Space Station will lead the way

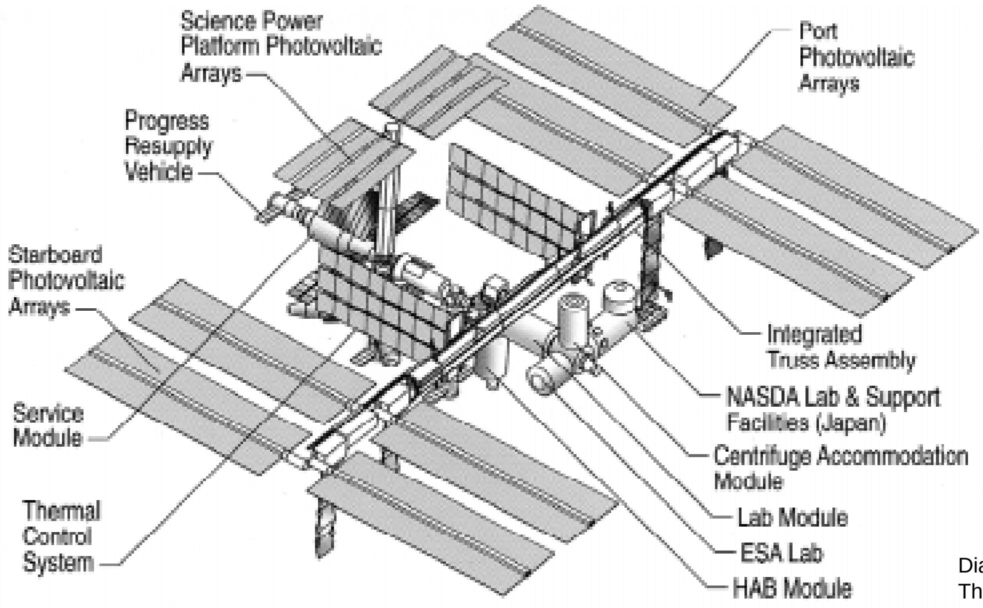


Diagram from Station prime contractor The Boeing Co.

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."

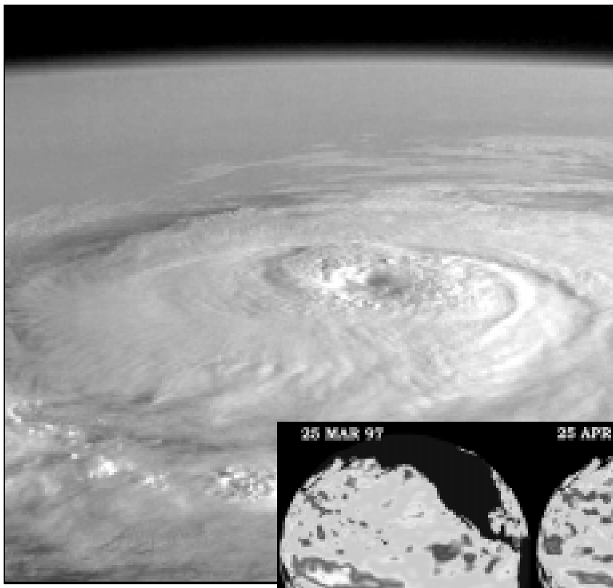
A spin-off example includes lightweight rechargeable batteries developed for space use that also made possible the creation of many cordless appliances and tools. Paints developed to keep spacecraft cool by reflecting the sun's rays could help us keep cooler on Earth in our cars, homes, and planes. Indeed,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

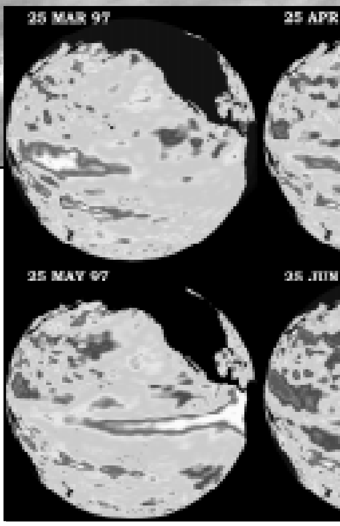
The Road Ahead

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





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.

