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INDIAN SPACE – TOWARDS A "NATIONAL ECO-SYSTEM" FOR FUTURE SPACE ACTIVITIES

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ABSTRACT

The vision of Indian Space was enunciated (in early 1970) by Dr. Vikram Sarabhai - who envisioned the development of Indian space capability for benefit to society and meeting national development goals. The programme is founded on self-reliance and indigenous capability development. Indian space activities have made tremendous progress in the past 50 years with successful satellites that have contributed to national development, science endeavor and technological capability. Indian communication satellites in INSAT; Indian EO satellites in IRS; Indian positioning satellites in IRNSS; various science missions; Indian launch vehicles in the PSLV and GSLV; mission to Moon - Chandrayaan-1; a mission to Mars have paved the way for advanced successful development of space capability in India. Successful foray into global markets have also been achieved. All this has enabled a high-class end-to-end systemic capability of design, development and operations of Indian space assets and applications.

Space based services have created a huge and growing user base - which is a unique opportunity for developing space industry and creating high technology jobs. Changing policy environment in India - favoring deregulation; investments and thrusted privatization; impetus to manufacturing; intensive co-operation etc are generating a strong market drive for space activities in India. Indian space needs to orient for a quantum jump in technological growth, adopt organisational models that will ensure economic efficiency and position a vibrant private sector. National consequences for Indian human space-flight and planetary exploration programme; quest for a larger share and role in global space market; strategies to deal with changing political and economic environments and focused imperatives of international cooperation need strategic focus.

National Institute of Advanced Studies (NIAS) has taken up a policy-research study to determine a futuristic Indian Space Policy - a comprehensive "Indian Space Policy" which addresses the long-term strategy of Indian space and promotes a holistic Indian Space enterprise - alignment to national goals of industrialization and development; evolving a vibrant eco-system of government-private sector partnership that assures operational space services (communications, EO and navigation etc) and advanced technology development; national commitment for \long-term' human space-flight and planetary exploration mission investments and a strategic international cooperation regime. NIAS has undertaken wide consultation with Indian space professionals and is organising a National Space Policy Workshop - all of which will be assimilated into the Policy document. The paper presents the outcome of this study and the future Indian Space Policy.

I. INTRODUCTION

(This study is a continuation of the suo-moto study initiated by NIAS in 2014 on Indian Space. The elements of this study have been documented and incorporated based on articulations made by various Indian space experts in recent times. This analysis by NIAS in assessing the past achievements of Indian Space and identifying challenges ahead clearly indicates the line of thought that has to emerge for Indian Space in coming decades to maintain performance, excellence and success. NIAS hopes that creating such thought-material will be useful in crafting a futuristic Indian Space Policy.)

Outer Space has been a source of curiosity and inspiration for human kind. As an abode of an ancient civilization and rich culture, India had made some of the earliest and outstanding contributions to the scientific method and thought. These can be seen in many fields such as astronomy, mathematics, and medicine and plant sciences, as revealed through a vast collection of literature as well as archaeological findings. Ever since history records are available, venturing into "other worlds" as seen by many thinkers

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has been an imperative of discovery, knowledge, curiosity and also for long term human survival - it is not for mere satiation of our innate spirit of adventure or natural drive for exploration but it is to discharge a basic responsibility that we owe to our species.

Reflecting on the beginnings of space endeavors, however, it is not surprising to see that the origins of space activities does not owe to the utilitarian or scientific goals but they were born and grown in the backdrop of military competition. What started as a competition for military superiority between two super powers then - is now transformed today into multi-dimensional endeavors of large number of state-actors, both from the government and private sector, impacting many of the social, economic, scientific, security and economic dimensions of global human society. In the past 50-60 years, there has been phenomenal advances in the technologies and applications of Space. Space has become a part of daily life for a majority of the citizens of the globe. The spread of space activities, though uneven across the world, the depth of technological advancement has been phenomenal.

