

**Address through multi-media tele-conference to
The Symposium on
“The Future of Space Exploration: Solutions to Earthly
Problems”
Boston University, USA
12 April 2007**

Space Exploration and Human Life

“Dream transforms into thoughts
Thoughts result into actions”

I am delighted to participate in the Symposium on “The Future of Space Exploration: Solutions to Earthly Problems” organised by (a) the Centre for Space Physics, (b) the Pardee Centre for the Study of Longer Range Future and (c) the Secure World Foundation of Boston University to mark the occasion of the Fiftieth Anniversary of the dawn of Space Age. My greetings to this distinguished gathering of space scientists, technologists, academicians, futurologists, industrialists, social scientists and students. May I address you, as a fellow scientist, who has been part of the growth process of space science and technology in India. This field of human endeavour has, in the last fifty years, made an unprecedented impact on the life of human race. As the first citizen of India, I am aware of the aspirations and pain of our people and the great expectations they have for further improving their quality of life using technology including space. I am glad to know that you will be discussing how

Dr. A. P. J. Abdul Kalam
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space technology can enhance further, the quality of life of world citizens while examining many innovative ideas for space exploration, exciting aspects like space colonies, search for extra terrestrial intelligence and planetary exploration. We have to understand our planet more completely, evolve and adapt our life to its environment and ecology. Hence, I have chosen the topic, **“Space Exploration and Human Life”**.

Indian Space Visionary

As you know, fifty years ago, space initiatives started with only two major space-faring nations. Now, there are

Indian Space Visionary - Prof Vikram Sarabhai

VISION To Reality

- Established PRL in Ahmedabad with Space Research as Focus
- He unfurled the Space Mission for India in 1970 – Today India can launch any type of satellite and any type of launch Vehicle
- 14,000 Scientific, Technological and Support staff and 500 support industries and academic institutions

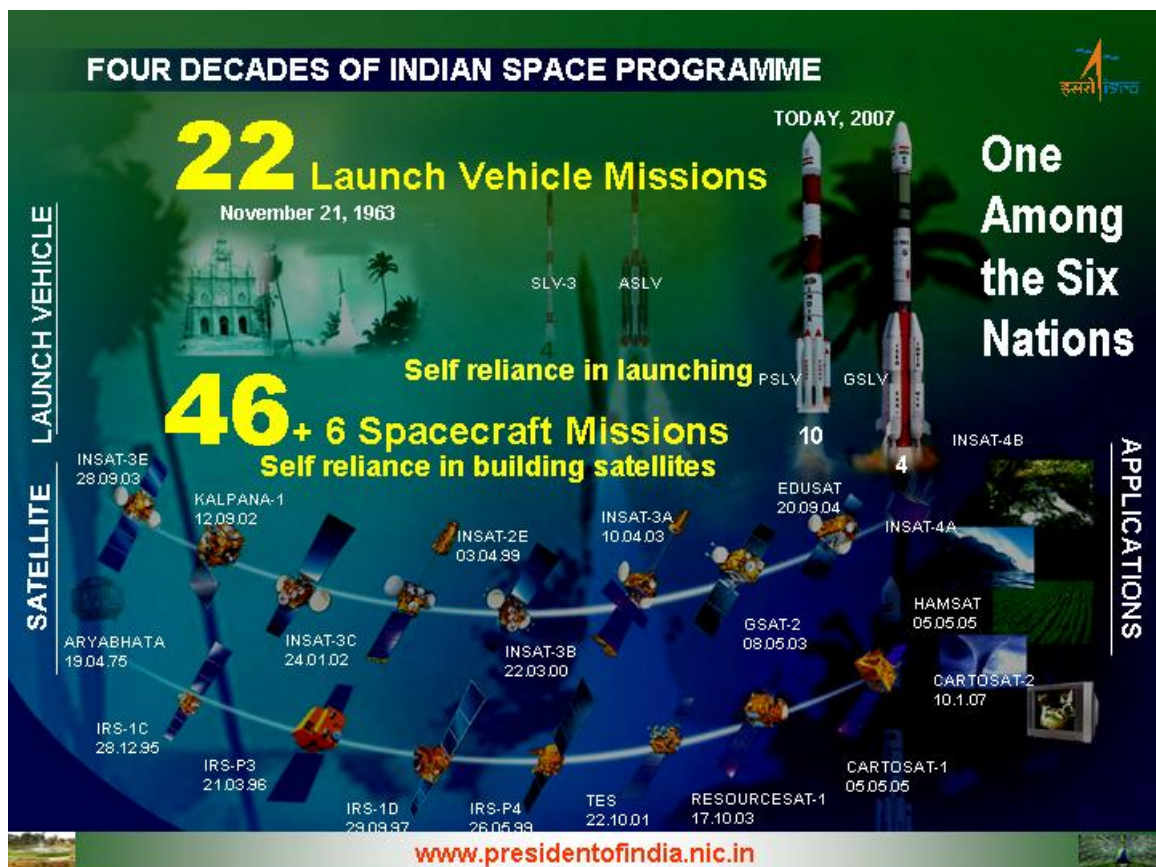
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many. I am happy to say that India is one among them with space science and technology accelerating the social and

economic advancement of the nation. When I think of space accomplishments of the last fifty years and the vision for the future, I recall Dr. Vikram Sarabhai, who pioneered India's space programme, which in the last four decades has been touching the lives of many among the billion people of India in several ways.

