A Renewed Spirit Of Discovery

The President's Vision for U.S. Space Exploration

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The White House

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A Renewed Spirit Of Discovery

White House

"Today we set a new course for America's space program. We will give NASA a new focus and vision for future exploration. We will build new ships to carry man forward into the universe, to gain a new foothold on the Moon, and to prepare for new journeys to worlds beyond our own."

-- President George W. Bush
January 14, 2004

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Since the end of the Apollo program, the Nation has lacked a compelling vision for human space flight. Once we had landed on the Moon and returned safely to Earth, the underlying rationale for our human space flight program was dramatically altered. Gone were the days when the country would spend whatever it took to beat the Soviet Union in a race to demonstrate a spectacular feat by a date certain. We had won, and we no longer agreed on what to do next.

For the next 30 years, the Nation would engage in a highly public debate about where we should go, what should be the role of humans in space, and even whether we should be sending people into space at all. Following the *Columbia* tragedy, President Bush's instincts were shown clear. He said this of the Columbia astronauts and human space flight:

"The cause in which they died will continue. Mankind is led into the darkness beyond our world by the inspiration of discovery and the longing to understand. Our journey into space will go on."

Nearly one year later, the President outlined a new vision for the exploration of "worlds beyond our own".

This, at once, bold and pragmatic vision provides an overall framework and focus to space exploration, sets ever increasing technical challenges to be overcome, and initiates development of capabilities that will fundamentally open up new ways to study the cosmos.

Clear Direction

- Implement a sustained and affordable human and robotic program to explore the solar system and beyond

NASA / JPL

NASA Strategic Plan

- Humans beyond low Earth orbit
  - Return to the Moon by 2020
- Develop the required innovative technology, knowledge, and infrastructure
- Promote international and commercial participation

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The President has now provided clear direction for the Nation's space exploration efforts. The vision he laid out has five main tenets:

1. It calls for a sustained and affordable program for exploration – This is not an Apollo-like effort; rather, the pace of exploration will be set by the resources available. Further, this vision is not intended for a single decade or even two – but describes a journey for the foreseeable future.

2. It defines a role for both robots and humans. This vision calls for the two to work "hand in glove" with robots being the trailblazers and humans with robotic helpers to follow when the unique attributes of humans are required.

3. It clearly calls for humans to venture beyond Low Earth Orbit – Since the end of the Apollo era, the human spaceflight program has been confined to low earth orbit. Those shackles are now removed and humans can step out to new worlds. There is now a commitment to return to the Moon by 2020 in preparation for exploring worlds beyond.

4. It develops the framework for focusing resources to enable the vision – With a clear vision, it is now possible to prioritize the investments and ensure that the most critical efforts are fully funded.

5. It promotes international and commercial participation – The journey articulated by the President is open to any country that wants to partner, and who further shares our vision for the peaceful pursuit of space exploration. And NASA will make use of creative commercial approaches in order to accomplish the vision within a fiscally constrained environment.

Current Programs

NASA

- *Space Shuttle*
  - Focus use of the Shuttle to complete assembly of the ISS
  - Retire as soon as assembly of the ISS is completed, planned for the end of this decade
- *International Space Station*
  - Complete assembly – including international components
  - Focus U.S. research and use on supporting space exploration
  - Meet U.S. obligations
- *Space Science*
  - Continue robotic exploration including observatories
- Maintain commitment to non-exploration missions
  - Earth Science, Aeronautics

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Implementing the vision will have a significant impact on NASA's current programs. The Space Shuttle – the most technologically sophisticated launch vehicle created – will complete assembly of the International Space Station and then will be retired.

The US will meet its commitments to our partners on the International Space Station. The focus of the US research on the ISS will be to support our understanding and development of countermeasures to the effect of the space environment on human health and well-being.

Space Science programs will increase the emphasis on Mars and lunar exploration. This is in addition to the planned mission to study 3 of Jupiter's moons, a flyby of Pluto, Webb telescope, Gamma-ray Large Area Space Telescope (GLAST), Gravity Probe B, and Swift. It will also continue to pursue better understanding of solar physics and its impact on Earth. Sun-Earth Connection funding is expected to grow from $746 million in 2005 to $1.05 billion in 2009, providing for the ability to begin new and exciting major solar and space physics missions.

At the same time, NASA will continue its other important missions, such as Earth science and aeronautics. NASA's Earth science program will continue to provide key data sets and building blocks required for climate science and a comprehensive Earth observing system. It will also support new research oriented missions to measure ocean salinity, carbon dioxide concentration, and measure aerosol concentrations in-line with the Climate Change Strategic Plan. In addition, funds are provided to ensure the continuity of Landsat data as well as test key sensors on the next-generation of operational Polar orbiting satellites, both of which are key components of our Earth observing infrastructure.

Aeronautics will also get a new emphasis within NASA. NASA has reorganized the Office of Aerospace and created the Office of Aeronautics to focus attention on its importance to the US.

A Common Vision

- President's vision consistent with National Research Council Workshop released same day stating:
  - Why humans go into space: *"exploration should be the primary motivation of human spaceflight"*
  - Where we should go: range of destinations considered, including *"eventual human exploration of Mars," "a mission to the moon as a precursor",* and others
  - When should we go to Mars: *"It was seen as premature to set a firm date for or cost of that goal"*
  - Infrastructure:
    - *"research on the ISS focused on addressing the questions posed by human exploration away from low Earth orbit"*
    - *"development of a space transportation system…[for] human exploration…beyond low Earth orbit"*

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The President's Vision for Space Exploration was echoed by participants in a National Research Council Workshop on the very same day it was announced.

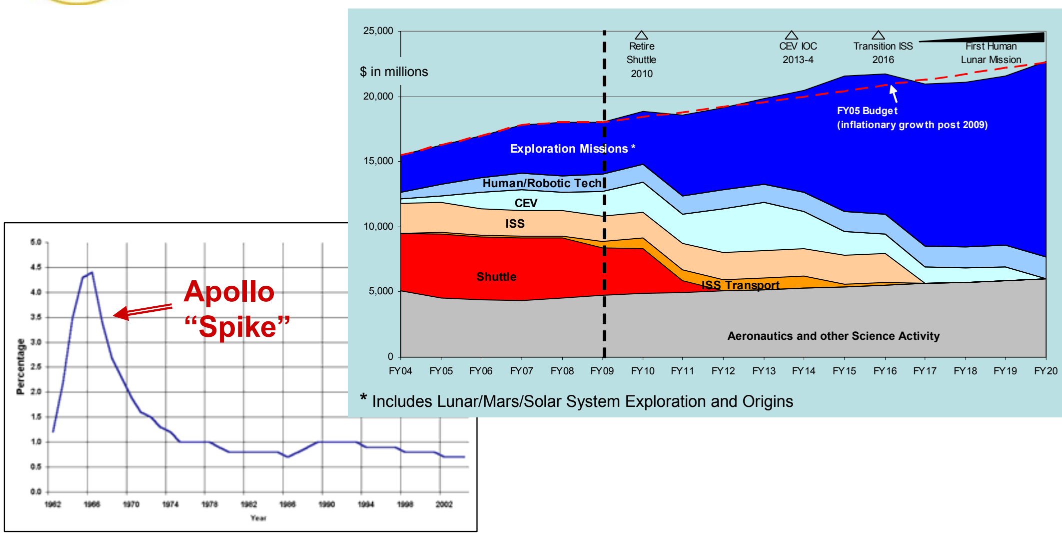
The Space Studies Board and the Aeronautics and Space Engineering Board put out the Workshop report outlining the fundamental tenets of the way forward for human space flight. As you can see, there is remarkable agreement between their conclusions and the Vision outlined by President Bush.

