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FUTURE INDIAN SPACE – RISK ASSESSMENT AND ORGANISATIONAL STRUCTURING

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Abstract

The main emphasis of the future Indian Space Programme extending up to the year 2030 is stated to be contributing to the national developmental goals of sustainable development. This is envisaged to be pursued through activities and programmes mainly in the areas of Space Transportation Systems, Space Infrastructure (satellites), Space Applications, Capacity Building, and Institutional Support. As the investments envisaged by the government alone will be about three trillion Indian rupees (over the next 13 years) and also that the Programme is well poised to evolve risk sharing partnerships with Industry besides many international collaborative relationships, a systematic risk assessment and management assumes paramount importance. Hence a study is made to identify and assess risks and discuss on the risk management planning perspectives for the national space activities.

The methodology adopted comprised of generating a register of top level risks under two broad categories of programmatic risks within space sector and risks due to environmental factors. The programmatic risks are analyzed in terms of likely design, developmental and operational risks, which will be manifested in terms of financial, technical performance and schedule impacts beyond specified limits as well as the human resource/organization related impacts. Environmental risks are classified into factors related to political stability, possible policy and regulatory changes, major technological advances and disruptions, economic trends, factors relating to international environment and risks due to changing space environment.

Impacts and likelihoods are mapped for all major planned initiatives in space transportation, earth observations, space communications, navigation and space exploration missions as well as applications- resulting out of the imperatives and trends in domestic and international environment like increasing private sector participation, disruptive technological trends that can change cost trajectories (such as reusable launch systems concepts), upheavals in the space situation, and the national /international regulatory trends. In the third part, implications for organisation and governance is analyzed from the perspectives of risk management. The analysis establishes the key needs of governance structure and organizational change springing from the transformation of stakeholder profile and other trends of the environment.

Keywords: Space program risks, Risk management, Risk mitigation strategies, Space governance

1. INDIAN SPACE PROGRAMME IN PERSPECTIVE

Over the past 50 years, India has accomplished more than 150 space missions that has won global recognition to include her into the big-league of "space powers". Capabilities for autonomous access to space and world class satellite missions including proven record of Lunar and Mars orbiting missions distinguish her accomplishments. Over these decades, with an overall expenditure of about 700 billion Indian rupees she had accomplished 92 satellite missions and 64 launch vehicle missions, and two satellite recovery/ re-entry missions, with a fairly high success record. Out of the 92 satellite missions, only four satellites failed in orbit and for the 64 launch missions comprising of four different varieties of launch vehicles, eight failures were encountered mostly in their initial development phases. Even these few failures contributed enormously to the learning process. As the national space missions were funded by the government, the economic impacts of failures were absorbed into the investments in recognition of the technology development objective. However, in the case of INSAT operational satellites which were launched by commercial launchers, they were insured for launch and on orbit risks. Another major distinguishing characteristic of India's space endeavours is the extensive efforts to use space technology for accelerating national development. The range and scale of space applications are truly impressive. Space programme is made relevant to the common people through solutions to the problems of the large populace of India. Examples include monitoring and warning against natural disasters like cyclones, applications in tele-education and telemedicine, assessing ground water potential for drilling wells, pre-harvest prediction of agricultural yields and a plethora of other applications contributing to sustainable development strategies. The Indian Space agency, ISRO, currently collaborates with as many as 58 ministries in the Government of India on space applications. While the Indian space segment is totally dominated by the infrastructure and assets invested by the Government of India, the space application services, like Direct to home Television and a variety of satellite based telecommunication, remote sensing data services are provided by Industries in private sector. Through technology transfer and industry cooperation programs, ISRO has endeavoured to progressively advance the capacity and capabilities in Indian industry for space products and services[1]. As a result, several industries in the manufacturing sector are active in the supply of equipment, components and technical services to the national space programs undertaken by the space agency. As an economic driver, space activities influence annually about 5 billion US dollar downstream applications. Apart from the goals of technology advancement and socio economic outcomes, the Indian Space activities are also instrumental in promoting international cooperation, providing support to homeland and national security, and inspiring young people of India towards pursuit of science and technology careers and inculcating the spirit of exploration.