The Indian Space Programme

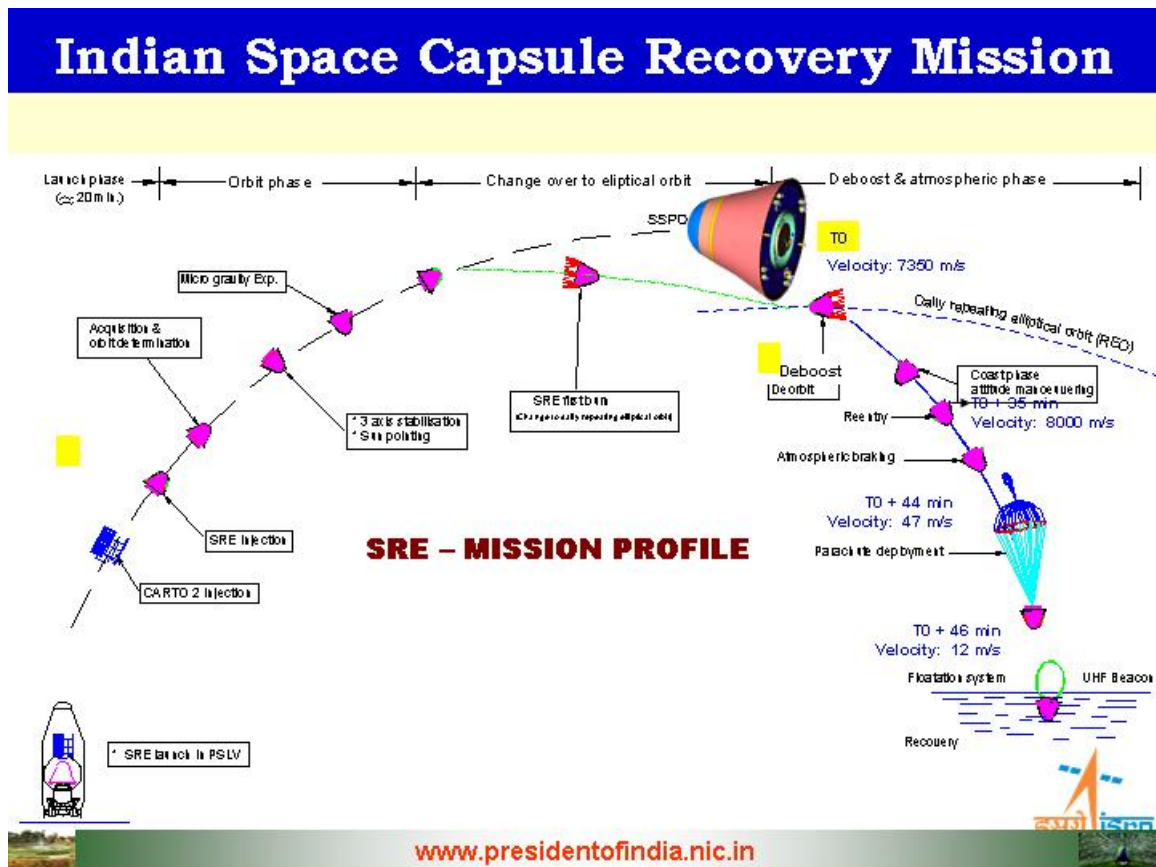
Prof. Vikram Sarabhai unfurled the socio-economic application oriented space mission for India in 1970. Today,



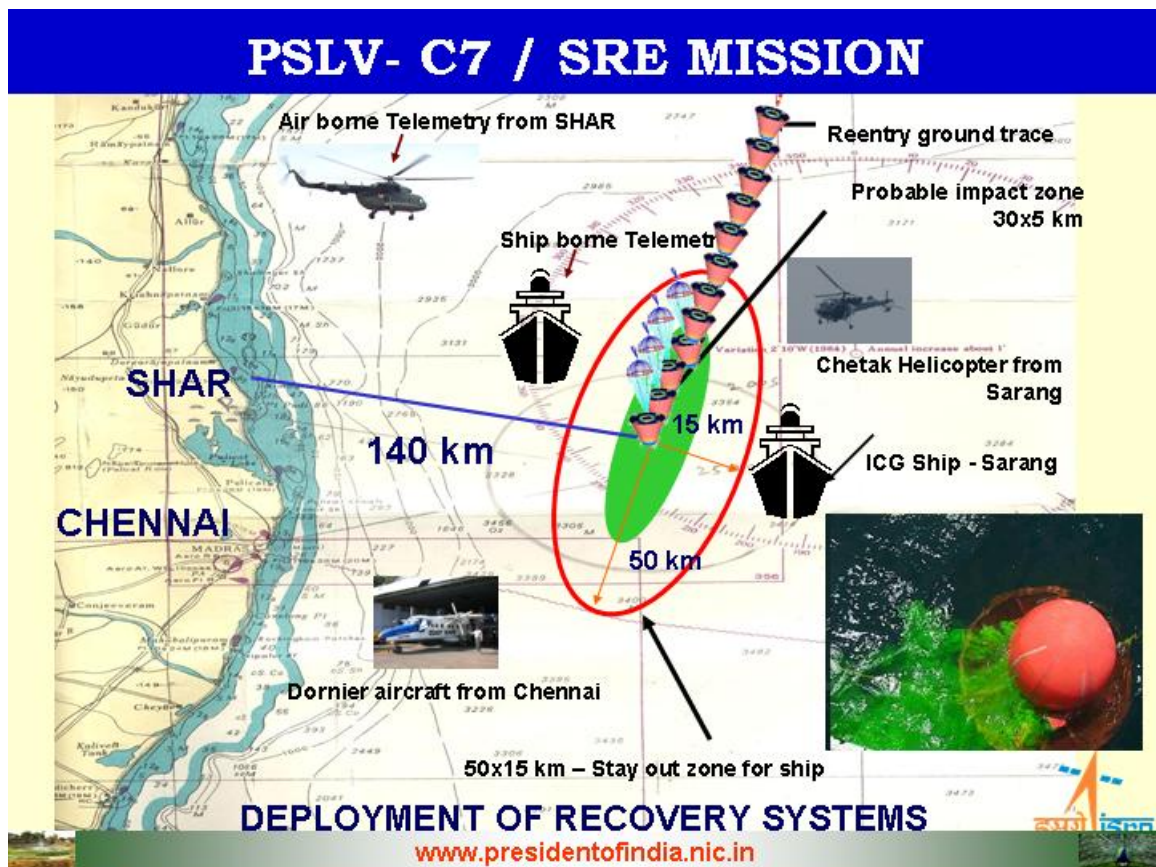
India with her 14,000 scientific, technological and support staff in multiple space research centers, supported by about 500 industries and academic institutions, has the capability to

build any type of satellite launch vehicle to place remote sensing, communication and meteorology satellites in different orbits and space application has become part of our daily life. India has today a constellation of six remote sensing and ten communication satellites serving applications like natural resource survey, communication, disaster management support, meteorology, tele-education (10,000 class rooms) and tele-medicine (200 hospitals). Our country is in the process of establishing 100,000 Common Service Centres (CSC's) across the country through public-private partnership model for providing knowledge input to rural citizens.

Recently, India has launched into orbit and recovered a



space capsule after performing micro gravity experiments. This



is a major technological milestone is an important step towards reusable launch vehicle and manned space missions. India is now working on its second space vision. I foresee that an important contribution for future of exploration by India would be, space missions to the Moon and Mars founded on space industrialization.

Space Research as a Technology Generator

Space research is truly inter-disciplinary and has enabled true innovations at the intersection of multiple areas of science and engineering. It has been consistently aiming at the “impossible” and the “incredible”, every time moving the