Space systems have emerged as critical infrastructures both at national and international levels. They contribute to national (and international security); day-to-day communications of people; TV broadcasting across the globe; synoptic weather observations; natural resources management – especially, crops, water, oceans and atmosphere; societal good – city management, infrastructure development; disaster management and monitoring; environmental monitoring; precision positioning anywhere on the globe; scientific knowledge pursuit and going beyond frontiers to deep space.

Within the above global scenario, it is significant to note that the early inspiration for the Indian space programme came not from any military objectives, but from the interests of a large scientific community who were actively engaged in research programmes related to geophysics and astrophysics. These early space efforts owe much to the vision given by Dr. Vikram Sarabhai which is extraordinary for its realism and pragmatism and unique for its deep insights into the socio-economic context of the country. The mantra of self reliance that he gave became the life current that enabled the Indian program to overcome numerous challenges in learning and experimenting and operationalising many new technologies. The early emphasis on development of systemic capability, which implied careful assessment of alternatives, and, developing an end to end competence ranging from the design of various complex systems to their development, testing, and deployment in space, operations and applications. Dr Sarabhai, and later Dr Satish Dhawan – yet another doyen of Indian Space, instilled user-involvement and consultation among various stakeholders as integral to the process of making detailed assessment of space needs, alternate methods and multi-organisational engagements for the programs envisaged through a series of steps of experimentation, analysis and simulation and duly factoring in the socio-economic context of the country.

II. INDIAN SPACE PROGRAMME – A NATIONAL SYSTEM

Over the past 45+ years, Indian space program has evolved into a national SYSTEM that came about in three distinct phases:

- **Beginnings**: The proof of concept demonstrations exemplified by the Satellite Instructional Television Experiment (SITE), the Satellite Telecommunications Experimental Project (STEP), and use of Landsat satellite data for natural resource management applications. The space segment was procured with international cooperation. By early 1970s, India was on its way to develop its first satellite – Aryabhata and started the "grand plan" of an indigenous end-to-end space technology development capability.
- The **experimental phase** saw the development of an end-to-end experience in the realization of space systems - experimental earth observation satellites like Bhaskara I and Bhaskara II; India's first experimental geostationary satellite APPLE and the initial space launch vehicles such as SLV-3 and ASLV characterise this phase. It facilitated competence building at the core level. Thus, by late 1970s and in 1980s, India invested considerably in building laboratories and facilities and also initiated a 3-pronged programme – Indian communication satellites in INSAT; Indian EO satellites in IRS and Indian launch vehicle programme through the Polar and Geo-synchronous launch vehicles.
- The **operational phase** was based on systems evaluation of alternate approaches to arrive at the most optimal space solutions; decide on exercising buy or build options for space assets; parallel indigenous development plan to achieve self-reliance goals in space technology. This phase resulted in establishment of National Space Systems such as (i) Indian National Satellites (INSATs) / GSATs for communications, broadcasting and weather observations (ii) Indian Remote Sensing Satellite Series and (iii) Polar satellite Launch Vehicle, PSLV - all examples of

operational space systems that have to meet stringent operational service performance criteria.

By early 2000, India had achieved a technological maturity of space systems and utilisation and this challenged it to envision missions to far-away Moon and thus came about Chandrayaan-1 – which originally started (in 2000) from a simple question "Can we go to the Moon?". Yet another aspect that emerged in mid 1990s and early 2000s was forays of Indian space products into the global market place – through Antrix Corporation which marketed Indian space capabilities globally and thereby capitalizing revenue models for Indian space. Soon by 2002, India also started planning for its own Positioning Satellites systems in Indian Regional Navigational Satellite System (IRNSS).

In 2011, ISRO made foray to Mars in the 2013 orbit-window for Mars. The Mars Orbiter Mission (MOM) was successfully launched in November, 2013 and on September 24, 2014, MOM was manoeuvred successfully to enter into Mars orbit and starts its experiments of imaging and measurements. MOM established the fact that India can successfully undertake long-duration planetary missions.