The rationale for human space flight is the same: exploration to discover new frontiers.

The NRC Workshop also agreed that the potential goal of a human mission to Mars is a daunting task, one that might require returning to the Moon as a precursor. Setting a date for Mars would be unrealistic, given the uncertainty the entire community has today over how we should best try to get there.

Finally, the NRC pointed out the International Space Station is a valuable laboratory for studying the effects of long-duration space flight on humans and for developing the means to mitigate those effects. At the same time, they recognized that to begin this journey, we would need to develop new capabilities for transporting humans into, through, and from space.

NASA Long-Term Budget Profile



"The vision I outline today is a journey, not a race..."
-- President George W. Bush
January 14, 2004

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The key to the President's vision is "affordability and sustainability." Gone are the days of unlimited budgets and of Cold War imperatives. Rather, we must learn how to pursue space exploration within the current fiscal context.

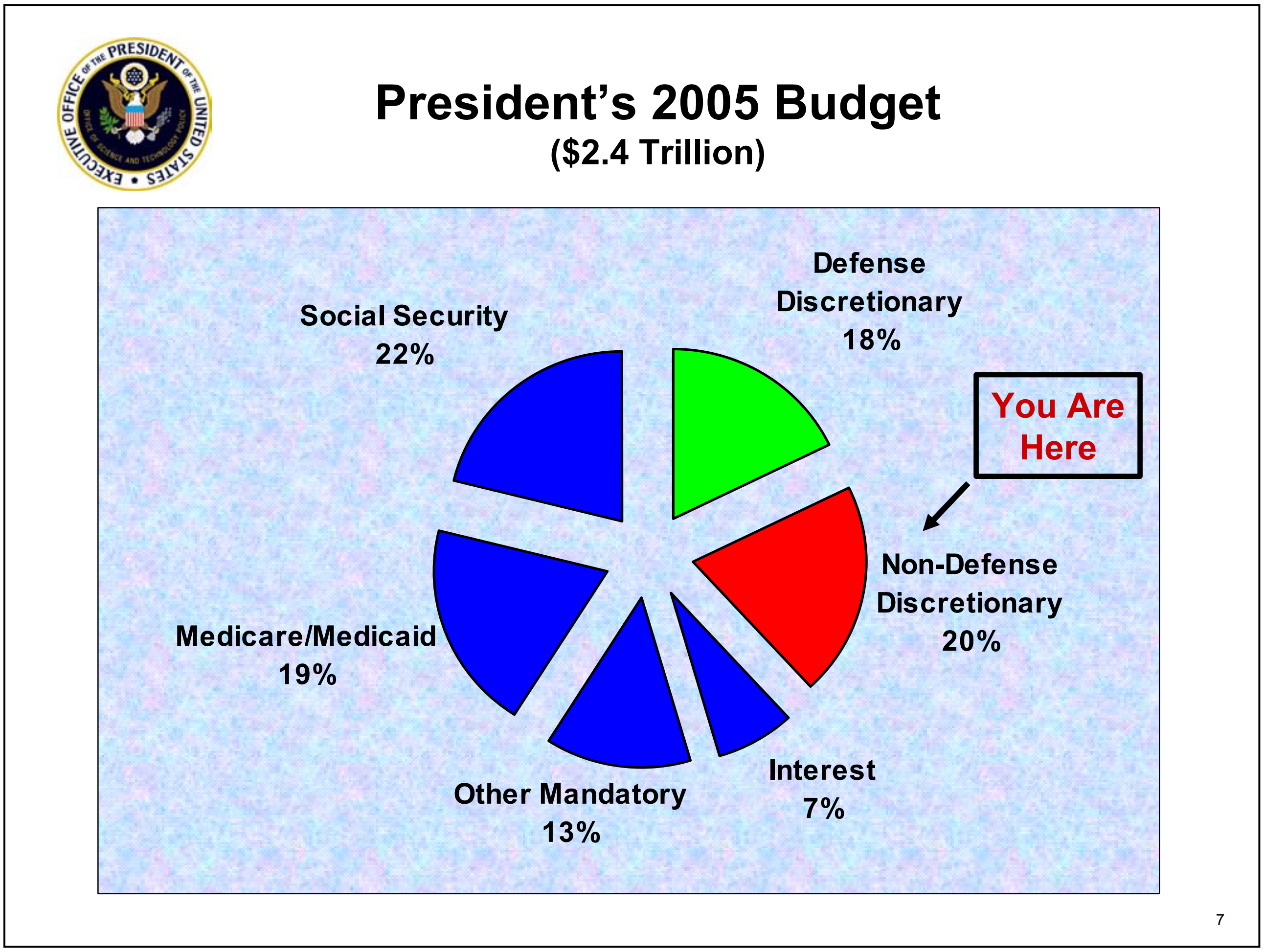
From its current 2004 level of $15.4 billion, the President's proposal will increase NASA's budget by an average of 5% per year over the next three years, and at approximately 1% or less per year for years four and five. Over the next five years, most of the funding we need for new endeavors will come from reallocating $11 billion within NASA's current $86 billion five-year budget.

But over the long term, NASA must learn to live within a budget constrained by inflationary growth. This has forced some hard choices. For example, in an ideal world, we would continue to fly the Space Shuttle until the Crew Exploration Vehicle is operational. But there is no way to maintain spending $4-5 billion a year on the Shuttle and complete the CEV.

The area in blue shows that as the Shuttle is retired and development of the CEV is completed, a significant amount of NASA's annual budget can be freed up for additional space exploration. This can be done without NASA having to give up any major responsibilities, such as aeronautics or earth sciences. You will notice that it is a very different spending profile than Apollo. "Affordable and sustainable" from a resource perspective is actually shown on the right side of the curve. From the end of Apollo up to now, NASA's budget has ranged between 0.7 and 1 percent of the Federal budget. Today, that means about $15-16 billion annually.

Again, the question is: what do we want NASA to be doing with these resources.