frontiers of our knowledge forward. Space research has had as

Space Research as a Technology Generator

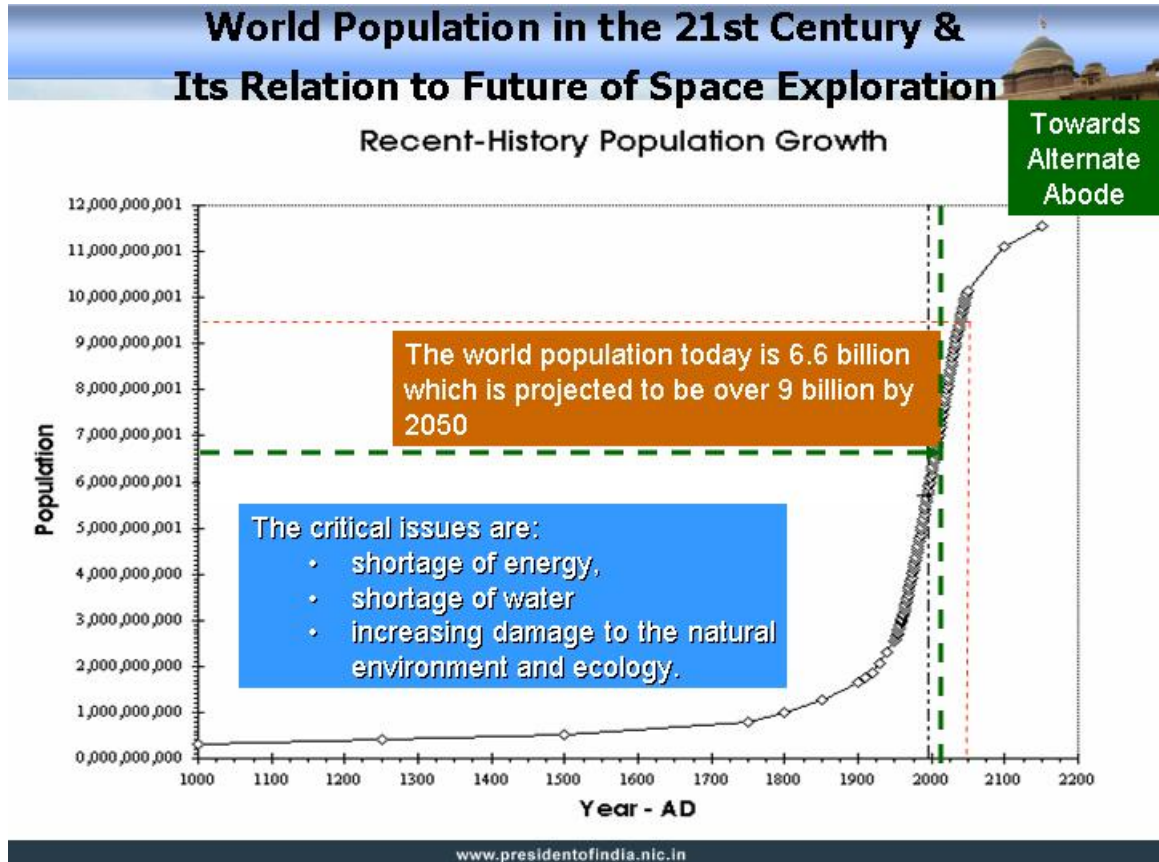
- Space research is truly inter-disciplinary and has enabled true innovations at the intersection of multiple areas of science and engineering.
- It is almost a “Green Technology”.
- Its greatest asset is that it enhances the quality of human life on the earth.
- Some examples are - the revolution in
 - Communication and tele-presence,
 - Infotainment and an integrated picture of earth and its resources.
- Besides direct contributions, the fruits of space research have also resulted in designing innovative products such as cardiac stent and heart pacemaker for healthcare.

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its major focus, on making things work and bringing the dreams of mankind to fruition through technologies that the mankind can be proud of. It is almost a “Green Technology”. Its greatest asset is that in many cases what is perfected as a space technology becomes a technology that enhances the quality of human life on the earth. Some examples are - the revolution in communication, tele-presence, infotainment, and an integrated picture of earth and its resources. Besides direct contributions, the fruits of space research have also resulted in designing innovative products such as cardiac stent and heart pacemaker for healthcare.

World Population in the 21st Century & Its Relation to Future of Space Exploration

The world population today is 6.6 billion which is

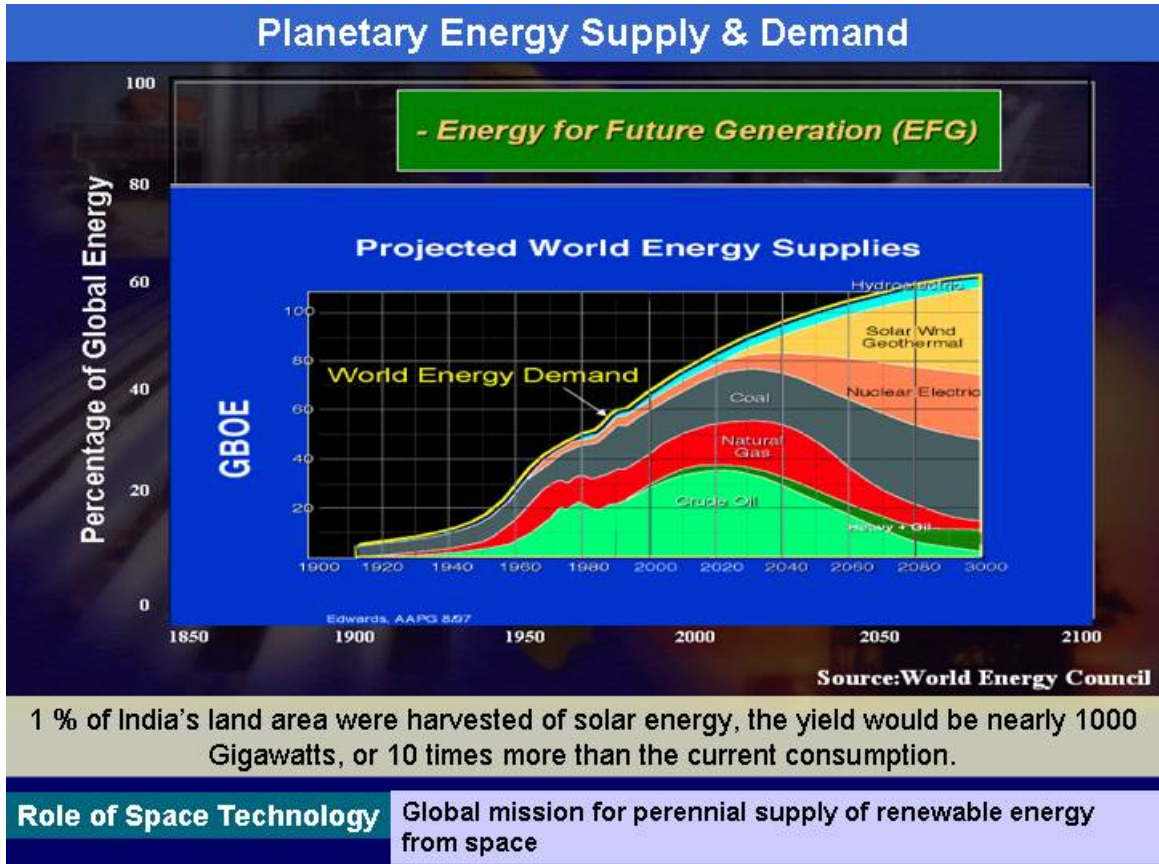


projected to be over 9 billion by 2050. The critical issues arising from this population growth are shortage of energy, shortage of water and increasing damage to the natural environment and ecology.