As of 2015, a cumulative budget of about INR 930 billion has been formally allocated in 40 years of eight 5-yr plans by Indian government. However, as against the committed allocations, the actual utilisation has been INR 543 billion. Approval for 200 missions has been accorded by Indian government but 124 missions have been accomplished - out of which 14 missions have been "declared" failures. Global commercial operations of Indian space in 52 commercial/foreign satellites on its PSLV; sale of IRS images and value-addition services and, more lucratively, transponder lease business in India are estimated to have resulted in revenue earnings of about INR 100 billion over the past 20 years, although only a part of the capacity created was available to the commercial activity.

II I Present scenario assessment

Presently, in the 12th Five Year Plan (2012-2017)[1], Indian Government has allocated INR 39 billion and has approved 58 missions over the 5 years period (which includes 33 satellite missions for national needs). As per the 12th Plan, India aims to make forays into heavy communications satellites, advanced EO and weather satellites, achieving operational status of geo-orbit launch systems, advanced missions for exploration of Mars, lander on Moon and IRNSS constellation and studies for human space-flight programme.

As of date (which is in 3rd year of the 5 year period, India has accomplished 23 of the approved 58 missions – less than half-way stage.

Most of the developments and manufacturing till now were organised from ISRO units of about 16000 strong expert-force complemented by contract-mode industry-interfaces – which has till now helped in the overall development process for Indian Space.

In a recently articulated statement by Chairman, ISRO, the coming times was towards "…..developing heavy lift launchers, reusable launch vehicles, cryogenic engines for low cost access to space and use of composite materials for space applications" AND ".. aim is to be future-ready to maintain an edge in technology .. and enhance them"[2]

There are challenges that have become apparent:

- **A sustained and operational GTO space access system with a fully operational GSLV**: Current space access capability of India is limited to PSLV and still-to-be-operational GSLV – taking about 2.5t into sun-synchronous/geo-synchronous transfer orbits using its PSLV. India had challenges because of failures of GSLV – though the indigenous cryogenic engine based GSLV has just recently been test-flown in 2015 successfully. How quickly India can get its GSLV to place 3-4t in GTO operational in the national and global market-place is critical – for, non-availability of indigenous operational GTO access system does drain the Indian ex-chequer for availing high-cost global geo-launch systems for its large number of communications and meteorological satellites. A non-operational GSLV is not just impacting public fund usage, but India seems to get restricted in developing indigenous large-weight class of satellites – in the absence of its own geo-launcher (if India wants to launch more than 2to2.5t geo-satellites, it has to depend upon global launch services OR restrict its communication satellites in <2.5t so as to be amenable to PSLV class launch).
- **Next-generation robust and sustained multi-level space access capacity:** Looking ahead of the PSLV and GSLV, India will need to develop advanced launch capability - reduced number of stages to improve cost performance; semi-cryogenic propulsion improving safety and cost factors and also increase geo stationary payload capacity to 6t and 10t- thereby giving the nation a capability to embark upon more ambitious planetary missions as also an ability to build a space station / habitat module in Low Earth Orbit;

develop a reusable launch vehicle which can deliver men and materials to space and then return back to earth for refurbishment, refuelling to embark upon next mission; technology for sub-orbital trans- atmospheric transportation systems. Thinking for an aerospace plane may also be required as a technology development for long-term future.

