the space station should be encouraged.

Longer term: We should plan to colonize (not merely visit) Mars through a deliberate, planned long-term process. The process should begin with plans for a human exploratory expedition in the 2014-2016 time frame using the Zubrin "Mars Direct" strategy, taking advantage of what we learn from Space Station and the lunar colony regarding long-term work in space. We must follow this with a PERMANENT colony, with as much for-profit commercial involvement as possible. We should be looking to begin terraforming within 50 years, a process which will take more than a century to complete. We can then begin mining the asteroids. The timing will be excellent, since Earth-bound mineral resources will be near depletion by then.

Later: Ad Astra! Human survival depends on it!

Space travel in the 21st century

Bill Lembke, Checkout and Launch Control System Project, Lockheed-Martin

The future human exploration of space should proceed in stages as our knowledge increases and technology advances.The destiny of humankind is not to remain bound to Earth, but to explore the vast unknown:

Location	Years	Objective
Space Station	Present-2005	Phase I construction
	2005-2010	Science experiments, supply station for moon construction.
	2010-2015	Phase II construction: expansion, space-based manufacturing.
	2015-2020	Additional space stations in higher orbits, between Earth and moon.
	2020-2025	Construction of larger, more powerful space vehicles.
Moon	2005-2007	Explore for resources and sites for future science stations and a colony.
	2007-2010	Construct science stations.
	2010-2015	Construct a permanent colony to accommodate at least 100 people.
	2015-2025	Expanded colony; self-sufficiency; moon-based manufacturing.
Mars	2025-2030	Explore for resources and sites of future science stations and colony.
	2030-2035	Construct science stations.
	2035-2050	Construct permanent colony to accommodate at least 100 people.
Asteroids	2030-2035	Explore for resources and future science stations.
	2035-2050	Construct science stations, mine for resources to construct Mars colony.

Lunar base

Send DNA first

Arthur Beller, Shuttle Processing Chief Information Officer representative

Before sending humans to Mars, we ought to recruit one-celled astronauts, billions of them, to go to Mars.

Basically we want to get DNA to Mars in the most cost-effective form. We already have proven delivery capability to preselected sites on Mars' surface, as Mars Pathfinder so spectacularly demonstrated earlier this year. Now, the payload will consist of the astronauts and months or years of food and water.

With proper matching of selection criteria for the astronauts to the site environment, the astronauts would have the opportunity and expectation to establish their own colonies on or beneath the surface of Mars. Furthermore, with proper selection, these brave "pioneers" could pave the way for their multicelled cousins. If necessary we can send "care" packages to sustain them and their progeny.

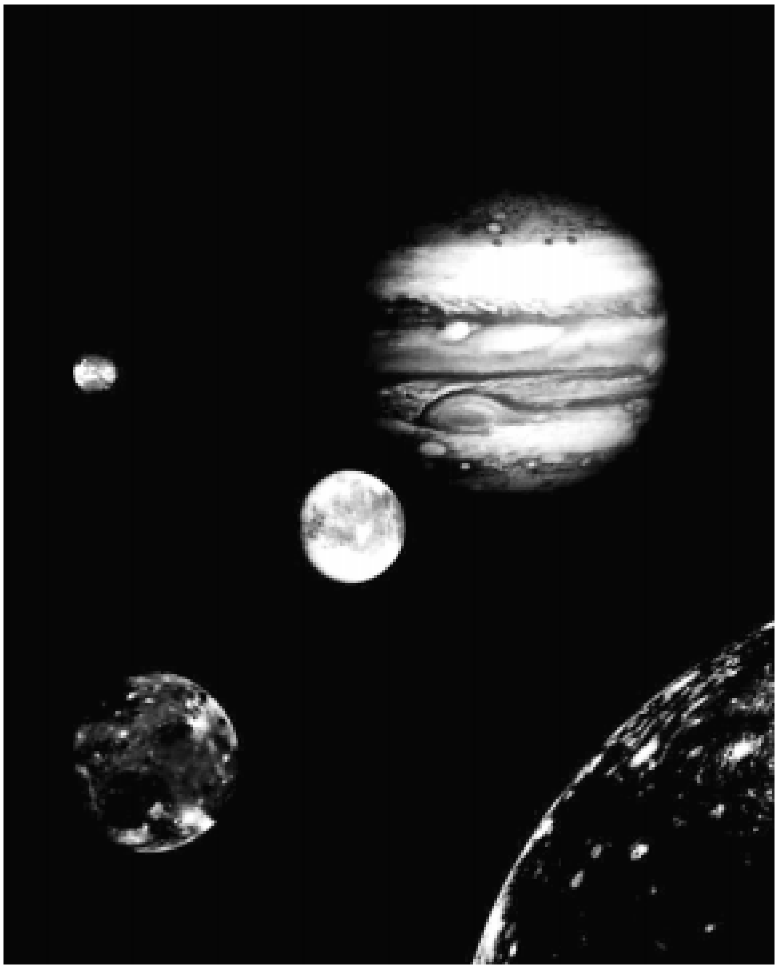
There is real science required to design this long-term approach to colonizing Mars with sustainable DNA-based life forms regardless of whether we ever send a human. In one of Kurt Vonnegut's novels, he criticizes humanity for its inability to plan a million years into the future. Here is our chance. This has to be akin to terraforming. But it really doesn't matter whether Terrans ever arrive. These astronauts would be the progenitors of the new Martians.