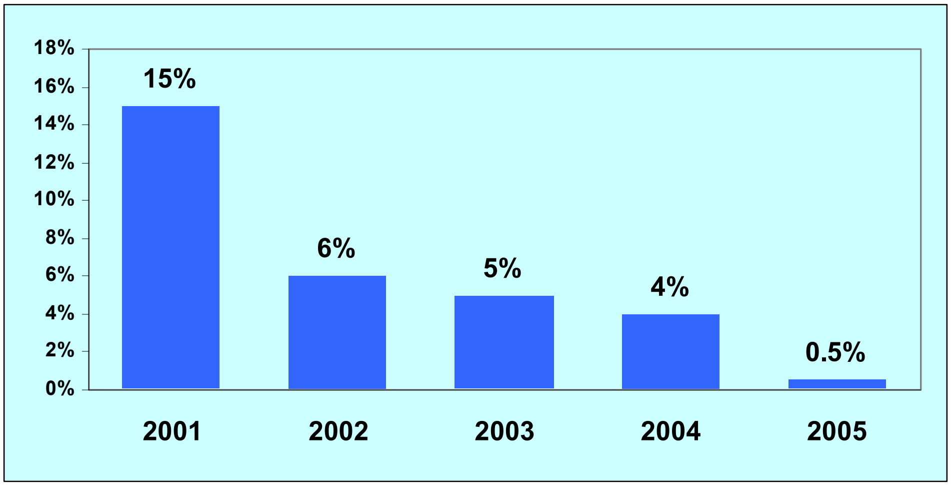
The President has outlined a coherent, compelling answer to that question.



It comes as no surprise to anyone that we are in an era of fiscal restraint. NASA's budget falls in the category of "non-defense discretionary" spending, which makes up approximately 20% of federal outlays.

Given the growth of non-discretionary spending – such as Medicare and Social Security – this portion of the Federal budget is shrinking with each passing year.

Growth in Discretionary Spending Declines



Percent growth in non-defense, non-homeland budget authority excluding supplementals

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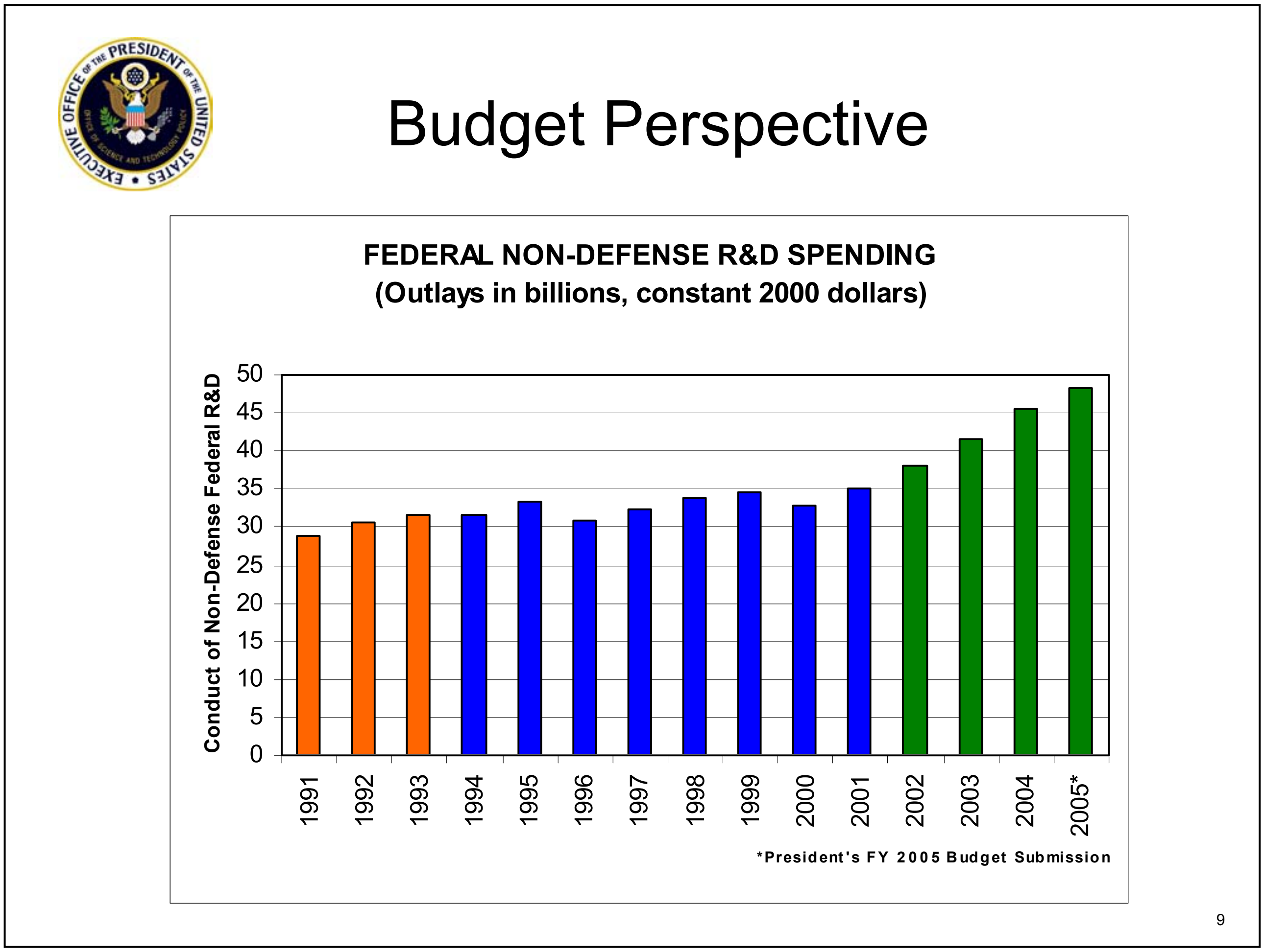
NASA must move forward with space exploration within that context.