It is evident that in her endeavours in Outer Space, India integrates multiple objectives. The space activities and the related terrestrial applications today encompass government and private actors. They are relevant to influence the quality of life of vast sections of populations in an inclusive way. Space infrastructure is a critical infrastructure as many a business, governance and citizen related services relevant to development depend on that. As of end of 2016, India had 62.65 million active subscribers[2], who depend on satellites for distribution of television services to their homes. This number is steadily growing too. Risk management for such multidimensional endeavours is of paramount importance.

2. RISK MANAGEMENT STRATEGIES HITHERTO IN THE INDIAN SPACE PROGRAMME.

In its journey from inception to the operational phases over a period of five decades in Indian Space endeavours, risk management strategies had been integral part of the overall governance and program management of the national activities in this field. At the core level, five pillars of risk management strategies adopted in the first five decades of the programme are the following

- Innovative organisational design,
- Goals for self-reliant development of technology,
- Focus on applications relevant to India's socio economic context,
- Engaging with stake holders from early phases, and,
- Learning culture.

Central to these risk reduction architecture in the evolutionary period is a three phase evolution[3] of the national space endeavours that provided stage gating for commitments of resources as well as generating the confidence in the political leadership on the performance. The first phase of proof of concept demonstration, demanding very modest amount of resources was directed at quickly evaluating the potential of the vantage point of space for addressing the nation's developmental needs and issues of scalability at the national level considering the technology, institutional issues and user interfaces. The second phase termed as experimental phase mainly was meant to create heritage in hardware and human resource strengths, and a test of total chain to develop confidence for subsequent very high levels of investments into operational systems. This strategy could reduce the impact of early failures in the minds of public or political system. Additionally, a judicious mix of make and buy decisions that could ensure maximising the long term value and minimising vulnerabilities for achieving ultimate goals was adopted. In the operational phase, emphasis was placed on achieving necessary service level standards, greater accountability and backup strategies for unforeseen changes, opportunities or interruptions. Wherever buy options are exercised for critical systems or services, a parallel indigenous development plan was created to achieve self-reliance goals.

As space programs demand large investments, lack of public support could also be a risk factor. When a scientific mission like lunar mission was conceived for

[1] Overview of Indian Space Sector 2010, by Deloitte, published by Confederation of Indian Industry and Antrix Corporation, World Space Biz – 2010, August 2010.

[2] Telecom Regulatory Authority of India http://trai.gov.in/sites/default/files/quarterly_press_release_Eng_07042017.pdf accessed last 12-09-2017

[3] K. Kasturirangan, Space—An Innovative Route to Development, ASSOCHAM, New Delhi, August 2001

the first time, there was a long process adopted by the space agency of awareness building, consultation and communicating the benefits and risks of such an endeavour. This interaction was carried out with the scientific community, academics, the political system and the public media before this mission was given the go ahead.[4] This process, spread out over four years, culminated in the announcement by the Prime Minister of India on the nation's decision to enter the new era of planetary exploration. This is also a good example of a practice of ethics of decision making in science involving consultation of a large cross-section of society and ensuring transparency.

3. BROAD CATEGORISATION OF RISKS – MANAGING RISKS AT A PROGRAMME LEVEL

Space activities involve different risk scenarios than encountered with terrestrial systems due to the hostile environment in which they have to function and lack of access to repair. These are to be overcome by design, process and operational measures which are unique to such systems. Consequently additional risks arise in terms of large capital deployment, long gestation, supply and demand fluctuations due to long life cycles, higher level of government involvement, and control/regulations; diverse legal environments to mention a few. Risks are broadly categorised as programmatic risks within space sector and risks due to environmental factors. The programmatic risks are analysed in terms of likely design, developmental and operational risks, which will be manifested in terms of financial, technical performance and schedule impacts beyond specified limits as well as the human resource/organization related impacts. Environmental risks are classified into factors related to political stability/support, possible policy and regulatory changes, major technological advances and disruptive trends, changing economic conditions, factors relating to international environment and risks due to debris and other adverse factors developing in the space environment.

