12th FIVE YEAR PLAN
OF
DEPARTMENT OF SPACE

REPORT OF WORKING GROUP (WG-14)
(Web Version)

OCTOBER, 2011

CONTENT

Working Group of the Department of Space for Formulation of 12thFive Year Plan (copy enclosed as Appendix-2)

S. No.	Name &Designation	
1.	Dr. K Radhakrishnan, Secretary, Department of Space	Chairman
2.	Secretary, Department of Agriculture and Co-operation, Ministry of Agriculture, New Delhi	Member
3.	Secretary, Department of Border Management, Ministry of Home Affairs	Member
4.	Secretary, Ministry of Earth Sciences, New Delhi	Member
5.	Secretary, Ministry of Environment and Forests	Member
6.	Secretary, Ministry of Information & Broadcasting	Member
7.	Secretary, Department of Information & Technology	Member
8.	Secretary, Department of Land Resources, Ministry of Rural Development, New Delhi.	Member
9.	Secretary, National Disaster Management Authority, Ministry of Home Affairs, New Delhi.	Member
10.	Secretary, Department of Science and Technology	Member
11.	Secretary, Department of Scientific and Industrial Research/ Director General, Council of Scientific & Industrial Research	Member
12.	Secretary, Department of Telecommunications.	Member
13.	Director-General, IMD, New Delhi.	Member
14.	Director, Town and Country Planning Organisation, New Delhi	Member
15.	Planning Advisor, NEC, Shillong.	Member
16.	Surveyor-General, SOI, Dehradun.	Member
17.	Chairman, Central Water Commission, New Delhi.	Member
18.	Additional Director General, Forests, Ministry of Environment and Forests, New Delhi.	Member
19.	Chief Engineer, AIR, New Delhi.	Member
20.	Chief Engineer, DD, New Delhi.	Member

S. No.	Name &Designation	
21.	Joint Secretary, HRD, New Delhi.	Member
22.	Additional Secretary, Department of Health and Family Welfare, New Delhi	Member
23.	Dr. P S Goel, Honorary Distinguished Professor, ISRO	Member
24.	Dr. B N Suresh, Vikram Sarabhai Distinguished Professor, ISRO	Member
25.	Dr. T K Alex, Director, ISRO Satellite Centre, Bangalore	Member
26.	Dr. R R.Navalgund, Director, Space Applications Centre, Ahmedabad	Member
27.	Shri P S Veeraraghavan, Director, Vikram Sarabhai, SpaceCentre, Thiruvananthapuram	Member
28.	Prof. J N Goswami, Director, PRL, DOS, Ahmedabad	Member
29.	Director, IIT, Chennai	Member
30.	Prof. R S Deshpande, Director, Institute for Social and Economic Change, Bangalore	Member
31.	Prof. J Srinivasan, Professor, Centre for Atmospheric and Oceanic Sciences Indian, Institute of Science, Bangalore.	Member
32.	Prof. P Venkata Rangan, VC, Amrita Vidyapeetham, Coimbatore	Member
33.	Chairman and Managing Director, HAL, Bangalore.	Member
34.	Shri JDPatil, Executive Vice president-Defense &Aerospace, Larsen & Toubro Ltd.	Member
35.	Shri S.M. Vaidya, Vice President & Business Head, Godrej Precision Systems Ltd.	Member
36.	Dr. Ajay Parida, Executive Director, MSSRF, Chennai.	Member
37.	Shri A.K. Verma, Adviser (S&T), Planning Commission	Member
38.	Shri V. Koteswara Rao, (succeeded Dr. V.S. Hegde on July 7, 2011), Scientific Secretary, ISRO	Member-Secretary

Terms of Reference of the Working Group

1. To review and assess the performance and role of the Department at the end of the Eleventh Five Year Plan. Identify priorities of the Department for the Twelfth Five Year Plan and suggest measures including policy initiatives for enabling India to emerge as a major global technological power by 2025.