This is a great hedge on the risk of Earth becoming temporarily uninhabitable. Since intelligence is an emergent property of DNA, if necessary the Martians could return the favor in a billion years.

Dream.

Beyond cutting edge

NASA-sponsored group searches for ways to revolutionize space travel



By Susan Walsh

Warp drives . . .hyperspace . . . tachyons . . . wormholes . . . space drives . . . If you believe that no one but science fiction buffs use these terms, *think again*.

A loosely formed and expanding group of more than 150 scientists and engineers from NASA, other government labs, universities and industries are looking for ways to make "credible progress toward incredible possibilities" in space propulsion. The ultimate goal is to revolutionize space travel and enable practical interstellar voyages.

It's the kind of stuff that, even if only partially successful, would add new chapters to the laws of physics as we know it and potentially make space as navigable as Earth's visible sky is by airplane.

The Breakthrough Propulsion Physics Program established in 1996 is managed by Lewis Research Center (LeRC) in Cleveland, Ohio, and receives funding from the Advanced Space Transportation Program under NASA's Marshall Space Flight Center, where some related experiments are being conducted. The program's sole full-time employee is LeRC aerospace engineer Marc Millis, who was a KSC co-op student from Georgia Tech in 1978-81.

"This is the most visionary thing going on in propulsion in NASA," Millis said. "This is looking at the emerging horizons. You're beginning to get a glimmer of light there. There's some hope that you can do this, but it's still far enough away that you can't be sure. There is, however, enough light to point to where to look next — the next steps."

The program's first workshop held at LeRC in August was to assess the prospect of discovering breakthrough means to propel spacecraft as far and as fast as possible with the least amount of effort. The 84 participants were encouraged to be "visionary" and yet identify affordable, near-term and credible research to make measurable progress toward propulsion breakthroughs.

"Admittedly, these breakthroughs may turn out to be impossible, but progress is not made by conceding defeat," Millis stated in a summary of preliminary workshop results.

Rocket technology dependent on propellant is adequate for human journeys into orbit, to the Moon, and to Mars, and for robotic probes to outer planets of our solar system.

"However, to dramatically reduce the expense of these journeys or to journey beyond these points in a reasonable time, some new, alternative propulsion physics is required," according to Millis.

Conference attendees looked at ways to make interstellar travel practical by removal of the three major barriers to such journeys: propellant mass, trip time, and propulsion energy.

In his essay, *Warp Drive, When?*, Millis said that the obvious challenge in interstellar travel, especially by humans, is speed. The next nearest star is 4.3 light years away. (A light year is the distance that light travels in one year or about 5.88 trillion miles.)

Consider traveling from Earth to that distant star in these known modes of transportation:

- A car traveling at 55 mph would take more than 50 million years to get there!
- At the speed of the Apollo spacecraft which landed on the Moon, it would take over 900,000 years!
- Even at the now-staggering 37,000 mph speed of NASA's voyager spacecraft as it left our solar system, the trip to the nearest star would still take 80,000 years!

That's why the Breakthrough Propulsion Physics Program is looking at recent theories about "wormholes" and "warp drives" — concepts for traveling faster than light.

As for the amount of propellant it would take to get there, you can forget using the chemical engines now on the Space Shuttle — there isn't enough mass in the universe to supply the necessary amount of rocket propellant.

Even with a fission rocket, it would take a billion super-tanker-sized propellant tanks; with fusion rockets, a paltry thousand supertankers worth! That's why the group is searching for new propulsion physics that do not require any propellant.

Even if we could convert energy into motion without propellant, sending a Shuttle-sized vehicle to the nearest star would require roughly the same amount of energy that the Space Shuttle's engines would use if they ran continuously for 50 years.

Tapping the energy stored within the vacuum of space is one idea being explored to overcome this hurdle to interstellar travel.

Millis readily admitted that he doesn't know when a breakthrough will occur, or if it is even possible.

"Even if it will not be in my lifetime or my children's lifetime or even if it is impossible, I am firmly convinced that we as a society will gain far more from trying to make such breakthroughs happen than if we didn't," he asserted in *Warp Drive, When?*, calling it a "noble and honorable cause."