For managing programmatic risks, a well-established industry practice and quality assurance standards relevant to space activities had been evolved by ISRO and these are adopted through the Project/ Programme Management Organisation. Main components of these practices are embedded into Parts, Materials and Process Control; design assurance; Reliability engineering; Test and Evaluation; software assurance; Non-conformance control and Configuration control.

Reliability engineering practices mitigate the risks of product performance by estimating, controlling and managing the probability of failure in devices, equipment and systems. This is achieved through activities/ techniques such as defining overall reliability goals and targets, apportioning the goals, predictions, parts stress derating analysis, Failure Mode Effect and Criticality Analysis, and Fault Tree Analysis. As a norm, only components/equipment and systems with either flight heritage or those which are specially qualified for flight are allowed to be used. As each project would involve many project specific developmental activities, risk reduction is addressed through a model philosophy for tests, qualification and acceptance at various levels. A comprehensive Quality Assurance Plan for each project is defined and documented at the very outset. Considering the lack of access to repair, design philosophy would ensure avoidance of single point failures, incorporating required level of redundancies or adopting stringent quality control measures. Meticulous tests and evaluation are carried out as per plans and for ensuring compliance to specified performance levels. Non-conformance control and configuration control systems ensure adequate evaluation and approval process for corrective actions and any changes to be implemented along with necessary documentation. To reduce damage of risks detected at late stages, review system is at the heart of managing risks in the space projects. Such reviews are formally conducted at important stages like preliminary design, critical design stage, pre-shipment, flight readiness, mission readiness and so on. Risks related to time schedule and costs are controlled through specified reporting information systems and variance analysis and reviews. For top level risks which are not addressed through project risk-management approach as detailed above (for time, cost and performance risk aspects), such top level risks are identified and mapped depicting severity of impact vis a vis corresponding frequency of occurrence to delineate level of control to be exercised. For each identified risk, corrective measures are also identified.

4. FUTURE SPACEDEVELOPMENT AND MAPPING RISKS

The main emphasis of the future Indian Space Programme will continue towards contributing to the goals of harnessing space technology to accelerate sustainable national development. This is envisaged to be pursued through activities and programmes mainly in the areas of space launch and transport, spacecraft, space applications, human resources development and indigenous capacity, and partnerships in the next ten to

[4] K. Kasturirangan, India's Space Enterprise—A Case Study in Strategic Thinking and Planning, K R Narayanan Memorial Oration, Australia South Asia Research Centre, Canberra, July 2006.

fifteen years. The investments demanded from the government will be about three trillion Indian rupees. Significantly, the programme would evolve towards forming risk sharing partnerships with Industry apart from many international collaborative relationships. Hence, a systematic risk assessment and risk management assumes paramount importance.

The implementation strategy of such plan would need (a) consortia of industries coming together to produce state-of-the-art, cost competitive satellites on one hand and manufacturing of launch vehicle and providing launch services on the other hand, (b) a modular heavy lift launch vehicle (HLV) development dovetailing the development of semi-cryo engine and stage catering to a wider payload band extending to 15 tons (LEO) with capability to carryout human spaceflight missions in the future (c) steps towards developing a two stage to orbit (TSTO) launch vehicle with both the upper stage and lower stage recoverable and re-usable (d) Evolving thematic satellite systems to address information and connectivity needs, challenges and decision support functions in many sectors [5] such as disaster management (DMS-SAT), education (EDUSAT), Railways (Rail Sat), Water resources (Hydro Sat), Urban applications (URB SAT) and so on, (e) Strengthening satellite navigation system and applications, (f) Steps in implementing human spaceflight activities as part of future space exploration by India

The major risk areas, their implications and mitigation strategies in light of the likelihood of risks are as follows:

In the field of Space Transportation Systems, the major risks relate to (i) external disruptive technological and economic trends in space launches (ii) likely time over runs of new developments like heavy lift launcher and (iii) unforeseen liabilities arising from launch services to customers. The outcome of such risks would be in terms of economic impact, delays in realisation of goals and deficient national services. All of these could lead to lack of public /govt. support in the long term. The risk mitigation strategies should include greater thrust on choice/development of new technologies like reusable stages and modular approaches in multi-sizing, judicious make/procure choices and national legislation to address issues of risk management, including national security provisions and insurance for operational launch services.