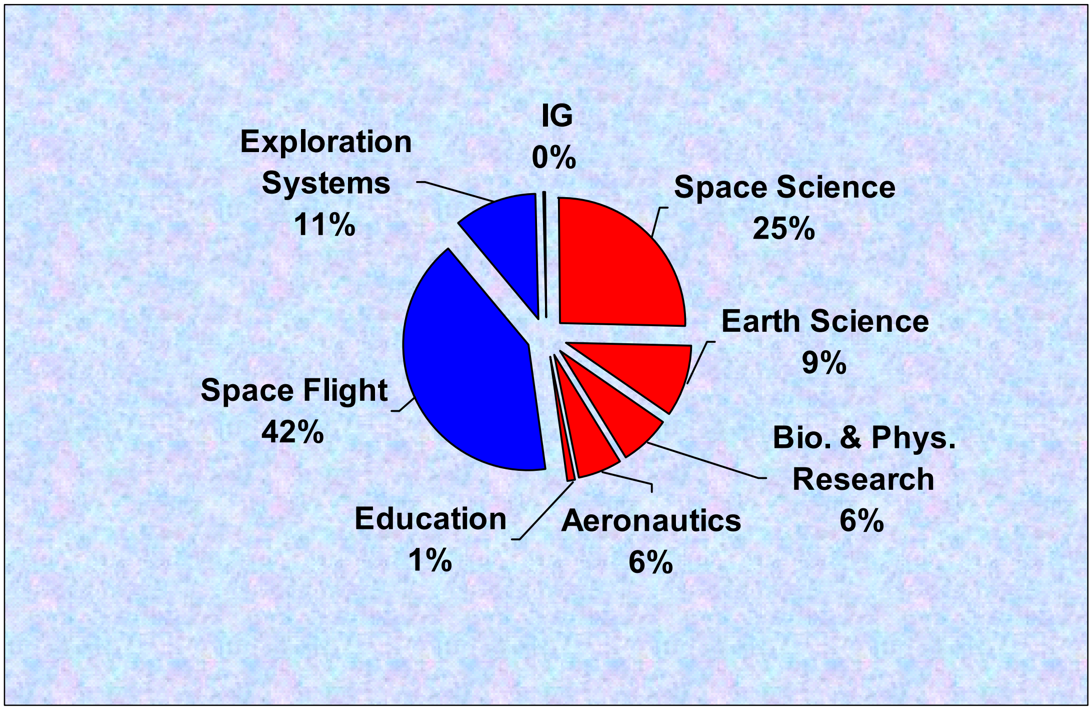
In the post-9/11 world, the growth of non-defense, non-homeland security discretionary spending by the Federal government has been slowed dramatically. The President's goal is to cut the deficit in half over the next five years, and his FY05 budget submitted on February 2nd does just that.



Despite this environment, R&D in the Federal budget has been doing very well in the Bush Administration. With the FY2005 President's Budget Request, Federal spending on R&D will have climbed more than 35% over the last four years.

These are investments in our future – in economic growth, in technology leadership worldwide, and in the health and well-being of the American people.

NASA’s 2005 Budget Request
($16.2 Billion)



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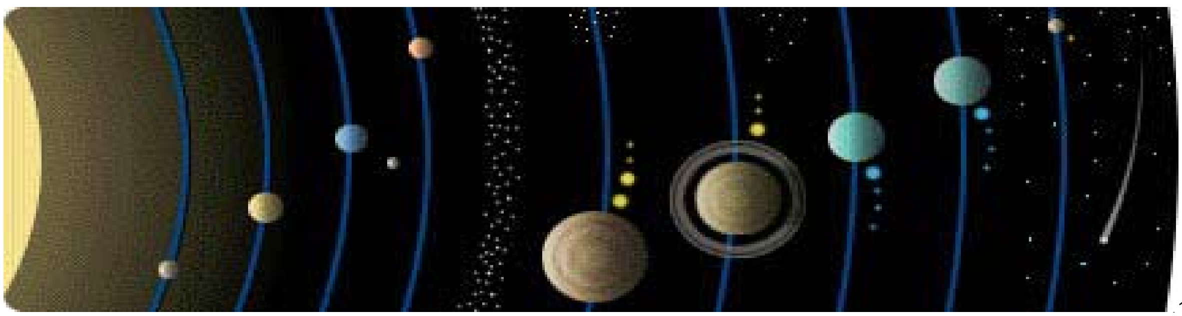
As you can see, NASA’s budget mirrors its diverse activities. The key enablers for the President’s space exploration vision are the space science, exploration, and space flight portions of the budget, as well as portions of biological and physical research.

Together, these comprise upwards of 80% of NASA’s resources.

What Makes Living and Working in Space so Hard (1 of 3)?

Object	Relative Distance	Time for 2-way comms	Relative Solar Power
Moon	1	2.5 sec	1
Mars	200 - 1000	8 – 42 min	0.4
Jupiter	1650 - 2440	1 – 1.7 hours	0.04



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We have been a space-faring nation for more than 40 years. And there is much that we have learned about living and working in space during that time – whether it is for humans or robots.

But there are some fundamental properties of space that make exploration challenging.

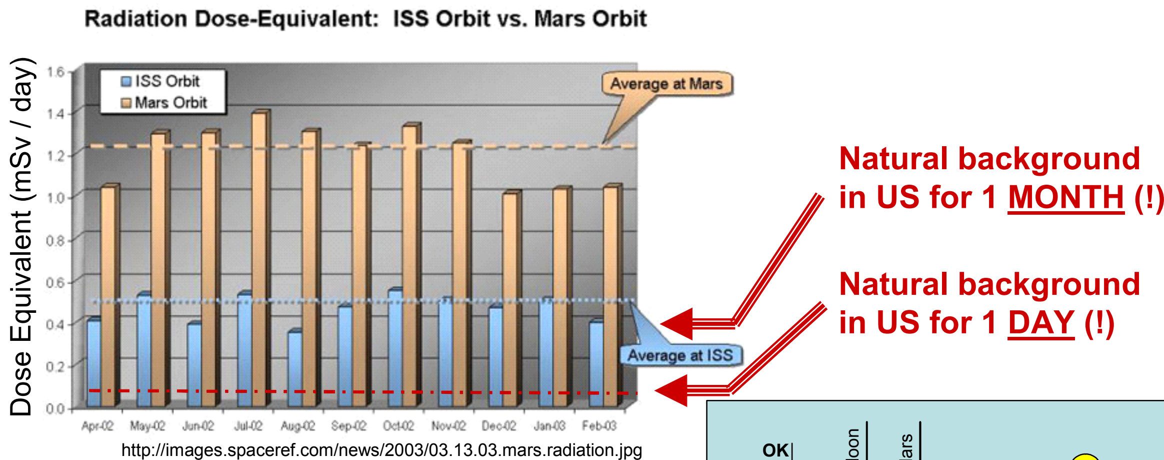
First and foremost – space in general, and the solar system in particular – is big and mostly empty. The distances between interesting points is large. And the relative position between objects change based upon their orbital position around the Sun.

If one considers the distance from the Earth to the Moon – Mars is 200-1000 times further away. And its closest approach due to orbital alignment occurs once every 2 years. Because of these distances, the finite speed of light starts to become an issue. Whereas there is a 2.5 second time delay for 2-way communication with the Moon, this time lag increases to 8 - 42 *minutes* with Mars. And between 1 – 2 *hours* to Jupiter.