For more information on the Breakthrough Propulsion Physics Program, see URL: http://www.lerc.nasa.gov/WWW/bpp/

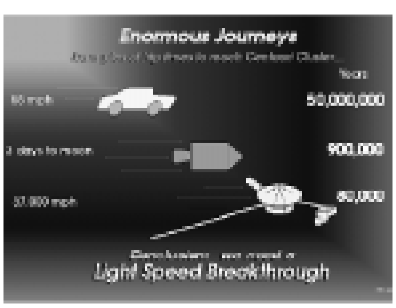


CHART from the Breakthrough Propulsion Physics Program managed by NASA's Lewis Research Center illustrates the need for a major paradigm shift in how we look at spacecraft speed and what is needed for future flights.

NASA's X-38 technology demonstrator for the Crew Return Vehicle could become the first new human spacecraft to travel to and from orbit in the past two decades. It is shown here undergoing captive-carry flight tests in California in July, attached to the wing of a B-52 carrier aircraft. The captive-carry flights will lead up to free-flight drop tests and eventually an unpiloted space flight test targeted for launch aboard a Space Shuttle. The effort, managed by Johnson Space Center, takes advantage of available equipment and technology for as much as 80 percent of the X-38's design in order to keep costs to a minimum.

Launch vehicles of future taking shape today

NASA, the Department of Defense and private industry are working on development of near-term and longer-range future expendable launch vehicles (ELVs) and reusable launch vehicles (RLVs).

The space agency is evolving into a developer of technology, and away from designing, building and owning launcher systems, according to Gary Payton, NASA's RLV program director.

"New commercial launchers will will be built out of the proven technologies," he said.

Among the highlights in the ELV category:

• **Sea Launch:** A two-stage Ukrainian Zenit rocket with a Russian Block DM upper stage will launch from a mobile, modified self-propelled oil drilling platform in the Pacific Ocean into either geosynchronous or medium Earth orbit. Up to 11,025 pounds of payload can be launched to geostationary transfer orbit. The Sea Launch home port in Long Beach, Calif., will include docking and provisioning for the Assembly and Command Ship and Launch Platform; launch will take place along the equator in the international waters of the Pacific Ocean. The first launch is targeted for late 1998.

• **DoD Evolved Expendable Launch Vehicle:** The Air Force has selected two contractors, The Boeing Co. and Lockheed Martin Astronautics, to proceed with the pre-engineering, manufacturing and development (Module II) phase for a new family of expendable rockets to replace the current medium- and heavy-rocket fleet of aging Delta, Atlas and Titan vehicles. The first test flight is targeted to occur in 2001.

• **Lockheed Martin Atlas IIAR:** The new Atlas IIAR vehicle is the latest configuration in Lockheed Martin's planned evolution to a new family of lower-cost ELVs featuring common elements such as a booster stage. The Atlas IIAR can deliver a payload of 8,600 pounds into geosynchronous transfer orbit, approximately an 8 percent increase over the current Atlas IIAS. The first launch is scheduled at the end of 1998.

• **Magnum Launch Vehicle:** Still only a design concept at this time, the Shuttle-derived Magnum would be a heavy-lift vehicle with a payload capacity of some 80 metric tons, more than four times what the Space Shuttle can carry to low Earth orbit. It likely would use a stretched version of the Shuttle's external tank and reusable, liquid-fueled flyback boosters being considered for development in the Space Shuttle program. Potential uses are for human exploration of the Moon and Mars; to carry the next-generation space telescope; in the Air Force space-based laser program; and even, possibly, for interception if an asteroid were hurtling toward Earth.

Some highlights in the RLV category:

• **X-33 and X-34:** The X-34 demonstrator vehicle is a bridge between the Delta Clipper and the X-33. White Sands Missile Range, N.M., will host the initial test flights to prove the major vehicle components, beginning in late 1998. With a current plan to fly a total of about 25 flights, KSC will provide landing support for the other opportunities.

The X-33, being developed under a cooperative agreement between NASA and Lockheed Martin Skunk Works, is a subscale technology prototype which Lockheed hopes to develop in the next century as a full-scale, commercial single-stage-to-orbit reusable launch vehicle called Venture Star™.

• **X-38:** The X-38 is a technology demonstrator for NASA's emergency crew return vehicle (CRV), a lifeboat for the International Space Station. The first captive-carry flights were held at Dryden Flight Research Center in California this summer.

The X-38 would glide from orbit unpowered like the Shuttle orbiter and use a steerable parafoil parachute for its final descent to landing. It also could be used as a spacecraft for humans that could be launched on an Ariane 5 booster.

Upgrades will keep fleet operational until year 2030

By Joel Wells

The Space Shuttle is America's only means of getting humans into space. With the International Space Station (ISS) era around the corner, it will be the workhorse that helps assemble and maintain the permanent space outpost. With NASA counting on the Shuttle, the Shuttle program is counting up ways to keep it flying.