For space communications, major risk areas are (i) alternate technologies shifting the economic attractiveness of space based services (ii) launch and on-orbit failure risks (iii) loss of opportunity due to delay in building orbital capacities, (iv) lack of availability of orbit/spectrum resources to meet the demands (v) lack of private sector investments in the space assets (v) technology development risks of state of the art payloads and large platforms. The impact of these risks are mainly in terms of economic aspects and reduction of value additions within India. Considering probabilistic scenario of each of these risks, mitigation strategies can be arrived. These include (a) policy drivers for incentivising private sector investments, (b) effective international coordination for orbital resources (c) collaborative approaches to harness orbital resources (d) judicious policies on procuring commercial services internationally (e) continued thrust for developing efficient platform/ payload technologies (f) enhancing protection of assets in space (e) insurance for commercial and other risks for all operational missions.

In the field of earth observations, the risks relate to (i) impact of alternate platforms/technologies for imaging (ii) possible loss of leadership in imaging systems and products (iii) delays in commercial exploitation of capabilities (iv) availability of resource funding for continuous upgrade in space infrastructure (v) transitioning to user driven investments and service-oriented organisational architecture. Developments in India's earth observations field has potential to transform into a national system of innovations essentially through policy and organisational architectures. The impact of aforementioned risks are economic as well as loss of opportunity in value building activities in the nation. There are also implications in the nature of foreign policy and national security. Taking into account the likelihoods of these risks, mitigation strategies include greater supportive role of the government for industry to move higher in the value chain, policy renewals, and strengthening of R&D for applications.

In the field of satellite navigation, risks include (i) dependence on external systems (ii) loss of business opportunities due to lag in ground segment technologies and application innovations. The mitigation strategies should centre on strengthening India's space assets in this field, transitioning towards global system and collaborative efforts for ground developments and applications.

5. INDIA'S NEEDS - 2030 AND BEYOND

India's economic growth is likely to take her to reach 8 trillion $ economy by 2030, a fourfold increase from now. India would also have largest numbers of young population in the world by 2030. Such a multi trillion

[5] India in Space – A Conceptual Framework for the 21st Century – by K Kasturirangan, Dr Satish C Seth Memorial Futurology Lecture series 5 organised by Indian Council of Management & Future and delivered on April 8, 2013.

$ economy would demand multi-faceted development in infrastructure, natural resources, environment, science and technology, social sciences, humanities, law and management and many other fields. Space assets needs to multiply to meet all the needs. Hence the whole national space ecosystem has to develop, much beyond the roles of national space agency, with a strong role played by industry. Indian industry should undertake to manufacture systems, investing into space infrastructure, space operations and services to users. So independent regulators, who are empowered by law, have to play a role to ensure competition, service standards and ensuring services tuned to user interests. Another challenge is to achieve manifold developments undertaken by Indian universities in areas such as small satellites, research in space sciences and advancing the technological frontiers in the context of expanding space activities and their impacts. As human resources under national space agency are not likely to increase very substantially, a major step is needed spread of activities and a healthy competition among academic research organisations for expansion / qualitative advancements in technology or research programmes and even some disruptive developments in space[6]. The space agency would be required transcend in its role to enable this transformation in industry and academia. The delivery of applications and their assimilation are also expected to vastly transform as space services are merged into ubiquitous applications, more widespread and integrated in to mainstream ICT application services. Implication is that the Indian space sector will have a vastly different stake holders' structure in 2030 and beyond.

6. CONCLUSIONS- MANAGING RISKS AND NATIONAL SPACE CAPABILITIES

Space is a critical capability for advancing growing number of services that form backbone of economic growth, good governance and meeting societal needs. It is an important resource for security and defence, an effective tool for monitoring environment and managing natural resources. Outer space endeavours have also been a powerful instrument of forging international relations and a catalyst for the growth of high technology industry. Inherently, space activities pose higher risks due to the complexities of the operational environment in space and higher investment demands. Sustaining and growing space activities pose a wide range of risks that affect a multitude of activities relevant to nation's socio economic development, national security and the nation's relations at international level conditioned by the influences of global political and security environment. Further, the environment in outer space itself had been constantly transforming, with increased actors and growing debris population.