- **Satellite communications – large social and commercial services**. Yet another challenge that faces India even now is the gap in quick availability of satellite communication transponders that has started stifling the service segment of DTH, social broadcasting, data communications. The market size of television and entertainment service industry which directly depend upon space infrastructure is presently estimated about INR 250 billion per annum and growing at a rate faster than 10% due to increasing DTH and pay TV penetration, growth in channels as well as increasing trend of HD channels. The demand for satellite capacity in the current and near future scenario, the industry projections indicate more than doubling of the demand for satellite transponders in a few years, from a level of 104 in 2012 to 276 in 2017[3]. Bridging the present gap in transponder availability against demand requires more than doubling of capacity and this is a major challenge that is impacting national economy and growth.
- **Advanced Satellite Communications technology**: Satellite communications technology needs to expand in newer areas and with newer methods (like Hybrid Satellite-Terrestrial Network system, Sensor Networks; High Capacity Satellite Links - Ka-band; large class Ku-satellites; advances in modulation techniques, spot beam-based geosynchronous and medium earth orbit High Throughput Satellite (HTS) technologies and Internet applications; enhanced mobility services with aeronautical and maritime applications; Machine to Machine (M2M) satellite applications; emerging ultra HD technologies; and electric propulsion etc) – for these newer areas need to be developed to meet the multi-farious social broadcasting needs across languages/states and also for commercial enterprises. Already delayed, this needs to be quickly done to fill the technology gap.
- **EO – instant powering a nation-wide GIS**: In EO technology the challenge is to be at cutting-edge and develop ability to intelligent and pervasive imaging systems and smart data delivery systems to users. In 2002, a 2025 EO strategic Plan of ISRO had outlined a series of steps to maintain the then lead that ISRO had in EO imaging after the IRS-1C series of satellites[4]. The data from EO satellites, position information from space and use of tools like GIS are highly relevant in the context of governance, commerce and citizen services. Through establishment of a National GIS system and promoting standards, Indian Space products need to significantly contribute to governance, business enterprises and citizen services needs. In a recent review of Space Applications by the Prime Minister of India on September 7, 2015, a common thread of challenge identified by 5 major ministries/department Secretaries was two-fold – the need for high-res images (even upto 0.25m) and policy for addressing access difficulty for EO images.[5] This clear messaging coming from Indian users is that high-res EO images are critical need and gap has to be filled.
- **Suite of advanced EO constellation capability**: In high-res imaging, which is a large demand in market, India has 2.5m stereo resolution operational capability and has reached near 1m resolutions in its IRS class satellites. It plans to have <0.5m resolution imaging by 2018-19 when the global market would be flooded by large number of imaging systems at 0.3 m then and with instant imaging and delivery capability. Delivery of EO images has been a constant challenge for users – takes time and bureaucratic processes and also hardship-limits for non-governmental access to high-res images. This is stifling the Indian EO and GIS market considerably. Similarly, the ability to expand into a SAR constellation and also enter the space of hyper-spectral and geo-synchronous imaging.
- A regional navigation system designed in early 2000s may not be the critical positioning infrastructure for Indian needs – development of an indigenous Indian **global positioning system** to achieve autonomy in access to global satellite navigation signals and also performances comparable to the best of the breed global systems. This will be essential in the context of a far-looking National Positioning Systems Policy that maintains national space-based Positioning services, augmentation service in an operational manner – for security, governance, commercial and citizen services across the globe where India's interests may require.
- **Planetary Missions continuity plan** is an important requirement from a long-term and continuity of planetary science plan of exploration, research and knowledge capability for India and build science and research capability in Indian universities and institutions. If India intends to habitat planetary systems, a continued

plan for planetary missions will be most crucial – to develop a knowledge base for planets, landing, habitation and other human activities.