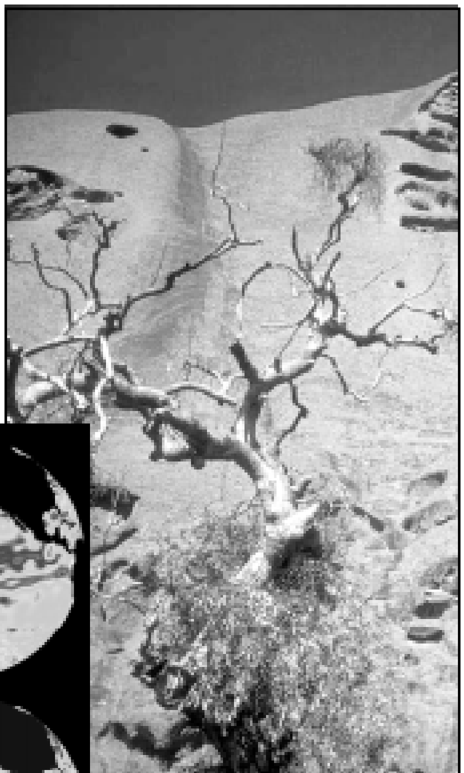
A human settlement on Mars, which would have to be self-sufficient to be sustainable, would satisfy human urges to challenge the limits of human capability, create the potential for saving human civilization from an ecological disaster on Earth (e.g., a giant asteroid impact or a nuclear incident), and 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

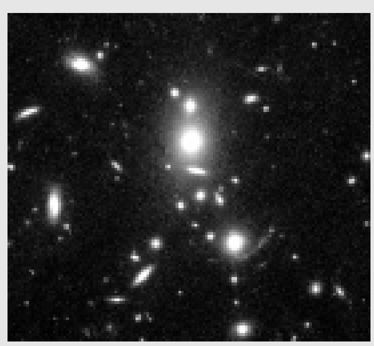
The 1998 NASA Strategic plan outlines four strategic enterprises representing the framework through which the agency implements its mission. The articles in this special issue touch upon all four in varying detail. The Strategic Plan appears on the agency Web site at http://www.hq.nasa.gov/office/nsp/NSPTOC.html

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.

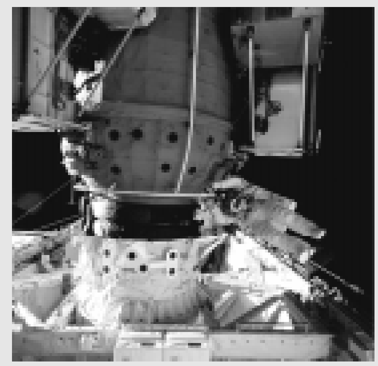
Space Science



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

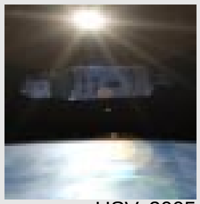
Joe Dean, Quality Assurance, Boeing

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.

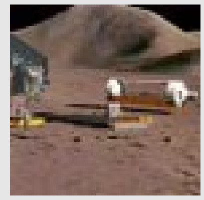


USV, 2005

• **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.

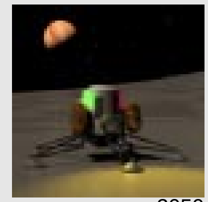


Lunar Telescope, 2007

• **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 inexpensive 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. 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.

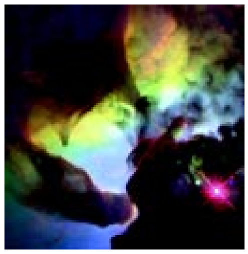
With Administrator Goldin's declaration Sept. 29, 1997, regarding the American explorer's spirit and attitude toward new challenges, this would be a good time to go back to the moon — only this time, on a more permanent basis.

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.

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!

Seek.

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.

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.