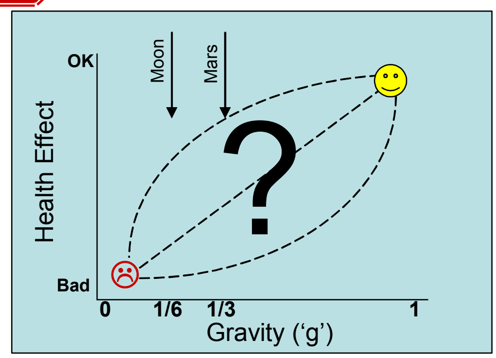
And as one moves further away from the Sun, using its power for instruments becomes increasingly difficult.

At Mars, the solar flux is only 40% of that at Earth – and decreases as one moves towards the poles. By the time one reaches Jupiter – the Sun is a dim speck in the distance with a flux of only 4% of that seen at the Earth.

What Makes Living and Working in Space so Hard (2 of 3)?



- Effect of long-term exposure to low gravity is *uncertain*.
- Months to years at low gravity needs to be understood and effects countered.



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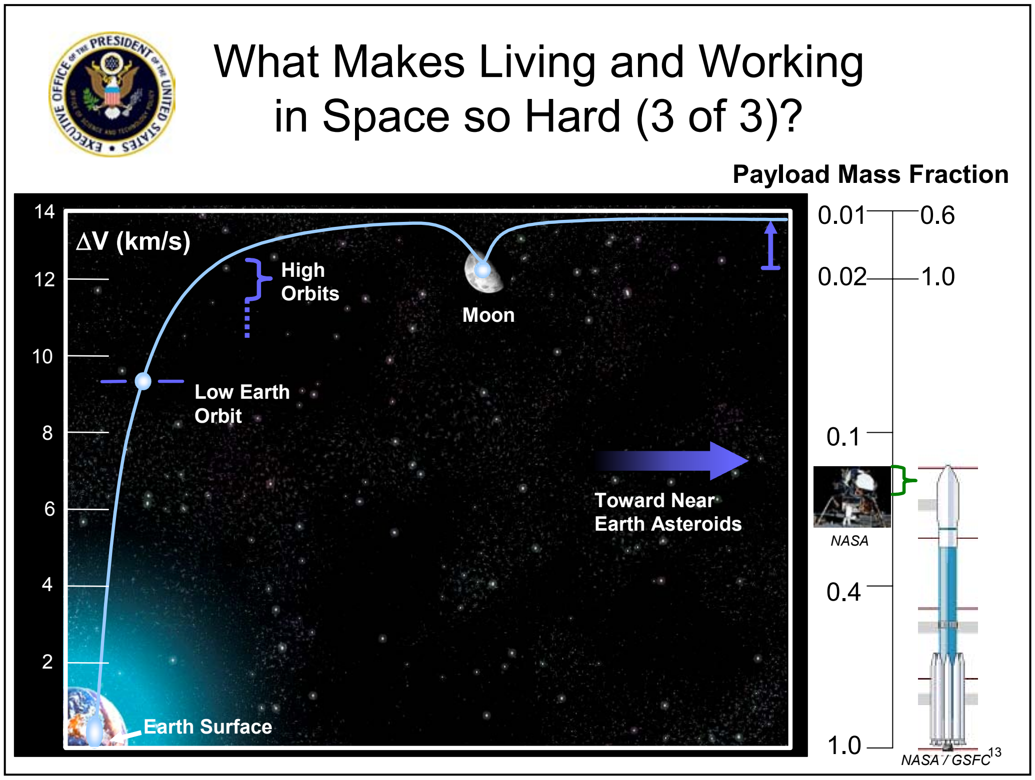
Another attribute to space that makes it difficult to work and live for long durations is the radiation environment. The radiation environment observed at the ISS is shown in the blue bars above. The average background for Mars is shown with the brown bars and is about a factor of 2 higher than at the ISS. How does this radiation level compare to the natural radiation background found in the US? The lower red line in the figure represents the average daily background. Also shown on the chart is the natural background in the US for 1 month – which is still LESS than the ISS radiation seen in a day.

In other words, one would experience the same radiation dose on the ISS in about 2 weeks that the average American sees in a full year. And on Mars – that exposure is doubled. The vision calls for understanding and countering the effects of radiation with ground-based experiments that can simulate the radiation environment and ISS experiments that monitor and counter the impact of radiation on other health effects.

Perhaps more important for human physiology is the impact of long exposure to low gravity. We know that human physiology is tuned to operate at 1-g as seen at the Earth's surface. We also now know that the long-term exposure to microgravity as seen at the ISS significantly decreases bone mass and creates other health problems. What we don't fully understand is how the health effects vary as the gravity changes from microgravity to full gravity.

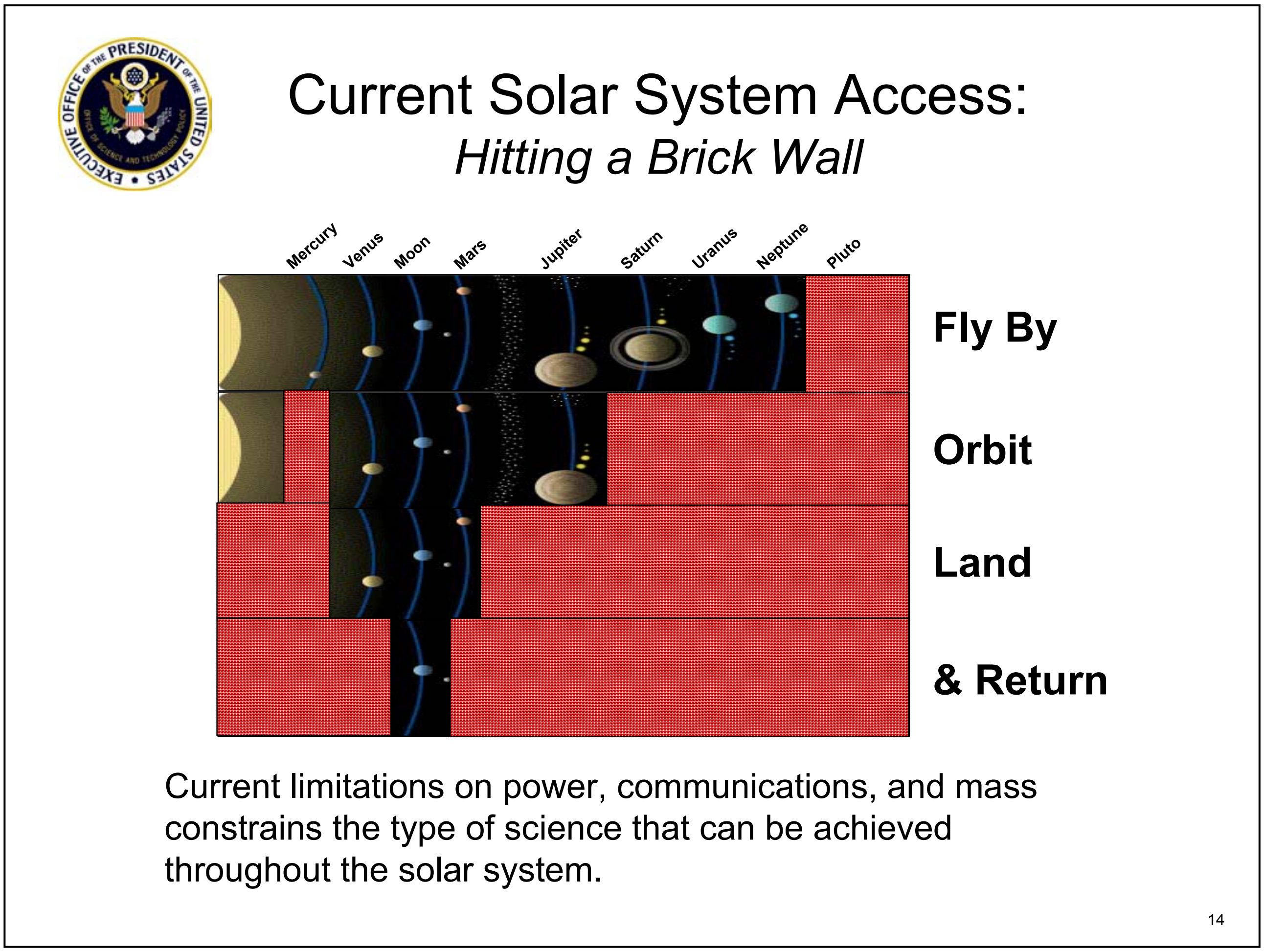
Since the Moon is at about 1/6-g and Mars is at about 1/3-g, it is important to know which of the possible curves shown in the chart in the lower right best represents the impact of gravity on physiology. Much of the US science focus on the ISS will be to characterize and counter the effects of partial-gravity on health.



