LEAD PAPER

AEROSPACE TRANSPORTATION SYSTEMS FOR 2050

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"When you wish upon a star,
Makes no difference who you are
Anything your heart desires
Will come to you"

I am indeed delighted to participate in this International Conference on High Speed Trans-atmospheric Air and Space Transportation organized jointly by the Aeronautical and Astronautical Societies of India. I had the pleasure of working with many of you from R and D Organizations, academic institutions, public and private sector industries. My greetings to all of you. A special welcome to the participants from abroad. I believe that the 21st Century aerospace ventures will be more global, in view of unique space missions, technological complexities, high costs and risks. When I am with you, I would like to discuss the topic, Aerospace Transportation Systems for 2050.

Recent National Aerospace Events

When I see in front of me, the confluence of Aeronautical and Astronautical communities, a number of major recent accomplishments by Indian institutions in these fields vividly come to my mind. On 10th January 2007, ISROs Polar Satellite Launch Vehicle (PSLV-C7) (Fig.1) successfully launched four satellites Indias CARTOSAT-2 and Space capsule Recovery Experiment (SRE-1) (Fig.2), Indonesias LAPAN-TUBSAT and Argentinas PEHUENSAT-1 into a 635 km high polar orbit. On 22nd January 2007, the Space Capsule was brought back from space in a controlled and safe manner to a designated point on Earth. This is an important step towards manned missions and for our future operations in industrialization of space, Tejas - Light Combat Aircraft (Fig.3) has undergone nearly 700 flight tests in six aircrafts, one of them belongs to the Limited Series Production (LSP) class. The performance and maneuver of Tejas in this years Air Show at Bangalore has led aircraft manufacturers to reckon Tejas as a competitive combat supersonic aircraft Indian 14 seater aircraft SARAS (Fig.4) was also displayed at the air show. In November of 2006, India successfully conducted the PADE (Prithvi Air Defence Exercise) in which an Anti-ballistic missile, called the Exoatmoshperic interceptor system intercepted a Prithvi-I ballistic missile. On 12th April 2007, Intermediate Range Ballistic Missile Agni-III (Fig.5) was successfully launched by DRDO paving the way for long range missions. On 22nd April 2007, the Army version of the Brahmos (Fig.6) supersonic cruise missile was handed over to the Indian Army after successful completion of the flight evaluation by the users. On 23rd April 2007, the Indian PSLV-C8 placed the Italian Scientific Satellite Agile into a precise circular orbit of 550 km graduating ISRO to a commercial system deliverer for international market. In an integrated way if you see the aerospace science it reveals that aerospace community in India have reached maturity in realizing complex technology products and missions through sustained efforts and have the ability to meet the stringent international standards in performance and cost and competitiveness. Now let me briefly touch upon some challenging future missions.

Future National Missions

The aeronautical community is ready with a roadmap for a 150 Seater Civilian Aircraft as a public private partnership management methodologies (Fig.7). ISRO has initiated programmes for a reusable two stage to orbit launch demonstrator and air breathing propulsion modules. Work has started on the feasibility studies for a manned mission to low earth orbit by 2014. DRDO has goals to develop stealth air crafts and long range reusable hypersonic cruise missiles. In the next two decades, I visualize the integration of multiple technologies of supersonic aircraft, missiles and spacecraft to transform into an unmanned supersonic long-range and low radar cross section aircraft replacing manned fighter aircraft. The academic institutions and the public and private sector industries have large roles in successful accomplishments of these national initiatives. Particularly the current production activities in aggregate and total systems will move over to industries.

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The World Aero Space Capabilities (Figs. 8-12)

Mankind has acquired tremendous capabilities in aircrafts, both civilian and military. The aircraft industry has also become a strategic, viable and competitive business proposition. However the quest for excellence continues with targets of covering end-to-end journey of the world in fewer hours. Advances in the transatmospheric propulsion research assumes great significance for this. As far as space is concerned, today the capability exists for design, development and deployment of any type of launch vehicle, any type of spacecraft, any type of instrumentation and any type of launch complex for societal and exploration missions. Mankind has also progressed challenging inter-planetary missions and also orbited space stations. However the space development is constrained by the current large costs of access to space. While I visualize in another 50 to 75 years, an industrial complex on the Moon and a beginning of human habitat at mars emerging, one of the major driving factor will be the low cost of access to space, which would require certain disruptive technologies to emerge. Can the synergy of aeronautical and space disciplines do this magic? How to make it happen? You are the people who can do this.