Planetary Energy Supply & Demand: Role of Space Technology

Civilization on earth will run out of fossil fuels in this Century. Oil reserves are on the verge of depletion, followed by

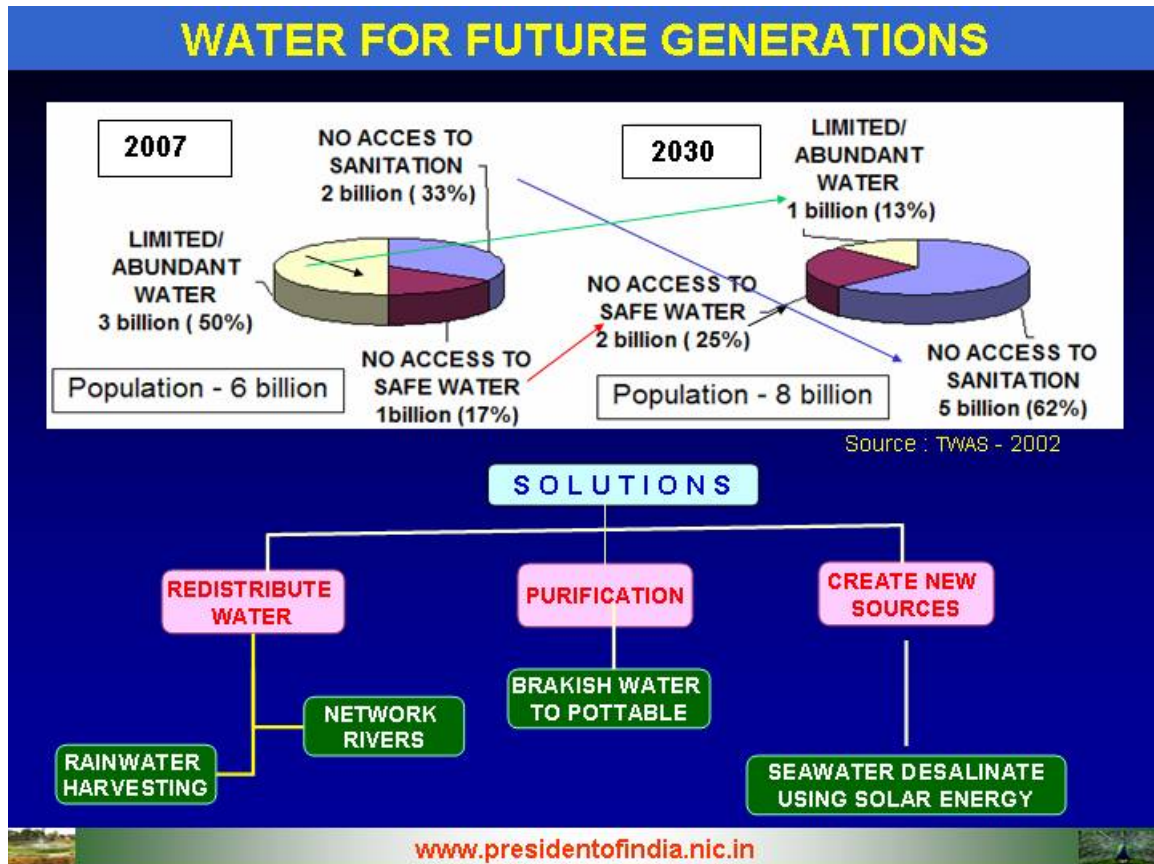
gas and finally coal. However, Solar energy is clean and



inexhaustible. For example, even if 1 % of India's land area were harvested of solar energy, the yield would be nearly 1000 Gigawatts, or 10 times more than the current consumption. However solar flux on earth is available for just 6-8 hours every day whereas incident radiation on space solar power station would be 24 hrs every day. What better vision can there be for the future of space exploration, than participating in a global mission for perennial supply of renewable energy from space?

Water for future generations

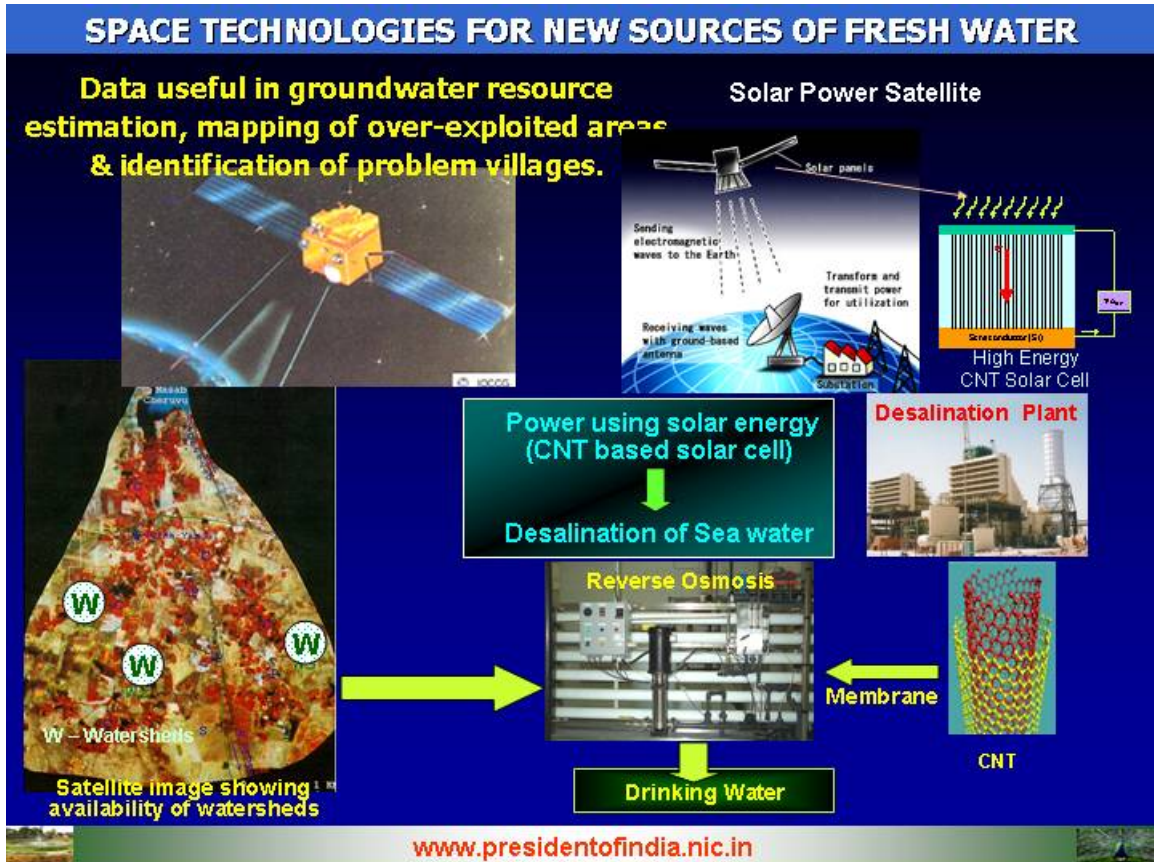
More than 70% of earth's surface is water; but only one



percent is available as fresh water for drinking purposes. By 2050 when the world population will exceed 9 billion, over 6 billion may be living under conditions of moderate, high and extreme water scarcity. There is a four-fold method towards providing safe and fresh drinking water for large population. The first is to re-distribute water supply; the second is to save and reduce demand for water; the third is to recycle used water supplies and the fourth is to find new sources of fresh water.