In April 1996, NASA launched a four-phased mission to assure safe and continuous operation of the Shuttle fleet through the year 2012 and to incorporate major improvements through 2030. Improving Shuttle safety, supporting the future flight manifest, increasing system reliability and reducing operational cost are the priorities of the Space Shuttle Upgrade Program.

4 phases

Phase One leads the way, focusing on performance enhancements which extend the Shuttle's capability to carry payloads to the ISS orbital inclination of 51.6 degrees and altitude of about 220 miles. The super lightweight external tank (SLWT) made of a new, aluminum-lithium alloy and the Block II Space Shuttle main engines with new safety features and a higher thrust rating are among the fully funded projects that will help accomplish the goals of Phase One by the year 2000.

High-value upgrades that can be implemented at low cost and still provide reliable support to the current flight manifest define the Phase Two projects. The Checkout and Launch Control System (CLCS), now under development at KSC, is a Phase Two effort to reduce launch processing time while lowering operations costs by 50 percent.

By 2000, many of the upgrades from Phases One and Two will be in place and implementation of the major system upgrades will begin. These Phase Three improvements will be more extensive than their predecessors. The changes would not alter the orbiter's original shape or basic aerodynamics, but would include significant enhancements to avionics and communication systems.

15 flights per year

With a goal to increase the Shuttle's missions per year by 2007, NASA must reduce the preparation time for a launch. By replacing the current orbital maneuvering system, reaction control system and auxiliary power units with systems that do not require toxic propellants or reactants, a safer work place can be achieved and significant time savings can be realized.

Using non-toxic liquid oxygen and ethanol instead of noxious ammonia-based fluids will allow work to be done in parallel with traditionally hazardous operations. Increased productivity, fewer components and cheaper propellants promise a savings of about $24 million every year.

Candidate projects for Phase Four will significantly change the Shuttle's configuration, and new design implementation will be carefully planned to minimize any impact to the flight rate.

A banner project being studied for Phase Four implementation is the liquid flyback booster (LFBB). The new boosters will not only shorten turnaround time, but are expected to demonstrate key safety features as well.

A CAREFULLY planned and implemented program of upgrades will keep the fleet of four Shuttle orbiters flying well into the next century, possibly as far into the future as 2030. The program began in 1996 and includes four phases. Shown here is the orbiter Columbia undergoing lifting in the Vehicle Assembly Building in October in preparation for Mission STS-87, the final Shuttle flight of 1997. Projections call for an increased flight rate of up to 15 per year in the next century, and many of the planned upgrades will contribute to a reduced turnaround time as well as greater safety and lower costs.

New Shuttle health monitoring system anticipates future demands

NASA's Shuttle Upgrades Program plans to outfit each Shuttle in the fleet with an Integrated Vehicle Health Monitoring System (IVHM), consisting of modern technology that will reduce planned ground processing work, streamline unplanned work, enhance visibility into orbiter systems operation and ultimately improve vehicle safety.

The current onboard Modular Auxiliary Data System (MADS) collects and records pressure, temperature, strain, vibration and event data from sensors placed throughout the orbiter. The information is gathered during ascent, orbit and entry and recorded for postflight review. While effective, MADS requires labor-intensive manual processing.

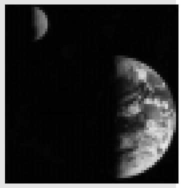
"This is a high-priority project," said Jack Fox, project development manager for KSC's Shuttle Upgrades Office. "When I see plans to increase the Shuttle's flight rate to 15 flights per year, I know we need IVHM to help reduce turnaround time."

The goal is not to scrap the proven MADS system, but rather absorb and improve it. Adding non-intrusive microsensors, strategically placed remote health nodes, and reducing the amount of wiring required, are all steps toward gradual IVHM implementation.

Beyond merely recording flight data, the evolved system will process the information in-flight and dump the data to ground controllers once a day. Onboard trend analysis will give engineers snapshots to help predict downstream maintenance, and improved ground support equipment will help Shuttle technicians do their jobs quicker. KSC managers estimate a fully operational IVHM system will reduce work shifts for orbiter processing by up to 20 percent.

"For example, Marshall Space Flight Center currently waits up to four weeks after a Shuttle lands to receive its engine data from KSC," adds Fox. "Through IVHM, earlier access would give it a jump on planning the processing flow for the Shuttle's main engines." IVHM hardware installation is slated to begin in late 1999.

2004: Deadline for Mars vs. moon decision



It's 2004 and final decision time for NASA. Should the agency press on to finalize plans for the human exploration of Mars? Or should the moon be used first to field-test habitats, life support systems and propellant propulsion units developed for the Mars mission?