The vision of various space faring nations as well as discussion in various international forums by space experts suggest that space missions beyond earth are vital for sustaining the spirit of deep space exploration and for build up of space infrastructure leading to space industrialization. Such missions would include bringing minerals and other special materials from Moon, Asteroids and Mars. Such missions would also enable building of infrastructure for solar power generation, building industrial complexes on the Moon and initiating human habitat on Mars. These missions would call for large mass flow into space. 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.

Space Vision 2050

With the background and strength of technological progress in Aerospace systems, I have suggested to the world space community to evolve Space Vision 2050 (Fig.13) with the following three components :

1. Space exploration and current application missions
2. Comprehensive space security
3. Large Scale Societal missions and Low cost access to space.

World Space Vision would enhance the quality of human life, inspire the spirit of space exploration, expand the horizons of knowledge and ensure space security for all nations of the world. I have also suggested creation of World Space Council (Fig.14) which could oversee the planning and implementation of exploration, space security and societal missions. Such a unified approach will enable the world to see a quantum jump in the progress in space science and technology for the benefit of all the nations of the world. These details are available in my website : www.presidentofindia.nic.in

As I am with the aerospace community, I would like to focus on the third component of the world space vision on large societal missions and low cost access to space.

Low Cost Access to Space (Figs 15-19)

As you are all aware, 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 tones in space requires more than one hundred tones of launch weight, most of which-nearly 70% - is oxygen. Such 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. There is definitely a need for all the countries to work together to develop reusable launch vehicles which can bring down the cost of launch from the present US $ 20,000 per kg to US $ 200 per kg.

Aeronautics and Space

Nature Partners for progress towards Reduction of Cost of Access to Space (Fig.20). High speed air and space transportation in collaboration can lead to a step-jump in the basic goal for reduction in cost of access to space. Space transportation systems that are fully reusable 100 to 500 times enable the cost of access to space reduced substantially. The aeronautical community has experience in designing air-breathing engines that have very high fuel efficiency. They can partner the space community to design reusable launch vehicles that perform like an aircraft while flying in the atmosphere, and like a rocket while flying in the outer space. Further, partnership in designing a multi-role aerospace vehicle would bring down the development costs substantially. While cost effective space transportation system will bring in new applications to absorb development costs, high speed transcontinental air transportation systems will become commercially viable.

Space Transportation Systems with High Payload Fraction

Several designs of aerospace transportation systems (Fig.21) have been carried out in many countries, like NASP in the USA and Hotel in the UK. These designs reported payload fractions of 5% and called for large, heavy launch vehicles weighing hundreds of tones, which could not be fully ground tested, and hence were abandoned as too risky to develop. Studies in India have shown that the smallest size reusable space launch vehicle, weighing about 25-30 tonnes can be developed with high payload fractions when designed with no oxidizer at launch, but gathers air, liquefies air and then separates out the liquid oxygen for onboard storage while the spacecraft ascends directly from earth to orbit. These studies in India suggest that an aerobic space transportation vehicle can have a 15% payload fraction for a launch weight of 270 tonnes.

This type of trans-atmospheric space transportation system 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 from $20,000 per kg to about $200 per kg (Fig.22).

India is already working to evolve innovative design concepts for both small as well as large payloads into space. Both single and two-stage to orbit RLV concepts are being examined. The goal here is to reduce the cost of access to Space by one or two orders of magnitude. Even a small scientific breakthrough, for example, in air breathing propulsion systems may lead to a revolution in Space Transportation. The Space community have a huge stake in such breakthrough research in advanced inter-disciplinary and inter-institutional collaboration.

Critical Technologies for Aerospace Transportation Systems

The real value of future societal space missions, like energy from space and seawater desalination using space solar power can take place only, when mankind builds fully reusable space transportation systems (Fig.23) with very high payload efficiencies. Several technologies are critical and need to be developed.