In view of the foregoing considerations, top level risks impinging on the national space capabilities can be identified as follows:

I. As experienced world over, there could be reduction in government support to space activities, especially as the demands on financial resources go up in proportion to government expenditures and in competition with many emerging areas of technology. This could result in interruption to further build-up of national capability in space.
II. There could be unforeseen delay or interruptions in major international collaborative efforts (like joint missions)
III. Risk to safe and secure use of space assets due to conflicts extending into outer space environment and increased threats from debris/ other interference
IV. Risks due to inadequate regulation
V. Dwindling of public support
VI. Discontinuities in technology capabilities leading to reduced performance outcomes.
VII. Threats for sustainability of national industry/institutions and employment
VIII. Legal risks such as international liability involving space activities of Indian nationals
IX. Major and repeating mission failures
X. Denial of access (international) to critical technologies
XI. Major disasters affecting critical space infrastructure

Although these risks could be real, their likelihood are relatively made small through proactive engagement with all relevant stakeholders. A key approach to managing such top level risks should be to ensure good 'Space Governance' at the root level. Such governance system should address mechanisms for goal setting, policy and regulatory developments through necessary participative processes and appropriate accountability. There is an inevitable need for National Space Legislation, well aligned with international law, to provide an overarching framework for growth and use of space activities and to ensure good governance in

[6] Indian Space – Towards a "National Eco-System" for Future Space Activities - Mukund Kadursrinivas Rao, Sridhara Murthi K. R. and Dr. Baldev Raj. Paper selected/to be presented at 66th International Astronautical Congress, Jerusalem during October 12-16, 2015

the field of space. As a minimum the legislation should address the following:

a. Affirming the long term policy and the objectives of Space activities

b. Empowerment to pursue space activities (by Government or its authorized agencies)

c. Provisions for Licencing and Authorization of space activities by non-governmental agencies

d. To address Liability issues- compensation for damages for space activities by Govt. or non-Govt. agencies.

e. Registration of space activities

f. To support International cooperation

Growth strategies of India's space program has to consider diversification of risk bearing actors beyond the government and creation of national ecosystem[7] for space activities Necessary incentives for industry including capping of liabilities in this regard deserve consideration. These have to be addressed through policy and regulatory measures.

Indian Space Programme had a long reputation of strong contributions to the national developmental goals. Also, ISRO is touted as a model of performing organisations under the aegis of a government system. The integrated management system and the apex structure of Space Commission in India had helped a focused goal oriented approach and inculcation of a learning organisational culture. However, integration of leadership of the Space Commission and leadership of the Space Agency ISRO, and the Department of Space in the Government of India in one single person was put into question in recent times. There had been a good philosophy of such integration of various wings of the space program including commercial arm under a unified single leader during the evolution of the program for over four decades and the mature leadership was able to resolve role conflicts. Over the decades, space activities had also multiplied and stake holders had emerged beyond the government system. Different dimensions of governance including innovation, promotion, industry, regulation, wider participation, accountability for services, delivery capabilities, catering to different stakeholders' interests and diversity of institutional infrastructures as per national priorities in the domain of space have to be addressed. Evidently some of these go beyond the concerns of national space agency. Therefore, the apex Space Commission would need broader and independent representation and leadership, with different members representing major stakeholder categories and vested with necessary authority and accountabilities. The Space Commission would thus be able to address more effectively the overall national space ecosystem issues and contribute to the top level risks identified.

In conclusion, managing risks of national space program should be an integral component of the goal. It can also be seen as an essential art of achieving success of the programme in the long term. Good governance and leadership are at the heart of such an effective risk management.

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[7] INDIAN SPACE – TOWARDS A "NATIONAL ECO-SYSTEM" FOR FUTURE SPACE ACTIVITIES - Mukund Kadursrinivas Rao, Sridhara Murthi K. R. and Dr. Baldev Raj. Paper selected/to be presented at 66th International Astronautical Congress, Jerusalem during October 12-16, 2015.