And ultimately, does all of the information gathered by robotic Mars explorers and NASA research personnel and mission planners prove that humans really could be safely sent to explore the Red Planet and return? Of course, any of these options would be contingent upon presidential and congressional approval, as well as public support. "It is the job of the KSC Exploration Think Tank to help provide the agency with enough information to make a rational go/no-go decision in 2004 if we are going to launch a crew to Mars by 2013," said Think Tank manager Mike O'Neal. "To do so, we are working to determine how KSC expertise and resources can be used to develop the technologies necessary to demonstrate the Mars mission concept."

Fuel . . .

(Continued from Page 4)

Mars Reference Mission. Once transported from Earth to Mars, the unit will use liquid hydrogen brought from home and carbon dioxide from the Martian atmosphere to manufacture tons of liquid oxygen and methane for the Mars Ascent Vehicle which will lift the crew off the surface to begin the return to Earth. Because propellants make up the majority of a launch vehicle's weight, propellant production on Mars greatly reduces the size and cost of the vehicles required to get there.

"The liquid hydrogen to be used by the ISPP as well as the liquid oxygen to be produced on Mars calls for experience in the handling, transfer and long-term storage of cryogenic liquids," Johnson said. "We have a lot of experience at KSC in doing just that, and we want to apply that knowledge to help design and test the Mars cryogenic systems to assure that they operate as efficiently and reliably as possible with minimum human involvement from Earth."

To provide an autonomous system to monitor the ISPP and to control fuel production and its loading aboard the Mars Ascent Vehicle, the Exploration Team has proposed the use of the KSC-developed Knowledge-based Autonomous Test Engineer (KATE), Johnson said.

"The KATE system can provide the kind of autonomous control that will be required for ISPP operations," Johnson said.

Preventive failure analysis can also be provided for the ISPP design by the KSC Materials Science Laboratory, Johnson said. The lab is planning to build a large environmental chamber that will simulate conditions on the surface of Mars.

In spite of the futuristic purpose of the ISPP, its design for the most part does not call for new technologies or the development of new chemical processes, Johnson said. "What it does call for are the knowledge and experience that can lead to the development of an efficient, reduced-weight and reliable system that is critical to the success of NASA's human exploration of Mars."

Food . . .

(Continued from Page 4)

NASA Mars Reference Mission calls for a six-member crew to remain on the surface of Mars for up to 600 days."

Sager is an advocate of the primarily bioregenerative approach to NASA's Advanced Life Support (ALS) Program as opposed to a more traditional one of mostly chemical and mechanical systems for several reasons.

"Bioregenerative systems are efficient ways to provide all life support elements — oxygen, water and food — as well as a livable psychological environment for the crew over a long period of time," Sager said.

White globe radish harvest

"KSC's job is to obtain sufficient ALS data for the agency to make an informed decision about how much of the life support system on Mars will be bioregenerative," Sager said.

The bioregenerative life support effort at KSC, formerly the Controlled Ecological Life Support System (CELSS) Breadboard Project, is located in Hangar L on Cape Canaveral Air Station.

The KSC-developed bioregenerative hardware and data from the successful growth of soybean, potato, wheat, lettuce and tomato crops are now supporting closed-chamber testing of an ALS regenerative life support systems with human subjects at Johnson Space Center. The latest phase of the Lunar-Mars Life Support Test Project at JSC began Sept. 17.

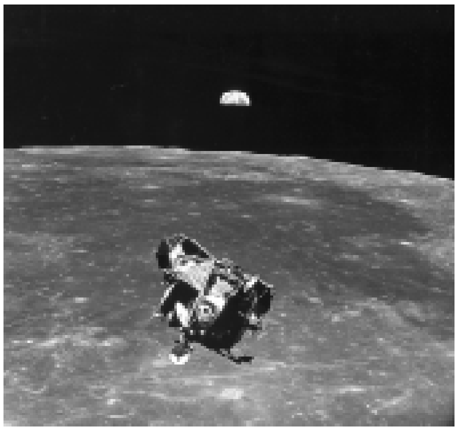
"Data from experiments up to more than a year long have shown that potato and wheat crops grown in the 20-square-meter KSC Biomass Production Chamber could provide all of the water needs for four or five crew members while also meeting the oxygen supply and carbon dioxide removal needs of one person," said Gary Stutte, a plant physiologist with the NASA Life Sciences support contractor Dynamac Co. "The crop could also supply 35 to 50 percent of the food requirements for one person."

Research in the KSC growth chamber is now concentrating on the recycling of inedible plant material — the plant stems, root systems and leaves — from the harvested crops for use in the plant growth chamber.

Work at KSC will continue to support human-rated ALS testing at JSC, the growth of new crops, and further development of the bioreactor, nutrient delivery and lighting systems, Sager said.