Space technologies for new sources of fresh water

In India earth observation satellites having unique resolution are being deployed for the survey of water bodies,

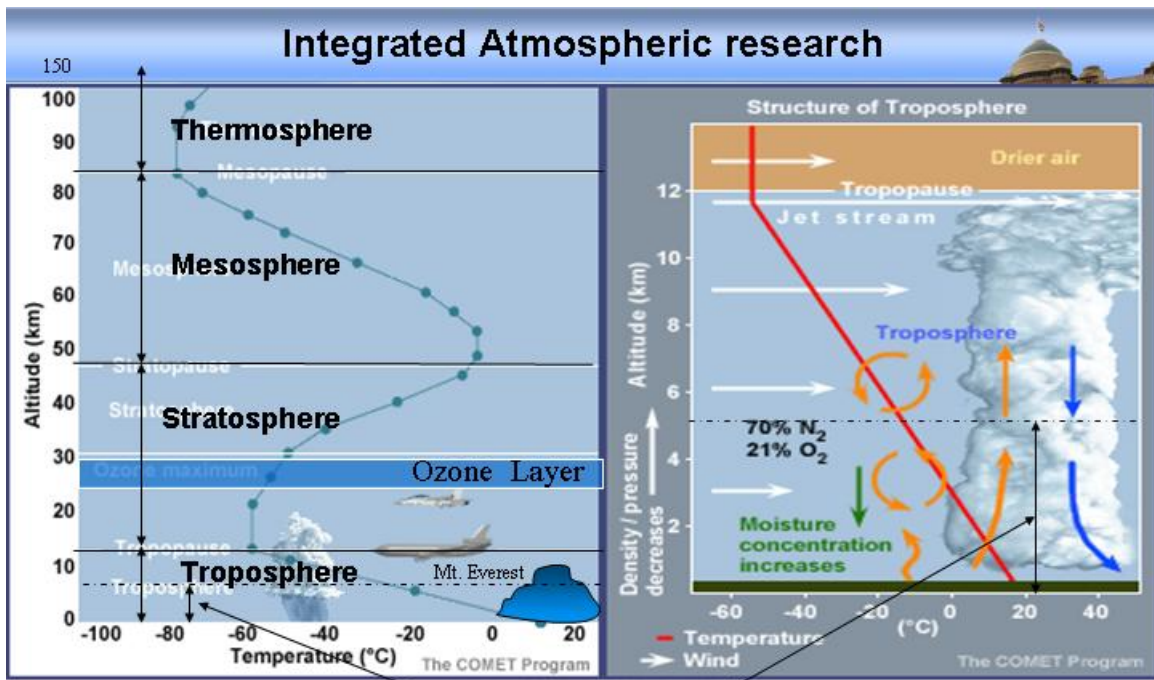


their continuous activation so that water storage during rainy season is maximized. Establishing new water supply sources using advanced reverse osmosis technologies for sea water desalination on large scales is a cost effective method of providing a new source of safe and fresh drinking water. However, desalination is an energy intensive process. Hence, the use of renewable energy through space solar satellites can bring down the cost of fresh water substantially. Space based solar power stations have six to fifteen times greater capital utilization than equivalent sized ground solar stations. Linking

Space solar power to reverse osmosis technology for large-scale drinking water supplies could be yet another major contribution of Space.

Integrated Atmospheric research

In the last four decades, space observations through



Breathable atmosphere

Atmosphere is indeed a great Aerial

Stratospheric cooling and Tropospheric warming

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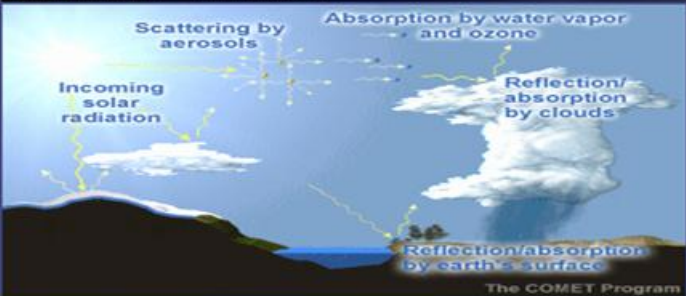
balloons, rocket experiments, satellites, recordings through sophisticated ground installations, experimental techniques and instrumentation have provided valuable integrated information on atmospheric processes. I asked myself what have we learnt from atmosphere during the last four decades. What information enriched us? How our atmosphere is dynamically changing in 20th century to now in the 21st

century? As you all are aware, Earth is experiencing both stratospheric cooling (due to ozone hole) and tropospheric warming (due to increased green house gases).

While the twentieth century has witnessed CO₂ content

What we have learned from our Atmospheric Research?

How our atmosphere dynamically changing in 20th century to now in the 21st century?




Earth is experiencing both stratospheric cooling (due to ozone hole) and troposphere warming (due to increased green house gases).

The dynamic changes occurring in mesosphere, stratosphere, ionosphere, with reference to climate change – needs to be explored

- 20th century CO₂ content in atmosphere was three parts per 10,000,
- Whereas the 21st century it is reported that CO₂ in atmosphere has already reached 6 to 10 parts per 10,000.
- This is equivalent to nearly 30 billion tones of carbon dioxide injection to the atmosphere every year.

Mission: Immediate adoption of energy independence through use of clean renewable sources of energy.




in atmosphere going upto three parts per 10,000, in the early part of 21st century we are already experiencing 6 to 10 parts per 10,000. This is equivalent to nearly 30 billion tones of carbon dioxide injection to the atmosphere every year. The solution for preventing further damage to the atmosphere would be immediate adoption of energy independence through use of clean renewable sources of energy.

Disaster Management

In many places in our planet, we experience severe disasters like earthquakes, tsunami, cyclone resulting in loss of life, loss of wealth and in some cases it destroys the decades of progress made by countries and their valuable civilizational heritage. India has earthquake problems periodically in certain regions. US, Japan, Turkey, Iran and many other countries also suffer due to earthquakes.


Earthquake/tsunami is a sub terrain phenomenon and

Disaster Management using Space Technology

DISASTER	STUDY	PREPAREDNESS		
Earthquakes	Mapping geological lineaments in prone areas and modeling	Geodynamic measurements of strain accumulation		
Volcanic eruptions	Topographic and land pattern and modeling	Precise detection / accurate measurement of gaseous emissions		

Space scientists of multiple nations should work together to use satellite deep penetration images to predict the earthquake or shock wave propagation.

Space technology can also be used for forecasting and modeling of volcanic eruptions, land slides, avalanche, flash floods, storm surge, hurricane and tornadoes.



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predicting this from space observations would be a great challenge. Space scientists of multiple nations should work together to use satellite deep penetration images to predict the

earthquake or shock wave propagation. Other possibilities are precise geodynamic measurement of strain accumulation by satellite to detect pre-slip, and electromagnetic phenomena prior to final rupture. The focus must be on earth quake forecasting with adequate warning so that the people can move to safer areas. Space technology can also be used for forecasting and modeling of volcanic eruptions, land slides, avalanche, flash floods, storm surge, hurricane and tornadoes.