And finally – the Earth does not give up its belongings easily. The force of gravity holds things down and it takes a lot of energy to escape the confines of the Earth. Shown graphically is the depth of the "ΔV well" for both the Earth and the Moon. ΔV represents the equivalent velocity you would need to impart to an object to have it reach a certain point. A few interesting things to note on this chart. First – just getting to LEO takes a large amount of ΔV. Once there – getting to the Moon, or beyond, is much easier in terms of energy. This ΔV is supplied by rocket propellant. The larger the ΔV – the more rocket propellant is required. The chart on the right shows typical payload mass fractions for chemical rockets. As shown, getting to LEO requires about 90% of the launch mass to be propulsion and tanks – and less than 10% to be payload. If one wants to get to the Moon or Mars – the payload mass fraction drops dramatically. The Mars exploration rovers weigh about twice as much as I do -- about 385 pounds – I should say, twice as much as I would like to weigh -- but each required a Delta II rocket weighing over 500,000 pounds at liftoff!!

Contrast this with mass launching from the Moon – where due to the much smaller ΔV, more than half the launch mass is payload. There is thus the potential, that if the Moon holds useful resources, and they were economical to process, one could combine mass launched from Earth (such as humans) with mass launched from the Moon (such as propellant and radiation shielding) to significantly lower the total launch mass requirements. From Apollo and unmanned missions, we know that the Moon *does* have potentially useful resources. About 40% (by weight) of the lunar regolith is oxygen. For a liquid oxygen & hydrogen propulsion system – the oxygen alone makes up about 6/7th the mass of the propellant. In addition, we know the lunar surface contains aluminum, silicon, pockets of titanium, and other elements that may be used to build a space infrastructure or provision an expedition.

There is also evidence from the Clementine mission, Lunar Prospector, and ground based radars that the lunar poles contain an abundance of hydrogen. There is still uncertainty as to the form this takes (e.g., ice mixed in the regolith) – but the data is tantalizing enough to explore and resolve the uncertainty. The next step is to better survey the potential resources and demonstrate cost effective means of extraction and processing. If enabled – the lunar capability could significantly enhance cis-lunar operations and potentially reduce cost and complexity for missions beyond the Earth-Moon system.



The physical limitations described above, clearly manifest themselves even in purely robotic science missions. Today we are bumping up against these fundamental limitations as we explore the solar system.

In the first 40 years of space travel, we have sent unmanned probes to fly-by every major solar system body except Pluto (and that one is being planned).

It takes more energy to slow down to orbit a planet – and hence we have only orbited a smaller number.

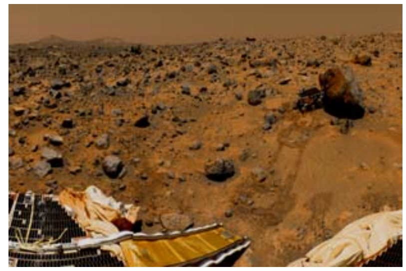
When you consider the objects we have landed on – which again takes more energy and hence the payload carried is smaller – we have only been on Venus, Moon, and Mars. And finally – when you consider the next level of complexity – returning an object – then only the Moon remains.

The one object with a sample return (Moon) is not due to lack of interest of other bodies.

But it is due to the increasing complexity, cost, small mass, long duration, and low power associated with other solar system objects.

Limitations on Exploration

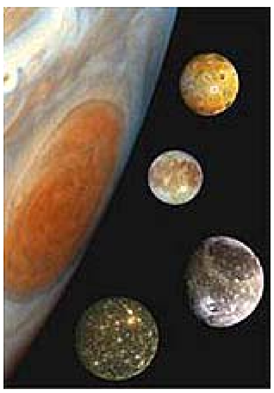
Today:
- Small payload mass to other worlds
- Difficult & expensive to return samples from other solar system objects
- Systems are power & communications constrained
- Tele-operation is slow and tedious
- Autonomy is essentially nonexistent



NASA / JPL

Apollo 17 Lunar Rover traveled as far as 7.4 km from the Lunar Excursion Module and a total of 30 km over 3 days (December 1972)

Headline: NASA rover travels nearly 70 feet, sets record on Mars (**Associated Press,** Los Angeles, February 11, 2004)



NASA / ARC

Future:
- *In situ* operations
- Wide area exploration of multiple planetary bodies
- Increasingly complex observatories in deep space

Requires:
- Increased power, communications, local cognitive capability, and mass transport

The vision opens up *NEW* opportunities for discovery

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The President's vision attacks these limitations directly. It funds development of high power sources, increased communications bandwidth, exploitation of in-space resources to enable larger masses, pushes robotics and human-machine interfaces, and ultimately enables human cognitive ability on site at the place of exploration.