- **Building a robust national private sector space industry**: The gap of a full-scale private sector in Space is being felt like never before at this time. The ability of India to mature and develop a commercial private sector in space – for technology and applications is utmost critical[6] and is still a dream for India, even as the global space industry has marched forward in a very strong way in the global markets already. Nevertheless, in India, the services industry that makes use of space systems, such as in telecommunications and television services and value-adding business with remote sensing data, has been commanding a multi-billion dollar market nationally, and it comprises some of the enterprises from the most reputed and the largest industry groups of the country. The limits of a public space agency being able to cater to space requirements are being felt throughout and the future challenges will pose much more demand for an independent commercial private sector in space. At various times, ISRO has also publicly acknowledged to develop industrial capability and involve Indian industries for its national and global programmes. The shortage of communication transponders and gaps in remote sensing images have triggered many industries to look at private-sector space activities – but these are yet to take off in a major way mainly due to lack of policies that can enable a national space eco-system with industry and commercial activities. It is imminent that operational space activities that have been developed in past 40-50 years – of PSLV, communications satellites, ground systems, EO image satellites and downstream services are aggressively privatised – this will benefit the nation and also help a health growth in national capacity, with participation of Indian industries.
- Yet another challenge is also in **future activities of human space-flight programme** – not just technologically but also from investment and sustenance point of view. Public acceptance of such programmes have to be forth-coming but the technological aspects along with organizational structures are yet to be defined and fructified – though study level activities have been just funded and initiated.
- **Intensifying a two-way international cooperation** is a desirable strategy – on one side, to embark on major exploratory programmes through synergy of partnership and assimilating technology and experiences from other nations and on the second side, for reaching/bringing Indian capability in the global markets of space. This combined approach must be intensified by active participation in multi-lateral space frameworks and selective bi-lateral space cooperation – especially in future human space flight and planetary exploration activities. The Indian Prime Minister exhorted for a SAARC satellite in June, 2014 – hopefully the successful achievement of the cooperative mission will pave way for many new and innovative international cooperation steps in space.
- Indian Space has triggered many new services and products/applications – which reach out all over the country and deep into society at multiple levels - administratively and jurisdictionally. **Newer institutional frameworks** are called for down-stream national-level applications and delivery systems – especially to address delivery systems for large demand for societal applications related to space. In an end-to-end concept, national space agency must rid itself of "burden" to undertake large national-level societal applications that emanate from administrative and governance demand as this can be easily spawned into newer and larger structures/organisations for applications and usage. One important element that needs to be addressed is critical orbit/spectrum allocations and protection for Indian needs – not just over India but across the globe and prepare for futuristic trading in slots/spectrum for mutual interests.

In the far-term of 20-30 years, issues like asteroid mining, resource exploitation on planets and celestial bodies, planetary habitats and space travel between stars and interplanetary travel would be a major area of scientific exploration of space. How India would address these long-term issues needs planning and story-boarding right now.

II II Long-term Scenario "Visualisation"

NIAS has undertaken a simulative exercise of determining the number of missions that India will have to address in the coming 10-15 years – ahead of the 12th Plan. It may be recalled that in the 12th Plan, 58 mission has been planned and financial outlays provided.

In a back-of-the-envelope estimation, we estimate that number of missions in 2025 time-frame to be accomplished may be anyway near 100-150 missions for national needs/system, and which would include:

- missions for advanced high-tonnage and bulk-transponder communications that will be required

to meet large demand for societal and commercial needs. Of course, availability of slots/spectrum allocations will be crucial.

- missions for EO – including high-res, ocean, meteorological and earth science applications
- planetary and science missions that maintain a continued dove-tailed mission strategy
- enhanced positioning system that augment regional services into global high-precision services of positioning
- human space flight missions – mainly technology proofing and early experimental missions, including man-rating of launchers and a host of technological development missions for human space-flight.
- Access to space missions/launchers that put the NEO and GTO missions into orbit. While the existing PSLV and yet-to-be operational GSLV may still be work-horse, advanced launch technology missions for re-entry testing etc would get be implemented.
- Crucial technology demonstrators and R&D missions in launch and satellites that are futuristic – including, advanced communications technology, advanced EO technology etc.

III. POLICY SCENARIO FOR INDIAN SPACE

In 2014, NIAS[7] had analysed policy scenario of Indian Space and had proposed the following components for the comprehensive Indian Space Policy:

- Indian Space Vision – in alignment with national vision. This can be long-term vision of space programmes/missions (this could be rolled over every 5-10 years).
- A comprehensive Satellite Communications Policy that ensures un-interrupted and advanced satellite services for communications – public services, commercial and citizen services
- A pragmatic Remote Sensing Policy that commits availability of best quality remote sensing satellites data for land, oceans and atmosphere for national development – government needs, commercial needs and research needs
- A far-looking National Positioning Systems Policy that maintains national space-based Positioning services, augmentation service in an operational manner – for security, governance, commercial and citizen services.
- Indian Space Transportation Policy that ensures India's technological competency in space launch sector by way of development of efficient and advanced space transportation systems that are reliable, efficient and affordable and that support Indian space access needs operationally and also support launch business of global markets competitively.
- A National Space Science policy which covers a long-term and continuity planetary science plan of exploration, research and knowledge capability for India and builds science and research capability in Indian universities and institutions.
- A Space Industrialisation Policy that envisions developing and positioning a vibrant and superior Indian space industry capability which can simultaneously undertake full-scale space missions development for national needs and global markets.
- A National Space Applications Policy which will encourage "integration actions" of dove-tailing space technology into user domain of governance, business and research education by way of end-to-end user solutions concept.
- Indian Space International Cooperation Policy that will outline the international cooperation aspects as a 2-way mechanism – of India gaining/participating from cooperation and of India contributing in international arena. Issues of international Space Governance – debris, code of conduct, planetary treaties etc are key for future and a policy perspective is essential.
- Human Spaceflight programme element that clearly outlines the full panorama of human spaceflight plan and national commitments that are required.
- National Space Security policy that outlines the space security aspects of Indian national space.
- A Public or Citizen Space Charter which enables defining (on regular periodicity) the benefits that Space Policy is bringing to India and its citizens and provides metrics for measuring performance.

At some time in coming years, space legislation would also be appropriate to position a long-term commitment and public endorsement.

IV. FUTURE NATIONAL SPACE ECO-SYSTEM

We envisage that future space activities can be categorised into 3 groups of major activities:

- Continuity of operational missions for operational and un-interrupted national services in communications, EO and space/planetary science. These would be continuing the present technological levels of missions with adequate improvements but operational production-line establishment.

- Advanced technology missions that require intense development and R&D efforts – especially for advanced communications services, advanced EO, human space flight, advanced launchers like re-entry systems, aerospace plane and planetary missions. These would have considerable knowledge-base requirements and learnings from international cooperation efforts.
- International cooperation missions that emerge from India's enhanced forays for joint science/planetary missions, joint space flight opportunities, multi-lateral efforts and others. These would be important for technology acquisition and sharing of resources.

We have not accounted for many global missions that India may launch or build under commercial arrangements – there could be many opportunities for these.

Such a mission profile for future 10-15 years raises an important question – will ISRO as the sole agency be able to meet the requirements of such a space growth (a doubling or tripling of its existing capacities). If one looks at mission performance till now it stands at 8-10 missions per year and spend levels at INR 70 billion at present budgets of 2015. Human resources are stagnated at 16000 level. If one looks at these indicators – it is clear that national space system has to expand and cover a wider net of role-players.

In the present context and looking ahead, certain questions need to be answered:

- whether just the national space agency - ISRO can, by its present levels, meet the national needs of space in next 10-15 years and scope its annual mission achievement to almost 20-30 missions per year? Does it have the elasticity or bandwidth?
- Can public funding of space be tripled (or even quadrupled) from present levels of INR 6-7 billion per year – as would be required over next decade or so? Would private investments in space be inevitable for future growth of space activities?
- Today, with all activities of space in ISRO-centricity – can this sustain the future needs of space AND how can the excellent efforts of national space agency be augmented to bring high elasticity towards meeting the future needs.

Presently, Indian Space has a national space agency centricity that has about 16000 work-force and is augmented by contractual industries. This system, according to us, is inadequate to meet the large mission needs for the nation.

In our view, the above challenges require a new thinking, a new order of Space and time is ripe for crafting a larger National Eco-System for Indian Space – which expands from the excellent indent of the present single-agency system to a multi-level framework and position an investing private sector and a innovative academia. How……..our visualisation is given below.