Potentially Dangerous Asteroids

Space community has to keep monitoring the dynamics

Potentially Dangerous Asteroids

- Space community has to keep monitoring the dynamics of all potentially dangerous asteroids
- We should aim to deflect or destroy converging asteroid with the technology available with mankind

KEEPING AN EYE ON POTENTIALLY DANGEROUS ASTEROIDS

Diagram showing the solar system with Earth, Mars, Venus, and Mercury. Asteroid 1950DA is shown in an inset with the text: "Asteroid 1950DA (Arecibo radar image)".

DIAMETER - 1.1 KM NEAR SPHEROID
RENDEZVOUS - MAR 16, 2880
IMPACT PROBABILITY - 1 IN 300
EXTENSIVE DAMAGE EXPECTED

CAN THESE SCHEMES HELP ?

- IMPLANT A ROCKET ENGINE ON THE ASTEROID'S BODY AND DIVERT
- USE SOLAR SAIL SPACECRAFT TO IMPART SUN RAYS TO DEFLECT THE ASTEROIDS TO A DIFFERENT DIRECTION
- USE NUCLEAR / LASER / ANTI MATTER ENERGY FOR DISINTEGRATING THE DANGEROUS ASTEROID WHEN IT IS MILLIONS OF KILOMETERS AWAY FROM EARTH

SOURCE: JPL, NASA

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of all potentially dangerous asteroids. Asteroid 1950DA's rendezvous with earth is predicted to be on Mar 16, 2880. The

impact probability calculations initially indicated a serious condition of 1 in 300 which has to be continuously monitored. In such a crucial condition, we should aim to deflect or destroy this asteroid with the technology available with mankind.

Space Missions (2050)

Now, I would like to discuss with you certain specific priority areas in space technology and exploration.

Geosynchronous Equatorial Orbit (GEO) is a well utilized

Space Missions (2050)

Space Satellite Service Stations:
Lives of spacecraft are determined by component failures, capacity of fuel, internal energy systems and space environment.

It is essential to extend the life of satellites through in-orbit maintenance such as diagnosis, replacement, recharging, powering, refueling or de-boosting after use.

Creation of Space Satellite Service Stations for all the spacecraft in the GEO as a permanent international facility.

Future satellites and payloads have also to be designed with self healing capability and midlife maintenance.

<http://Science.nasa.gov>

NASA's TDRS-3 satellite is part of a fleet that keeps the agency in touch with orbiting spacecraft like the International Space Station (Illustration: NASA/MSFC)

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resource. The spacecraft orbiting in GEO are very high value resources. However, the life of these spacecraft are determined by component failure, capacity of fuel, internal energy systems

and space environment. While new design practices and technologies are constantly increasing the life of satellite, there is a requirement for extending the life of satellite through in-orbit maintenance such as diagnosis, replacement, recharging, powering, refueling or de-boosting after use. This calls for creation of **Space Satellite Service Stations** for all the spacecraft in the GEO as a permanent international facility. Future satellites and payloads have also to be designed with self healing capability and midlife maintenance.

Space Industrial revolution

Mankind's 21st. Century thrust into space would herald in the world's next industrial revolution, what might be termed

SPACE INDUSTRIAL REVOLUTION

Mankind's 21st Century thrust into space would herald in the world's next industrial revolution, what might be termed as the Space Industrial Revolution.

Possible drivers for a Space Industrial Revolution

- Man's quest for perennial sources of clean energy such as solar and other renewable energies and thermonuclear fusion.
- Helium 3 from Moon is seen as a valuable fuel for thermonuclear reactors.
- Mining in planets or asteroids
- Moon could become a potential transportation hub for interplanetary travel
- Moon has potential to become a "Telecommunications Hub" for interplanetary communications.
- Electromagnetic mass drivers powered by solar energy could provide low-cost transportation of lunar materials to space construction sites.

How would we create livable conditions on Mars?



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as the Space Industrial Revolution. This does not mean that the revolution will take place only in Space. What it essentially means is the creation of architectural and revolutionary changes leading to new space markets, systems and technologies on a planetary scale. Such a Space Industrial Revolution will be triggered by the following missions that can address all segments of global space community. What are the possible drivers for such a Space Industrial Revolution?

The first major factor will be man's quest for perennial sources of clean energy such as solar and other renewable energies and thermonuclear fusion. Helium 3 from Moon is seen as a valuable fuel for thermonuclear reactors.

Mining in planets or asteroids would need innovative methods for exploring, processing and transporting large quantities of rare materials to earth. Moon could become a potential transportation hub for interplanetary travel. The moon's sky is clear to waves of all frequencies. With interplanetary communication systems located on the far side, the moon would also shield these communication stations from the continuous radio emissions from the earth. Hence the moon has potential to become a "Telecommunications Hub" for interplanetary communications also.

The Moon also has other advantages as a source of construction materials for near Earth orbit. Its weak surface

gravity is only one-sixth as strong as Earth's. As a result, in combination with its small diameter, it takes less than five percent as much energy to boost materials from the lunar surface into orbit compared with the launch energy needed from Earth's surface into orbit. Electromagnetic mass drivers powered by solar energy could provide low-cost transportation of lunar materials to space construction sites.

Low gravity manufacturing holds tremendous promise for mankind in new materials and medicines. Studies also have shown that the needs of 12 workers could be met by a 16-meter diameter inflatable habitat. This would contain facilities for exercise, operations control, clean up, lab work, hydroponics gardening, a wardroom, private crew quarters, dust-removing devices for lunar surface work, an airlock, and lunar rover and lander vehicles.

Habitat at MARS: As my friend Prof UR Rao, former Chairman of ISRO says, space scientists are habituated to protecting systems against single point failures; so, in the longer term, creation of extra terrestrial habitat in MARS should be studied as fail safe mechanism for our problems on earth. How would we create livable conditions on Mars?

Moon-Based Solar Power Stations

Space solar power stations have been studied extensively during the past 30 to 40 years. However, non-availability of low cost, fully reusable space transportation has denied

mankind the benefit of space solar power stations in geostationary and other orbits.

Moon is the ideal environment for large-area solar

Lunar Solar Power Stations (LSP)

Moon-Based Solar Power Stations

Ideal environment for large area solar conversion

Technically and economically feasible to provide at least 100,000 Gigawatt of solar energy

Electric Power is independent of biosphere and environment friendly.