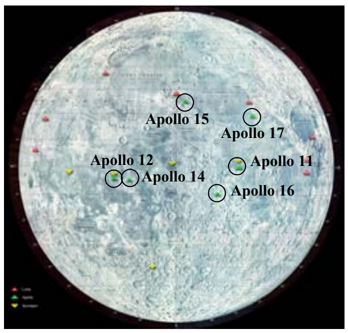
The presence of humans will dramatically enhance the ability to conduct science. For example, on the Moon, astronauts were able to roam far from their landing site to examine different areas of interest. During the Apollo 17 mission in December 1972, astronauts Eugene Cernan and Harrison Schmitt traveled a total of 30 km over 3 days, and up to 7.4 km away from their lunar module. Over thirty years later, NASA's Mars Exploration Rover *Spirit* set a record for a robotic mission by traveling nearly 70 feet in one day, quite a difference.

Enabling the vision should lift the self-imposed veil of constraint that the science community has imposed on its thinking about only what space missions are *possible* – now we can start to enable and think about what missions are *desired*. Once the full impact of the vision becomes apparent – the science community will be clamoring for more sophisticated and higher power sensors, exploration of continent sized areas, simultaneous atmospheric, surface, and subsurface probes, or sophisticated UAVs or helicopters on Titan.

We are on the cusp of changing the paradigm for how and what we explore. And we should expect that this new capability will alter our understanding of planetary formation and evolution, and offer a better understanding of the limitations under which life can arise.

Why the Moon Next?

- It is close, scientifically interesting, and largely unexplored
- Development of lunar resources has potential to be a major advancement in space logistics capability
- Transport system to Moon can also access GEO, cis-Lunar, Earth-Sun Lagrangians, and some Near Earth Objects
- Advance science, improve engineering state-of-the-art, and inspire



NASA / JSC

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The 1st step along this journey is to establish a sustainable exploration agenda. The President's vision calls for undertaking lunar exploration activities to further science, test out new technologies and techniques, and to develop key capabilities to support more distant, more capable, and/or longer duration human and robotic missions.

The Moon has roughly the same surface area as the continent of Africa – yet remains largely unexplored. The figure on the left shows all the Apollo landing sites – all located on the near-Earth side of the Moon within a fairly narrow longitude and latitude band. The total time that humans have spent on the surface of the Moon is about 300 hours – or about 12 days. Going back to the Moon will help to resolve open issues about the formation of the Moon, its cratering history (used to date events throughout the solar system), and the lunar bulk composition across the surface and at depth.

In addition – the development of lunar resources has the potential to be a major advancement in space logistics. Part of the early robotic missions to the Moon will likely map and assess the resources, and may consist of processing demonstrations. If shown to be economically feasible – more extensive missions may be undertaken to more fully exploit the potential.

Also the Crew Exploration Vehicle ("Constellation") developed for cis-lunar operation should have the energy capability to reach some Near Earth Objects, lagrange points, and geostationary orbits around the Earth. This capability should open up new opportunities for enhancing the science that can be accomplished within the Earth's local region of space.

And of equal importance – pushing the frontier of space travel back to the Moon is cool. It should prove inspirational to the next generation of students to appreciate technical disciplines, and the technical challenges we must overcome to reach routine access to the Moon, should attract and hold the "best and the brightest" of the current students.

Mars

Mars Could Once Support Life, Scientists Now Say, but Did It?

(NY Times – March 3,2004)

NASA / JPL

NASA / JSC

NASA: Liquid water once on Mars

Red planet may have been hospitable to life

(CNN – March 3, 2004)

Mars Rover Finds Evidence of Ancient Water

(People's Daily (China) – March 3,2004)

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Mars captures the imagination of people around the world. In fiction, Mars is typically depicted as an exotic world teeming with life -- often hostile as in *War of the Worlds*, but occasionally introspective and philosophical as in *The Martian Chronicles*.

In general authors have used Mars as a mirror to the Earth – chronicling our own history and foibles.

Today, we know that Mars is barren. It's canals relegated to a "quaint" understanding, the "face on Mars" is now just a large surface feature with an opportunistic shadow, and the alien life forms, if any existed or currently exist, are likely to resemble microbial extremophiles and unlikely to have rayguns.

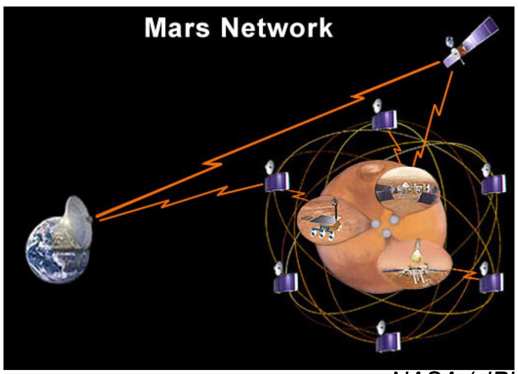
And yet Mars still beckons. The recent discovery by Opportunity and Spirit that Mars likely had regions of flowing water is important to the search for life in the cosmos and for better understanding the geology and morphology of the rocky planets. Mars also offers a moderate gravity and atmosphere, and temperature extremes that are manageable.

Many space enthusiasts are convinced that Mars will some day be teeming with human life – researchers and possibly colonists along with an occasional Starbucks.

I don't know what the future will hold for Mars – but I do know, that this nation is committed to exploring Mars and to enable the technology necessary for that exploration.

Enhancing Mars Exploration

- Before Vision:
  - Mars Reconnaissance Orbiter (2005 launch)
  - Phoenix Lander (2007 launch)
  - Mars Science Laboratory (2009 launch)
  - Mars Telesat communications orbiter (2009 launch)



NASA / JPL

- After Vision:
  - Additional Mars Scout in 2011
  - Mars Testbed Lander in 2011
    - "Safe on Mars"
    - *In situ* resource utilization
  - Technology for post-2010 Mars science pathways
    - Sample return as early as 2013
  - Technology for post-2013 Mars testbeds

NASA / JPL

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As part of that commitment, we will enhance the robotic exploration of Mars that will be a precursor to future human missions.

While most Mars exploration missions through the end of this decade are already scoped out, we have the opportunity to expand the number and type of robotic missions to Mars in the next decade. Overall, we will roughly double the number of missions planned for after 2010, including adding an additional Scout lander in 2011 and a long-anticipated sample return mission as early as 2012.

Many of these future missions will test technologies and systems to enable human exploration of Mars, such as the processing and use of *in situ* resources, as well as the "Safe on Mars" activity to assess the environmental, chemical, and biological hazards before sending a human mission to Mars. This is both to keep astronauts safe, as well as to minimize contamination of the Martian environment and contamination of our own environment upon return to Earth.