2. To suggest plan programmes for the Department by adopting a ZBB approach and keeping in view the priorities and goals for the Twelfth Five Year Plan as well as the agenda for the Decade of Innovations during 2010-20.

3. To define deliverables as well as goals for the Department for the Twelfth Five Year Plan period as well as Annual Plans, both in terms of tangible and non-tangible outputs and formulate guidelines for deployment of resources for relating inputs to the specified goals.

4. To suggest an optimum outlay for the Department, comprising of the on-going commitment and new programmes proposed to be undertaken.

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Executive Summary

The guiding vision for the Indian Space Programme, from the very inception has been to be *'second to none'* in the development of space technology and its applications to solve the real problems of man and society. The emphasis on self-reliance has been an important component of the vision, with which India undertook development of satellites, launch vehicles and associated ground segment indigenously in a progressive manner.

Today, India's core competence in space is its ability to conceive, design, build and operate complex space systems and use them in various frontiers of national development. India today has developed two operational space systems namely IRS (Indian Remote Sensing) and INSAT (Indian National Satellite System) satellites and capability to launch them through PSLV (Polar Satellite Launch Vehicle) and GSLV (Geo-stationary Satellite Launch Vehicle). India has also taken initiatives in space exploration missions such as Chandrayaan-1

Accomplishments of 11th Five Year Plan:

During the first four and half years of the 11th plan, Indian space programme witnessed several major successes and achieved greater heights. The successful launch of Chandrayaan-1 on-board PSLV-C11, a historic feat of placing Indian tri-color on lunar surface and detection of water molecules on Moon surface were the most significant events.

The other notable achievements were launching of TEN satellites (including CARTOSAT-2A and IMS-1) in a single launch of PSLV-C9, launch of Microwave Radar Satellite (RISAT-2) and Mini Satellite ANUSAT on-board PSLV-C12, OCEANSAT-2 and six nano-satellites onboard PSLV-C14; CARTOSAT-2B, ALSAT-2A, NLS 6.1 & 6.2 and STUDSAT on board PSLV-C15, RESOURCESAT-2, YOUTHSAT and X-SAT on-board PSLV-C16. The INSAT/GSAT system was further augmented with the launch of INSAT-4CR (on-board GSLV-F04), GSAT-12 (on-board PSLV-C17) and GSAT-8 (Procured Launch). Two satellites for international customers (AGILE and TECSAR) were launched on commercial basis by PSLV-C8 and PSLV-C10. In addition two state-of-the-art communication satellites (W2M and HYLAS) were built for European customers. Further, four major on-going missions are getting ready for launch

before the closure of the 11th Plan viz. PSLV-C18/Megha-Tropiques and PSLV-C19/RISAT-1.

During 11th Plan, a total of 27 missions have already been accomplished (15 satellite missions and 12 launch vehicle missions). Keeping in view the progress of on-going missions, another 4 missions (2 satellite missions and 2 launch vehicle missions) are realizable before March 2012. Hence a total of 31 missions are likely to be achieved during the 11th Plan Period as compared to 20 missions accomplished during 10th Plan. In addition, substantial progress has been made towards realization of ongoing missions such as INSAT-4/GSAT-series, INSAT-3D/3DR, GSAT-11, GISAT, CHANDRAYAAN-2, ASTROSAT, IRNSS, SARAL and ADITYA-1.

Besides this, several societal application missions such as Tele-education (over 55,000 EDUSAT classrooms established), Tele-medicine (382 Hospitals provided with Tele-medicine facility), Village Resource Centres (set up in 473 locations), space based Potential Fish Zone mapping benefitting the fishermen community of coastal areas, locating drinking water sources using IRS imageries covering more than 2 lakh habitations in ten States, Space technology based Disaster Management Support etc. have made significant contributions to the National Development.