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Reference: A. Ignatiev, U. Of Houston

converters. The solar flux to the lunar surface is predicable and dependable. There is no air or water to degrade large-area thin film devices. The Moon is extremely quiet mechanically. It is devoid of weather, significant seismic activity, and biological processes that degrade terrestrial equipment. Solar collectors can be made that are unaffected by decades of exposure to solar cosmic rays and the solar wind. Sensitive circuitry and wiring can be buried under a few- to tens- of centimeters of lunar soil and completely protected against solar radiation, temperature extremes, and micrometeorites. Studies have also

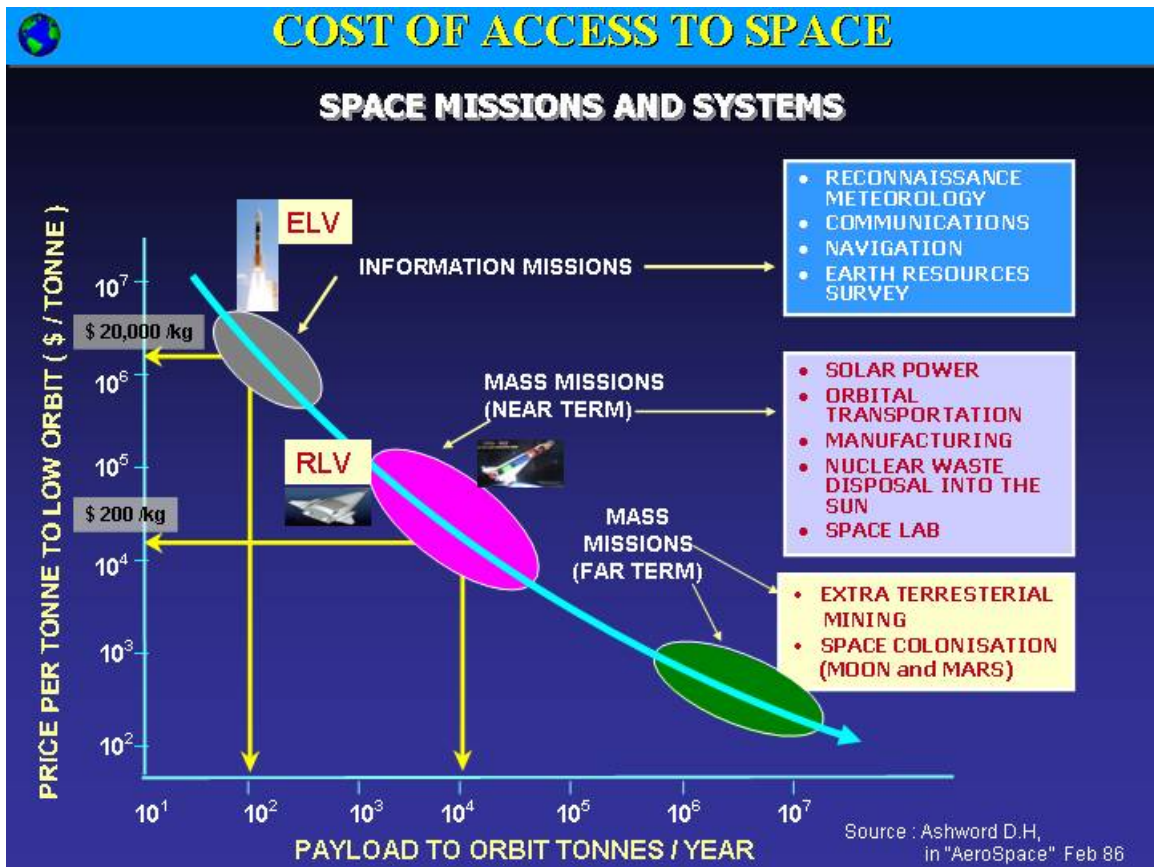
shown that it is technically and economically feasible to provide about 100,000 GWe of solar electric energy from facilities on the Moon.

If we have to achieve these along with the full potential of space benefits with current applications, there is one major problem we have to solve. That is, how are we going to make the cost of access to space affordable?. The question hinges on creating space markets and developing cutting edge technologies to make low cost of access to space a reality. The future of the space industrial revolution created by a space exploration initiative would hinge greatly on new means of safe, affordable access to near earth space, as the platform for deep space exploration.

Cost of access to Space

It is becoming clear that present level of markets for communication, are getting saturated. Optical fiber technologies are providing large band width for terrestrial communications. The life of satellites in orbit having increased to 12-15 years, along with advanced technology with higher bandwidth for transponders have further reduced the demand for telecommunication satellites. The current cost of access to space for information missions such as telecommunication, remote sensing and navigation varies from US \$ 10000 to US \$ 20000 per kg in low earth orbit. As mentioned, this market is saturated. Hence the future of space exploration requires that

space industry moves out of the present era of information



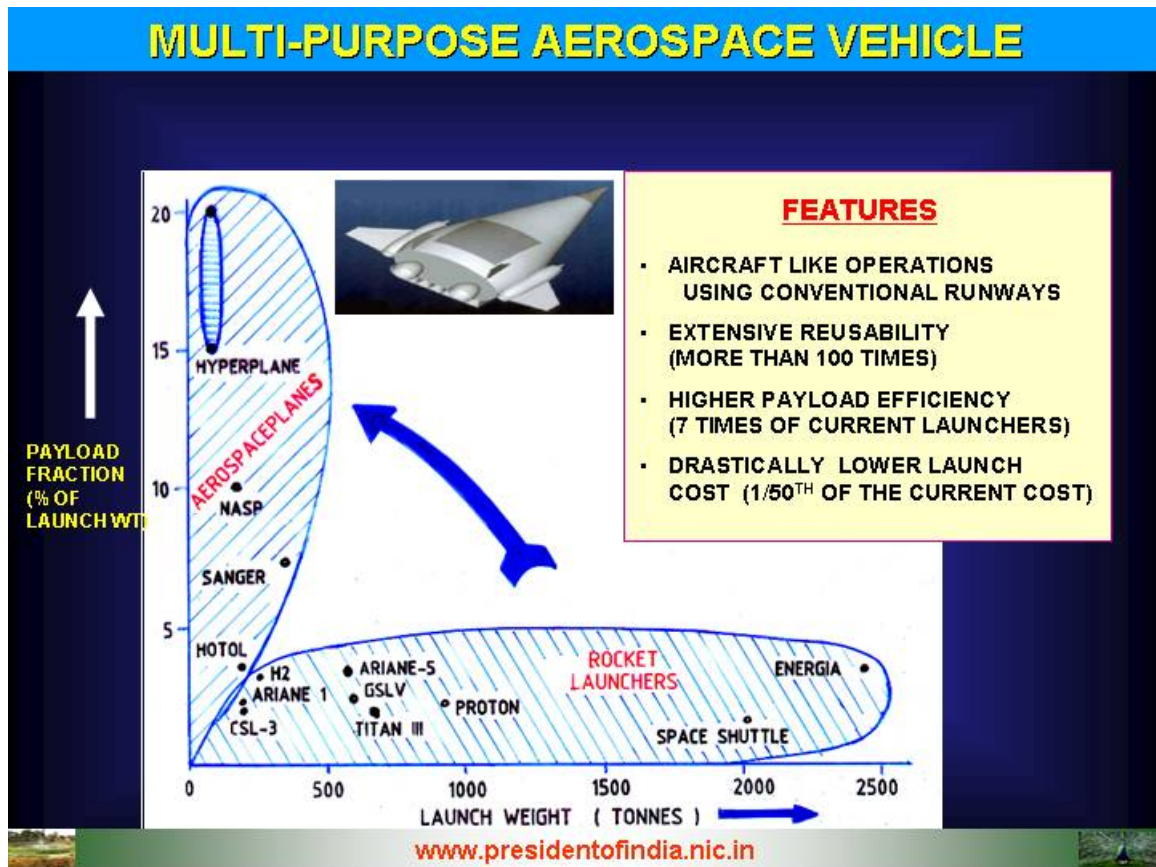
collection missions, into an era of mass missions. There is a need to reduce the cost of access by two to three orders of magnitude. It is only by such reduction in cost of access to space that mankind can hope to harvest the benefits of space exploration by 2050.