"Reliable regenerative life support systems will reduce the amount of materials that need to be sent from Earth to Mars and use less power than currently available life support systems," Sager said. "They are an integral element of NASA's Human Exploration and Development of Space effort and essential to the successful human exploration and colonization of space."

PLANT researchers examine a harvest of lettuce from the KSC Biomass Production Chamber. Wheat, potatoes, soybeans and tomatoes also have been harvested.



Apollo 11

U.S. space exploration yesterday, today and tomorrow

Explorer I

1950s

Jan. 31, 1958. Explorer I, first U.S. satellite.*

October 1958. National Advisory Committee Agency (NACA) becomes National Aeronautics and Space Administration (NASA).

Aug. 7, 1959. Explorer 6, Thor-Able. Returned first television images of Earth from space.

Alan Shepard

1960s

April 1, 1960, Tiros 1, Thor-Able-5. First weather satellite.

May 5, 1961. Freedom 7, Mercury-Restone 3. Alan Shepard become first American to fly in suborbital space.

Feb. 20, 1962. Friendship 7, Mercury-Atlas 6. John Glenn. First manned U.S. orbital flight.

July 10, 1962. Telstar 1, Delta-11. First commercial communications satellite.

Aug. 27, 1962. Mariner 2, Atlas-Agena-6. First U.S. interplanetary probe to reach Venus.

Aug. 22, 1963. X-15 aircraft achieves altitude record of 354,200 feet (67 miles).

July 28, 1964. Ranger 7, Atlas-Agena-9. First U.S. spacecraft to impact on the moon.

June 3-7, 1965. Gemini-Titan 4. Edward White becomes first American to walk in space.

May 15, 1966. Nimbus 2, Thor-Agena D. Produced satellite pictures that became popular feature on television evening news.

May 30, 1966. Surveyor 1, Atlas-Centaur-20. First U.S. spacecraft to soft-land on the moon (in the Ocean of Storms area).

Jan. 27, 1967. Apollo 1 ground test fire takes lives of astronauts Grissom, Chaffee and White.

Dec. 21-27, 1968. Apollo 8, Saturn V. Borman, Lovell, Anders. First manned flight to the Moon.

July 16-24, 1969. Apollo 11, Saturn V. Armstrong, Aldrin, Collins. First humans to set foot on another celestial body, Earth's moon, July 20.

1970s

March 2, 1972. Pioneer 10. Atlas-Centaur-27. First spacecraft to explore beyond Pluto, first man-made object to leave the solar system.

July 23, 1972. LANDSAT 1, Delta-89. First satellite to perform major assessment of Earth resources from outer space.

Dec. 7-19, 1972. Saturn V/Apollo 17. Cernan, Evans, Schmitt. Final Apollo mission; first night launch in program.

April 5, 1973. Pioneer 11, Atlas-Centaur-30. Performed flyby of Jupiter and first flyby of Saturn.

May 25, 1973. Saturn IB, Skylab 2, Conrad, Kerwin, Weitz. First crew on Skylab.

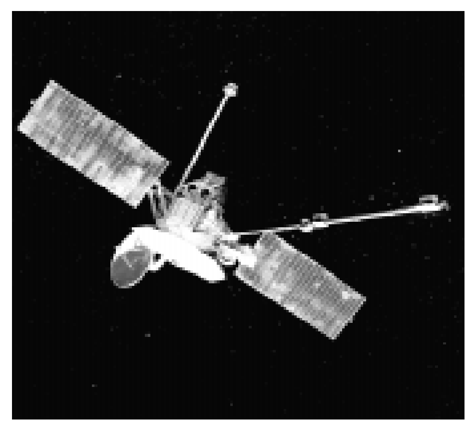
Nov. 3, 1973. Mariner 10, Atlas-Centaur-34. First flyby of Mercury. Three encounters, 1974-75.

July 15-24, 1975. Saturn IB, Apollo-Soyuz Test Project. Stafford, Slayton, Brand. First linkup between U.S. and Soviet crews in space.

Oct. 16, 1975, GOES-1, Delta 116. First weather satellite to photograph complete disk of Earth every 30 minutes from geosynchronous orbit.

Aug. 20, 1977. Voyager 2, Titan III-Centaur-7. First flybys of Uranus, Neptune and their moons.

Sept. 5, 1977. Voyager 1, Titan III-Centaur-6. Performed flybys of Jupiter and Saturn.



Mariner 10

1980s

April 12-14, 1981. STS-1, Columbia. Young, Crippen. First flight of the Space Shuttle and first flight of a reusable space transportation system.