12th Five Year Plan 2012-17 Proposals

12th Five Year Plan proposals have been formulated under the overall programmatic directions laid out by "Space Vision India 2025". Inputs generated by various committees/task forces on long term planning such as Earth Observation Strategy 2025 committee, The GSLV/ Satcom Strategy Review and Formulation Committee, Mars Mission Study Team, the PC-NNRMS deliberations etc. have been considered while formulating 12th Plan proposals. In addition, the broad directions for the 12th plan brought out in the approach paper by Planning Commission have also been suitably taken into account.

In the area of Satellite Communications, the approach to plan preparation for the 12th FYP for has been to augment the INSAT capacity to bridge the gap between the demand and supply of the transponders for meeting all the requirements of the country and also to maintain sufficient spares capacity to

meet contingencies. Development of state of the art technologies and latest applications areas shall also be pursued.

In order to accommodate the projected demand for 794 transponders from the operational transponder capacity of 198 from INSAT/GSAT satellites at the end of 11th FYP, 14 communication satellites are planned to be realised during the 12th Plan period for (a) increasing the transponder capacity (b) introducing new generation broadband VSAT systems (c) introduction of Ka band systems (d) building high power S-band satellite mobile communications and (e) introduction of new generation geo-imaging satellite.

In terms of spacecraft platforms, it is planned adopt I-2K, I-3K and I-4K buses for the communication satellites. I-3K and I-4K buses are planned to be launched using procured foreign launcher. It is also planned to initiate development of High throughput I-6K – 12KW bus in higher frequency bands like Ka/Ku and the technologies associated with it.

Maintaining and securing sufficient orbit-spectrum resources for country's Satcom activities will be a thrust area of 12th Plan. It has been planned to pursue rigorously to secure spectrum for 100 additional Ku-band transponders and around 50 C-band/Ext C-band transponders in newer orbital locations.

Satellite based Navigation service is an emerging satellite based system with commercial and applications. Establishment of an independent Indian Regional Navigation Satellite System (IRNSS) over Indian region, Implementation of the final operational phase for satellite based augmentation system (SBAS) GAGAN (GPS Aided Geo Augmented Navigation) over the Indian Airspace are important targets for 12th Plan. Formulation of Indian Satellite Navigation Policy to facilitate growth of Satellite based navigation application will also be pursued.

The thrust areas of **Earth Observation and Atmospheric Sciences Programme** for the 12th Plan will be on continuation of established services with improved capabilities with three thematic series of Indian EO satellites i.e. Natural resources, Cartography and Ocean & atmosphere, including all-weather capability; development of newer state of the art capabilities to meet specific user requirements; augmentation of ground segments for effective

utilization of the various sensors; and special emphasis application missions in the areas of agriculture, environment, large scale mapping, infrastructure planning, oceanography, climate and atmospheric studies. To achieve the above, eight Earth Observation missions are planned during the 12th Five Year Plan. With the realization of these missions, there would be significant improvements in the areas of short term weather and ocean state forecasting, natural resources management, high resolution cartography, large scale mapping, space based Essential Climate Variables (ECVs) with enhanced spatial, spectral, radiometric and temporal resolution.

The **Disaster Management Support (DMS) Programme** of ISRO is intended to provide near real time information support and services from imaging and communication satellites towards efficient management of disasters in the country. Major programmatic targets of DMS programme during 12th Five Year Plan will be Operationalization of National Database for Emergency Management (NDEM), Continuation of impact mapping and monitoring of natural disasters with improved turnaround time and with newer capabilities, acquisition of close contour data through ALTM, extension of the communication network to the District Emergency Operation centres, geo-location based services such as Search & Rescue and distress alerts, operational dissemination of the information and products directly to the affected areas, Operational utilization of early warning systems and extension of the Hydro-meteorological network.