Affordable, Low Cost Space Transportation for Space Exploration Missions

The payload fraction of current generation expendable launch vehicles in the world does not exceed 1 or 2% of the launch weight. Thus to put one or two tonnes in space

requires more than one hundred tonnes of launch mass most of which-nearly 70% - is oxygen.

Such gigantic rocket based space transportation systems,



with marginal payload fractions, are wholly uneconomical for carrying out mass missions and to carry freight and men to and from the moon.

Studies in India have shown that the greatest economy through the highest payload fractions are obtained when fully reusable space transportation systems are designed which carry no oxidizer at launch, but gather liquid oxygen while the spacecraft ascends directly from earth to orbit in a single stage. These studies in India suggest that a “aerobic” space transportation vehicle can indeed have a 15% payload fraction

for a launch weight of 270 tonnes. This type of space plane has the potential to increase the payload fraction to 30% for higher take off weight. For such heavy lift space planes, with 10 times the payload fraction and 100 times reuse, the cost of payload in orbit can be reduced dramatically by several orders of magnitude lower than the cost of access to space with expandable launch vehicles.

While space industrialization and space exploration will expand initially using the current generation launch vehicles, the real value of space exploration for human advancement will occur only when mankind builds fully reusable space transportation systems with very high payload efficiencies. This will become available when the technology of oxygen liquefaction in high-speed flight in earth's atmosphere is mastered. This technology will also be useful for mass collection from the atmosphere of other planets at a later stage in space exploration.

Maintaining Peace in Space

We must recognize the necessity for the world's Space community to avoid terrestrial geo-political conflict to be drawn into outer space, thus threatening the space assets belonging to all mankind. This leads on to the need for **an International Space Force** made up of all nations wishing to participate and contribute to protect world space assets in a

Maintaining Peace in Space

World's Space community should avoid terrestrial geo-political conflict to be drawn into outer space, thus threatening the space assets belonging to all mankind

An International Space Force

Made up of all nations wishing to participate and contribute to protect world space assets in a manner which will enable peaceful exploitation of space on a global cooperative basis.

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manner which will enable peaceful exploitation of space on a global cooperative basis.

Challenges before the Space Research Community

Space research has many challenges that can stimulate intellectually alert and young minds. But the attraction for the youth of today to take up science or technology as a career option has many lucrative diversions. The future of space research cannot be as green as it was in the last fifty years, if we the space scientists do not ensure a steady stream of youngsters embracing the discipline. For this to happen, the scientists of today must come up with a steady fountain of ideas that would attract the students. This is a great

challenge. I would be happy if the great minds gathered here, articulate to the young, the space vision for the next fifty years and challenges presented and discussed in the Symposium. Space does not have geographic borders and why should those who pursue space research have any borders?

Space Missions 2050

I would like to suggest the following space missions for the consideration by the space community assembled here to be fully accomplished before the year 2050.

1. Evolving a **Global Strategic Plan** for space industrialization so as to create

Space Missions for the 21st Century

- **Evolving a Global Strategic Plan for space industrialization so as to create large scale markets and advanced space systems and technologies, for clean energy, drinking water, tele-education, tele-medicine, communications, resource management and science; and for undertaking planetary exploration mission.**

The slide contains three diagrams: 1. 'Tele-education Delivery System' showing a satellite in orbit connected to a 'University Studio' on the ground and 'Virtual Tele-EDU' on a laptop. 2. 'Tele-medicine' showing a 'Patient's end' with a 'Referral Hospital' and 'Video Conferencing' connected to an 'Expert Doctor's end' with 'Health specialist centers' and 'Panel of Doctors'. 3. A photograph of a modern building with a solar panel array on its roof.

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large scale markets and advanced space systems and technologies, for clean energy, drinking water, tele-

education, tele-medicine, communications, resource management and science; and for undertaking planetary exploration mission.

2. Implementing a **Global Partnership Mission** in advanced

Space Missions for the 21st Century

- **Implementing a Global Partnership Mission** in advanced space transportation, charged with the goal of reducing the cost of access to space by two orders of magnitude to US \$ 200 per kg. using identified core competencies, responsibilities and equitable funding by partners, encouraging innovation and new concepts through two parallel international teams

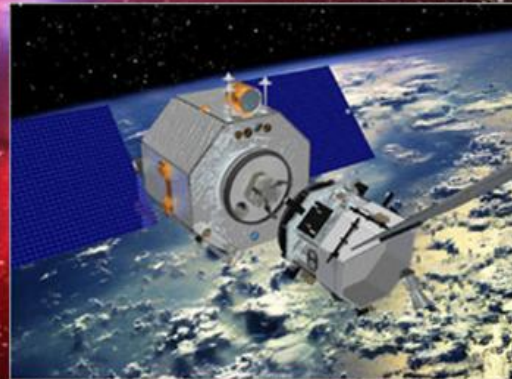
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space transportation, charged with the goal of reducing the cost of access to space by two orders of magnitude to US \$ 200 per kg. using identified core competencies, responsibilities and equitable funding by partners, encouraging innovation and new concepts through two parallel international teams

3. Developing and deploying in-orbit Space Satellite Service

Space Missions for the 21st Century

- Developing and deploying in-orbit Space Satellite Service Stations for enhancing the life of spacecraft in GEO as a permanent international facility.



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Stations for enhancing the life of spacecraft in GEO as a permanent international facility.

Conclusion

Since the dawn of space era in 1957, space science and technology has enhanced man's knowledge of earth, atmosphere and outer space. It has improved the quality of life of human race. Our space vision to the next fifty years has to consolidate these benefits and expand them further to address crucial issues faced by humanity in energy, environment, water and minerals. Above all, we have to keep upper most in our mind the need for an alternate habitat for

the human race in our solar system. The crucial mission for the global space community is to realize a dramatic reduction in the cost of access to space.

To meet this challenge the scientific community can draw the inspiration from the saying of Maharishi Patanjali, about 2,500 years ago "When you are inspired by some great purpose, some extraordinary project, all your thoughts break their bounds. Your mind transcends limitations, your consciousness expands in every direction, and you find yourself in a new, great and wonderful world. Dormant forces, faculties and talents come alive, and you discover yourself to be a greater person by far than you ever dreamt yourself to be."

I wish you all success for this Symposium on "The Future of Space Exploration: Solutions to Earthly Problems"

May God bless you.