IV.I National Space Eco-System: Private Sector

Indian Space industry need to be an important part of the larger eco-system and can address Space Assets Manufacturing, Private Ownership of Space Assets, National-level Space Services and Global Market Access

Indian operational space systems – like, operational communication satellites (INSAT-class) OR operational imaging systems (IRS-class) could be easily built, owned and operated by Indian private sector under a good "regulatory/licensing" regime? Similarly, why cannot operational PSLV-variants be fully manufactured, assembled and launched by Indian private sector under appropriate supervision and authorisations by the government, meeting international law and obligations? In fact, this would not only create Indian industrial capability in space but also make it globally competitive for large-scale business acquisitions and at same time help address the "gap in capacity problem" in the country that exists today of transponders, images, launch systems etc. On the other hand, some Indian industrial capabilities are building full satellites for other markets or young entrepreneurs are building a rover for the Moon for a commercial prize. A few private sector satellite industry start-ups in India are relying on/ looking for overseas manufacture of satellites in view of capacity and policy constraints within the country. Also for India's domestic needs new and more efficient technologies need to be spun in. An effective way to enhance national capacity is to encourage collaborative manufacturing.

From a long term national interest, it is essential to attract domestic private sector investments into space infrastructure and enable mutually beneficial collaboration between domestic and global industry players. It is also necessary to effectively enable the use of the public funded technologies in this field for accelerating economic engines of the nation. The effective direction for the mid-term is public private partnership.

- One step that is imminent is to move away from involving industries just as "contractors" to ISRO

but to develop independent and high-quality space industries that can, alongwith ISRO, be a part and parcel of Indian space eco-system.

- It is appropriate that ISRO sheds time and effort investments for routine PSLV/INSAT/IRS class of activities and these are "transferred" to private industry ownership and development, in a phased and planned manner. ISRO as the national space agency can play a larger and more effective role in advanced technologies and newer developments required for future national needs of future, planetary missions and HSF.
- Reform is needed for satellite communications is to ensure effective and independent regulatory mechanisms to facilitate public private partnerships and promoting competitive conditions satisfying the goals of meeting essential needs of the society.
- An area of ecosystem revitalisation will be the Government's proactive role and policies for internationally coordinated resource needs (such as orbit and spectrum) and technology advancement support for enabling industry development in India.
- Several issues of policy had been studied by authors for an effective GIS policy in India[8] to provide a leading role for space business applications for better governance, commerce and citizen empowerment.
- Such an "industrialisation" process would require careful planning and may have to be evolved over time – but would be a critical requirement for the future growth of Indian space.
- India needs to complete implementation of a suitable policy to enable further expansion of industrial capacity, to sustain Industries' interest and also to ensure their compliance to national security and export policy norms.

In our view, a good policy outline of "transfer and buy-back" will yield rich dividend in building Indian industrial capability in space. Industries can be selected for such a partnership and those that are selected must be assured of "services buy-back" for national good. Such methods have been successfully employed in other parts of the world and can be certainly adopted in India too.

It is worthwhile to note that India has umpteen examples of industry-building and private sectorisation of national activities – telecom, insurance, mining etc and principles of transparent industry licensing and buy-back have been successfully adopted within – we strongly believe that for operational and routine space activities there is much to learn from these privatisation.

Critical in this scenario is the national space agency today!!

IV.II National Space Eco-System: Academia and R&D Sector

Importance of Academia and institutional research in Space is extremely important. This element can address cutting-edge R&D capability/capacity in space, science missions and knowledge as users and research, industrial research and space education for R&D.

There are several futuristic concepts based on the new grounds being broken in science and technology, particularly through advances in material sciences, bio and nano technology fields, to prepare humanity for the unlimited opportunities and daunting challenges of the vast outer space. Indian space must indulge in this with serious research and institutional development.

A major step for expansion and qualitative developments in technology or research programmes and even some disruptive developments in space would require spread of activities and a healthy competition among academic research organisations. As human resources under national space agency are not likely to increase, a substantial ingest in resources are essential for developing improved systems and institutional mechanisms to ensure focus, accountability and human resource strength for future. Developments undertaken by Indian universities in areas such as small satellites, research in space sciences and advancing the technological frontiers must be multiplied many folds in the context of expanding space activities and their impacts.