And Beyond…

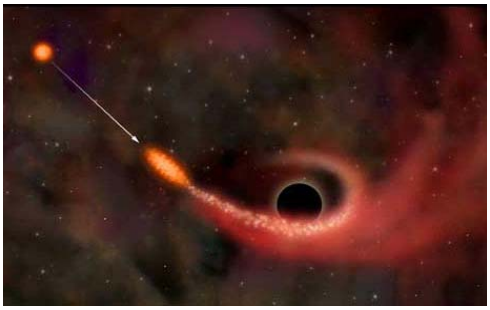
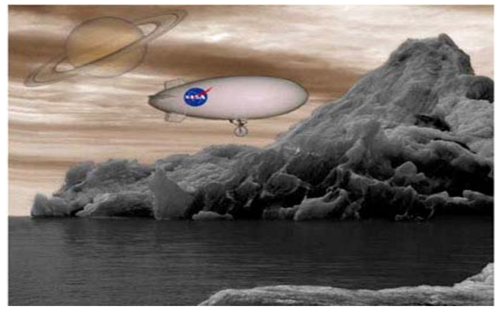
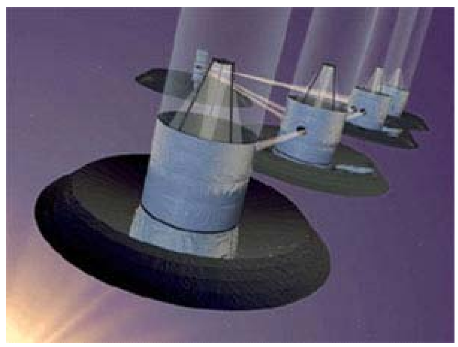


Illustration of a black hole destroying a star in the galaxy RXJ1242-11 (NASA; ESO/MPE)



NASA / JPL

An air vehicle exploring the atmosphere of Titan (a moon of Saturn).



NASA

An artist's concept of Terrestrial Planet Finder hunting for terrestrial planets outside our Solar System

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The President's vision is about more than the Moon and Mars. It is about opening up the cosmos for exploration.

This includes robotic and human *in situ* exploration – in addition to building new and sophisticated sensors to observe the universe remotely so that we may better understand how all the celestial pieces fit together.

Opening up the cosmos will enable:

1. More sophisticated exploration of the moons of Jupiter and Saturn;

2. Understanding of cratering and planetary evolution;

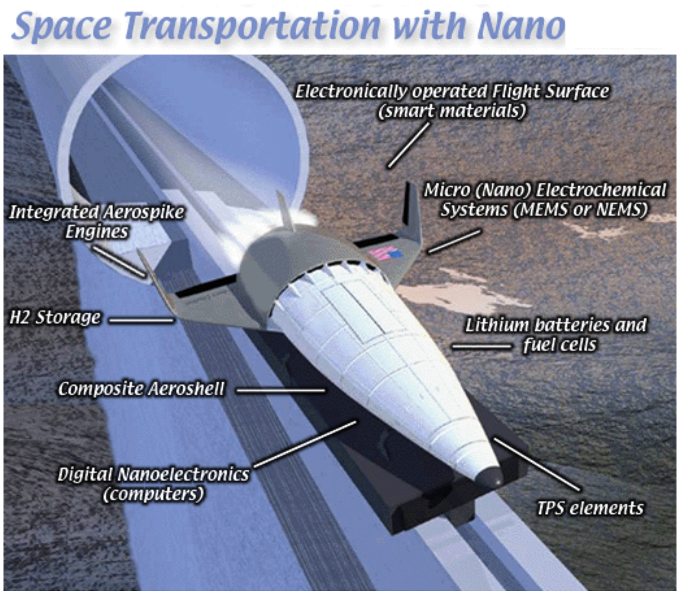
3. Comparative planetology and climate change; and

4. Understanding the formation of primitive bodies and their potential influence on the origin of life.

It will also further our understanding of fundamental physics questions remaining about the evolution of the universe.

Ultimately the vision is to make space something we travel through – to accomplish something – as opposed to being an end in itself. And when that is accomplished, new opportunities to assemble complex structures to observe back to the beginning of time or to directly observe continents on planets orbiting other stars will evolve from the realm of science fiction to technically plausible.

“Technospace”



http://www.ipt.arc.nasa.gov/spacetransport.html

Technology developments for this vision will push:

- Robotics
- Autonomous and fault tolerant systems
- Human-machine interface
- Materials
- Life support systems
- Nanotechnology
- Micro-devices, etc…

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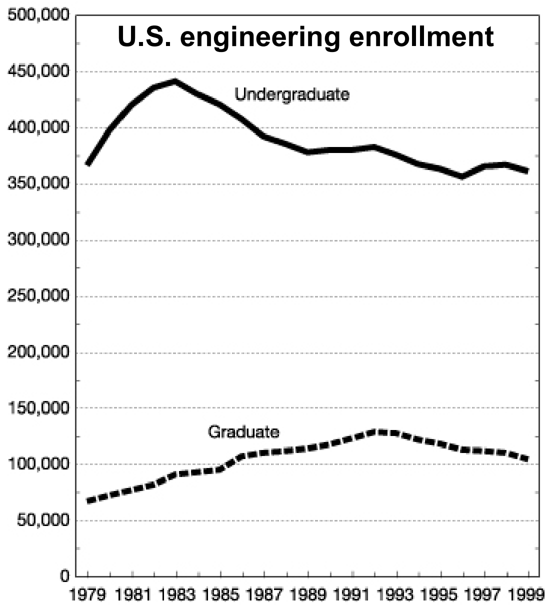
Along this journey, we expect additional benefits. To enable this vision will require ingenuity and the application of new materials and concepts currently in early research phases.

Having an overarching space exploration vision will serve to stimulate the nascent fields of robotics, autonomous and fault-tolerant systems and nanotechnology. The focus provided by this vision should accelerate specific applications and products. It should also provide substantive “spin-offs” to national security, homeland security, as well as to the economy.

Inspiration

"And the fascination generated by further exploration will inspire our young people to study math, and science, and engineering and create a new generation of innovators and pioneers."

-- President George W. Bush, Jan. 14, 2004



National Science Board, *Science and Engineering Indicators-2002*

NASA Strategic Plan

"In the last 40 days, the NASA web site has received 6 billion hits..."
Administrator Sean O'Keefe (House Testimony, Feb. 12, 2004)

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Space exploration inspires the young and old alike. Furthermore, difficult and compelling challenges capture students who want to be part of the team that solves the problem – and then takes on the next even grander challenge.

In an era where the technical needs and complexity of society is increasing – we face a downturn in the number of US students pursuing technical fields of study.

The President recognized the connection between these two points when he announced the vision on January 14 of this year. A bold and compelling space vision will excite the next generation. A technically strong workforce will continue to propel America's economy well into the future. The President's vision for space will be a boon to math and science education.

Continuing the Journey

NASA / JPL

"We do not know where this journey will end, yet we know this: human beings are headed into the cosmos."

-- President George W. Bush
January 14, 2004

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The challenges and risks of this journey are many. The rewards are unknowable – but the price to be paid by *not* exploring and forever looking outward, without being able to travel beyond our planet – is unacceptable. Thank you.