In-Flight Air Collection and Oxygen Liquefaction Technology

The technology of oxygen liquefaction in high-speed flight in earths atmosphere is a very critical technological building block and needs to be mastered. This technology will also be useful for collection of atmospheric constituents of other planets at a later stage in space exploration. This system consists of an air-liquefier made up of compact, lightweight cryogenic [hydrogen] cross-flow heat exchangers and liquid oxygen vortex or hi-gee separators.

This system is to be built at small-scale level and comprehensively ground tested over the entire proposed flight regime. Mach 5.0 to Mach 8.0. Such hot air facilities already exist in India and other parts of the world, and they are important to qualify this critical technology as well as the scramjet engines.

Ram/Scramjet Engines

This another technology that has recently been flight tested and validated up to Mach 10 in the US Flight Technology Demonstrator X-43 (Fig.24). They have been designed and developed both in the US and Russia since 1960s. India has also designed and tested scramjet engines, both kerosene fueled and hydrogen fueled, on ground test facilities.

These sub-scale tests need to be extended to flight testing on demonstrators that can comprehensively validate all critical technologies for advanced space transportation systems.

Ascent Turbojet/Turbofan Ramjet Engines (Fig.25)

The thrust-to-weight ratio of conventional gas turbine engines is about 6-8. However, air breathing ascent engines for space transportation will require very lightweight gas turbine engines, with a thrust-to-weight ratio of about 14-16, and capable of operating on hydrogen fuel. Such light weight gas turbine engines are currently designed for vertical lift aircraft (VTOL) but would need to be upgraded for hydrogen fuel.

Advanced Light Weight High Temperature Materials (Fig.26)

A major challenge would be in the area of hot-structure airframe materials. The highest temperatures during the ascent flight to orbit are the nose cap and leading edges of the wing. New high temperature, lightweight high strength materials that were not available when the Space Shuttle was designed in 1960s, have emerged over the last two decades. Carbon-composites, Silicon Carbide/Silicon Carbide Ceramic Matrix Composites are suggested for the highest temperature airframe components; and advances in nano-materials would son result in a step-jump in the state-of-art in high temperature materials technology. The rest of the airframe would need to be durable, all metal construction, using advanced titanium and nickel-chromium alloys.

Multi-Role System Architecture Required (Fig.27)

Keeping in mind these new technologies that need to be developed, and the wide range of commonality in technology that exists, between high speed air and space transportation, it is essential that all these technologies are flight tested comprehensively over the entire speed and height regimes that are common to the role of trans-atmospheric vehicles in air and space transportation.

The multi-role architecture flight test vehicle designed would have to comprehensively demonstrate in flight, all the special attributes of fully reusable space transportation for safe, affordable flight to space, as well as those attributes related to intercontinental passenger aviation.

Conclusion

Aerospace Mission (Fig.28)

Keeping the perspectives of world space vision in mind and the unique technologies and systems that can be realized by the combined power of the world aeronautical and space community. I urge the international experts to work on the following aerospace mission using the core competence of partnering nations.

To design and develop a single-stage-to-orbit fully reusable, safe, affordable aerobic space transportation system with a take off weight of 275 tonnes for a 25-35 tonnes payload optimized for launching multi-purpose mission including new orbiting space stations, space habitat and Space Solar Power Station (Fig.29). I presenting a configuration which has been discussed by the aerospace community. It can bring down the cost of access to space to US $ 2,000 per kg. From the existing US $ 20,000 per kg. The specialists here may like to debate this configuration for taking it up as a global partnership development mission. This can be the global aerospace mission for the two decades (Fig.30).

The delegates and participants present here represent countries that have brought about the incredible space revolution in the last 50 years. Here is an opportunity for the entire world aerospace community to bring about a revolution in air and space transportation by developing a single stage orbit reusable vehicle. This should call for innovative partnership among nations overcoming technological and other barriers which may appear impossible today. Such a challenge initiated will make this conference historic. I can assure you that India will be a partner in this effort.

With these words, I inaugurate the International Conference on High Speed Trans-atmospheric Air and Space Transportation. I would be glad to receive the conference recommendations. My best wishes to all the participants of this conference for success in their deliberations.

May God bless you.

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