IV.III National Space Eco-System: Crucial role of National Space Agency

The national space agency, ISRO, must take on a larger role of the "mature partner" in the new eco-system and become a "fulcrum and hub" of space knowledge enterprise. It has a major role to play for industrial development of space and innovative methods – full-system technology transfer licensing, hand-holding and joint development initially, buy-back assurances, fee and royalty-based commercial arrangements etc. Hand-holding the industry, in the initial stages of private sector development, must be part of the national eco-system role for ISRO. ISRO could also undertake testing and certification of reliability and technology in space – thereby slowly building reliability and quality for space assets/products in the nation.

Within ISRO, there has to be a drive and a fulcrum to usher in a good public-private regime for Indian space – a (new)Space for India. ISRO has to visualise that for the good of space activities it has to "shed some" and "build on some" and allow industries to mature in space arena over a few years of hand-holding and eco-system development period.

National Space Agency must take on a more challenging and responsible role in advanced technology development in satellites/communications/EO, complex development of human space-flight technologies operationalisation, continued space missions for planetary and space science, critical international cooperation development for 2-way benefit and developing crucial applications demonstrators for future. International cooperation must be the regime of ISRO and enable the national space eco-system with best of external technology and inputs.

The national space agency must see itself as "promoter" for the nation in space enterprise (like promoters in industries) and bring the value-add change agents in the national scenario. In future, the performance of national space agency may not be measured by number of missions or budget expended by them BUT by the number of missions or budgets that they make happen in the industrial and academic elements of the national space eco-system.

National Space Agency – an harbinger for new innovations and challenges in space AND a builder of the National Space Eco-system!!!

IV.IV Role for regulatory developments

In the new order, a national regulation for space could be called for as essential. Increased competition for orbital resources – for slots and frequencies particularly would call for increased level of coordination and sophistication would be called for in order to ensure interference free communications. India should also be participating actively in global fora which lead regulatory developments and protect Indian interests over India but also in the world.

Another resultant problem that India would have to address is orbital space debris that would be a very serious concern with large number of Indian Space assets in orbit. Protecting Indian assets would require good shielding and tracking technological capability and coordination at global level.

Coordination of Space Governance and international regimes would require extensive regulatory skills. How space could be prevented from becoming an arena for weaponisation and a medium for offensive and aggressive uses is too important a concern for India to ignore.

IV.V Governance and Institutional Structures

It may also be essential to look at newer governance structures for space. A top-level Government focus on space industry, space academia and space applications may be more appropriate in present times and tuned to the new national eco-system of space (Presently, it is Space Commission that is vested with space development as a whole). Inter-departmental framework, space industry forums, space academia committees and larger user involvement may be called for. The top space focus must include national space agency, space industry and space academia experts – apart from user groups. There are different possibilities of working this out – and at an appropriate time one could consider the same in different perspectives.

V. CONCLUSIONS

The Indian Space program has excelled in many dimensions and has also contributed to international dimensions through its commercial and cooperative endeavors. As tremendous opportunities are opening up in Indian economy, which is growing as a major world economy, needs for speedy infrastructure growth had arisen in several areas. Role of Indian industry will be crucial not only to extend the value chain but also to ensure that space infrastructure segment does not remain only within the domain of public investments. Further the Indian Industry should also be enabled to compete and play a role in global markets. Expanding space markets in India provide unique opportunities and at the same time several big challenges.

Great heights have been achieved in India in space endeavors through unfolding the utilitarian and pacific visions of Space. India could again expand its horizon and enable a major space thrust at national level and bring a global foray of Indian space in the 21st Century.

THE FUTURE ……..NATIONAL SPACE ECO-SYSTEM OF A VISIONARY ISRO + EXCELLING INDIAN SPACE INDUSTRY + KNOWLEDGE-ORIENTED ACADEMIA……..A NATIONAL ENETRPRISE FOR FUTURE SPACE.

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