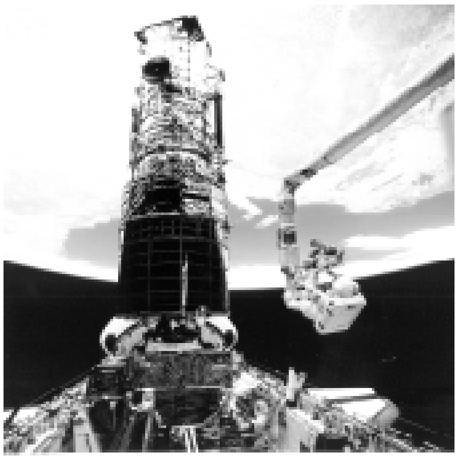
June 18-24, 1983. STS-7, Challenger. Crippen, Hauck, Fabian, Ride, Thagard. Sally Ride becomes first American woman to fly in space.

Nov. 28 – Dec. 8, 1983. STS-9, Columbia. Young, Shaw, Garriott, Parker, Lichtenberg, Merbold. First flight of Spacelab laboratory module, provided by the European Space Agency.

STS-1

Jan. 28, 1986. STS 51-L, Challenger. Scobee, Smith, Resnick, Onizuka, McNair, McAuliffe, Jarvis. Crew killed during mishap 73 seconds into flight.

May 4-8, 1989. STS-30, Atlantis. Walker, Grabe, Thagard, Cleave, Lee. Magellan mission to Venus. First U.S. interplanetary explorer in 11 years.



STS-61

1990s

April 24-29, 1990. STS-31, Discovery. Shriver, Bolden, Hawley, McCandless, Sullivan. Deployed Hubble Space Telescope, first of NASA's four Great Observatories.

Dec. 2-13, 1993. STS-61, Endeavour. Covey, Bowersox, Musgrave, Hoffman, Thornton, Akers, Nicollier. First Hubble Space Telescope servicing mission.

June 27-July 7, 1995. STS-71, Atlantis. Gibson, Precourt, Baker, Harbaugh, Dunbar, Solovyev, Budarin. First Shuttle-Mir docking.

Sept. 16-26, 1996. STS-79, 4th Shuttle-Mir docking, Atlantis. Shannon Lucid returns to Earth after 188 days in space, setting a U.S. record for human long-duration spaceflight as well as a record for a woman in space.

Oct. 15, 1997. Cassini, Titan IVB/Centaur. Mission to Saturn. Largest U.S. interplanetary spacecraft ever launched.

Future:

January 1998. Lunar Prospector, Athena launch vehicle. Discovery Program mission.

June 1998. Earth Observing System (EOS)-AM 1, aboard an intermediate class vehicle. First spacecraft in the EOS series. Will provide detailed measurements of clouds, atmospheric chemistry and the Earth's energy balance. Mission to Planet Earth Program.

June 1998. Functional Cargo Block, first International Space Station (ISS) element, to be launched on a Russian launch vehicle.

July 1998. STS-88, Endeavour. First U.S. International Space Station assembly flight.

July 1998. Deep Space 1, Delta. Asteroid and comet flyby, also Mars flyby. New Millennium Program.

August 1998. STS-93, Columbia. Advanced X-ray Astrophysics Facility (AXAF-I). Great Observatories mission, will perform extended research of X-ray sources.

September 1998. Wide-Field Infared Explorer (WIRE), Pegasus. Small telescope to study evolution of galaxies. NASA's Origins as well as Small Explorer Programs.

Late 1998. First flight of the X-34 technology demonstrator spacecraft. Suborbital.

First half 1999. Earth Orbiter 1 (EO-1). Mission to validate revolutionary technologies for Earth observation. Part of New Millennium as well as Mission to Planet Earth Programs.

January 1999. ISS 2R, Soyuz. Establishes first International Space Station habitation with three-person crew. Provides assured crew return capability without the orbiter present.

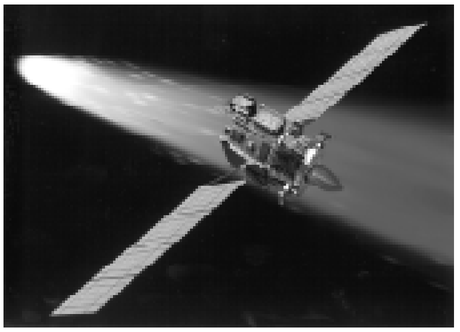
February 1999. Stardust. Will capture samples of interstellar dust particles and samples of dust from a comet. Discovery Program mission.

Late 1999. First flight, X-33 Advanced Technology Demonstrator, possible predecessor of next-generation launch vehicle.

2000s

2000, date TBD. High Energy Solar Spectroscopic Imager (HESSI), Pegasus. Small Explorer mission. Will observe the Sun to study particle acceleration and energy release in solar flares.

2001, date TBD. Galaxy Evolution Explorer (GALEX), Pegasus. Small Explorer mission. Two-year mission using an ultraviolet telescope to explore the origin and evolution of galaxies and the origins of stars and heavy elements.



Deep Space 1

January 2001. Genesis spacecraft, launch vehicle TBD. Discovery Program mission. Designed to collect samples of the charged particles in the solar wind and return them to Earth for study.

February 2001. STS-113, Columbia. X-38 Return Crew Vehicle flight demonstration.

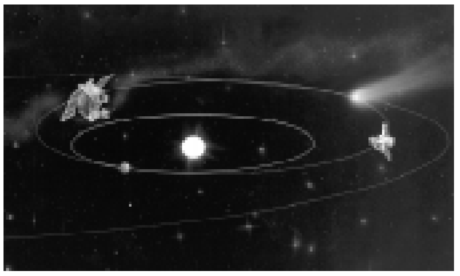
December 2001. Space Infrared Telescope Facility (SIRTF), Delta. Astrophysics mission to provide infrared imaging and spectroscopy. Part of NASA's Origins Program.

Late 2001. New Millennium Interferometer. Three spacecraft to be launched together and then deployed in formation. NASA Origins program.

July 2002. Comet Nucleus Tour (CONTOUR), launch vehicle TBD. Discovery Program mission. Will take images and comparative spectral maps of at least three comet nuclei and analyze the dust flowing from them.

2007. Next Generation Space Telescope, launch vehicle TBD. Will use infrared imaging and spectroscopy to study first stars and galaxies that formed after universe first cooled. Will operate farther away from Earth than Hubble.

End of first decade of new millennium. Terrestrial Planet Finder, launch vehicle TBD. NASA Origins Program to detect planets that fall into category of Earth-like.



StarDust

2010s

2013. Space Shuttle support for International Space Station is completed.

2013? First human mission to Mars.

** This is a selection of highlights from U.S. space exploration history rather than a complete chronology. Dates provided indicate when the mission was launched. See also Page 16 for Mars-related missions, past, present and future.*

Martian Odyssey

Milestones in the U.S. exploration of Mars

• **Nov. 5, 1964**, Mariner 3. Failed Mars flyby.

• **Nov. 28, 1964**, Mariner 4. First successful Mars flyby, July 14, 1965, returned 21 photos.

• **Feb. 24, 1969**, Mariner 6. Mars flyby, July 31, 1969.

• **March 27, 1969**, Mariner 7. Mars flyby. Returned 126 photos.

• **May 8, 1971**, Mariner 8. Mars flyby. Failed during launch.

• **May 30, 1971**, Mariner 9. First spacecraft to orbit another planet. Began orbiting Mars July 13, 1971.

• **Aug. 20, 1975**, Viking 1. Placed an orbiter in orbit around planet and a lander on the surface.

• **Sept. 9, 1975**, Viking 2. Same as Viking 1.

Mariner 4 spacecraft simulator test

• **Sept. 25, 1992**, Mars Observer. Lost prior to Mars arrival 1993.

• **Nov. 7, 1996**, Mars Global Surveyor. Arrived Sept. 11, 1997.

Mars Pathfinder arrives on Mars, July 4, 1997.

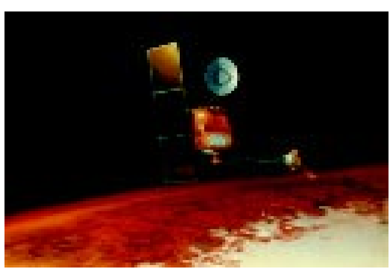
Mars Sample Return Mission, 2005

• **Dec. 4, 1996**, Mars Pathfinder. Landed on Mars July 4, 1997, deployed a rover to surface.

• **1998**, Planet-B. U.S./Japanese mission to study Martian atmosphere.

• **December 1998**, Mars Surveyor '98 Orbiter. Will characterize the Martian atmosphere.

• **January 1999**, Mars Surveyor '98 Lander. Will access Martian water reservoirs and deliver two soil microprobes that are part of the Deep Space 2 mission.



Mars Surveyor, 2001

• **March 2001**, Mars Surveyor '01 Orbiter. Characterize surface mineralogy and chemistry.

• **April 2001**, Mars Surveyor '01 Lander/Rover. Characterize the terrain over greater geographical distances. Select and gather soil samples for possible later return.

• **June 2003**, Mars Surveyor '03 Lander/Rover. Characterize terrain over wide area at a site chosen earlier. Other objectives, related to eventual human exploration, are expected to be added.

• **2003**, Mars Surveyor '03 Orbiter. Provide communications and navigation for 2003 and later missions to Mars.

• **2005**, Sample Return Mission to Mars. Return a sample from one of the rovers launched in 2001 and 2003.

• **2011**? Two Cargo Lander missions launched toward Mars, paving way for humans to follow.

• **2013**? First human crew lifts off on 180-day trip to Red Planet.

Human mission to Mars, 2013?

Viking 1 liftoff, Aug. 20, 1975, aboard Titan Centaur launch vehicle.

John F. Kennedy Space Center

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