The main focus of the **Space Transportation Systems** during 12th plan period will be towards achieving self-sufficiency in launching our satellites, developing launch vehicles for enhanced payload capability, adopting appropriate outsourcing strategies for assuring productionisation of launch vehicles, enhancement of infrastructure for launch vehicles and developing advanced technologies for the future. Towards this, enhancement of level of production of PSLV Vehicle systems with vigorous industry participation, completion of qualification of indigenous Cryogenic Upper Stage (CUS), proving GSLV, with indigenous cryogenic stage, as a reliable workhorse launch vehicle, Completion of development and qualification of C25 Engine & Stage, completion of development flights of GSLV MkIII with 4.0 T GTO capability, progress on the development of Semi cryogenic engine with the establishment of test facilities, augmentation spaceport infrastructure to meet the launch

vehicle requirements shall be pursued. During the 12th Plan period, 17 PSLV missions, 6 GSLV MK-II missions and 2 GSLV MK-III missions (this also includes one experimental mission) are planned to be accomplished.

Space Sciences & Planetary Exploration missions contribute significantly towards understanding the mysteries of the universe, our existence and provide an opportunity towards development of cutting edge technologies. Through space science investigations, we seek to understand the processes governing solar radiation, evolution of planetary system, formation of galaxies, evolution of stellar systems and the universe. Missions initiated during the 11th Plan such as Chandrayaan-2, Astrosat-1 and Aditya-1 will be realised in 12th plan. Undertaking India's First Mission to MARS will be an important milestone during the 12th Plan. In addition, an X-Ray polarimeter (POLIX) to study the x-ray polarization from bright x-ray emitting objects shall also be pursued.

Overall Mission Profile and Outlay

For 12th Five Year Plan 2012-2017, a total of 58 missions are projected to be undertaken which includes 33 satellite missions and 25 launch vehicle missions. Out of the 33 satellite missions, three missions viz. Cartosat-2C, Cartosat-2D and GSAT-7 are to be funded by user agencies. Considering the immediate pressing need to augment the transponder capacity of INSAT/GSAT system and the availability of GSLV-MK II and development status of GSLV-MK III, the Department has opted for availing procured launch services for few communication satellites.

The financial resource requirements for the missions planned for 12th Five Year Plan as well as for advance investments required for the missions to be realised during the early phase of 13th Plan works out to ₹ 55,000 Cr at current (2011-12) prices. (Provisional)

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1. Introduction

1.1. Since the inception, the primary objective of the Indian Space Programme resonated with the vision of Dr.Vikram A Sarabhai mandating the utilization of complex technologies like space for finding solutions to the real problems of common man. This vision has been shared, sustained, enriched and carried forward as it evolved over the past five decades. Today, the fruits of space research are reaching the common people and society, touching their daily life, be it a fisherman, a farmer, a student, a patient from a remote area, an administrator or a policy maker.

1.2. The Indian Space Programme saw its first ray of light in the early 60's in a Church building in a tiny fisherman hamlet in Thumba near Thiruvananthapuram with the setting up of Thumba Equatorial Rocket Launch Station (TERLS). The initial years were dedicated towards scientific experiments using sounding rockets, indigenous development of sounding rockets and dedication of TERLS to the United Nations.

1.3. The significant milestones of the 70's were (a) demonstration of the efficacy of satellite for developmental communication, (b) use of remote sensing techniques for study of natural resources,(c) realisation of India's experimental satellites Aryabhatta and Bhaskara-1 flown on Soviet launchers. Successful flight testing of Satellite Launch Vehicle SLV-3 in 1980 as well as development of satellites for Earth Observation (Bhaskara-II) and for Communication (APPLE) that were launched in 1981 marked the culmination of the experimental phase.

1.4. The Indian National Satellite (INSAT) System, the Indian Remote Sensing Satellite Constellation (IRS series), the National Natural Resources Management System (NNRMS) as well as undertaking development of the Polar Satellite Launch Vehicle (PSLV) and Geosynchronous Satellite Launch Vehicle (GSLV) *(and their forerunner ASLV)* were the cornerstones of the operational phase of Indian Space Programme during the 80's and 90's.

1.5. During the last decade, India emerged as a significant player in the comity of space faring nations with the capability of building and launching satellites to both Polar sun-synchronous and Geo-synchronous transfer orbits.

> *Today ISRO is credited with: (a) realisation of 34 launch vehicle missions (including 7 failed missions); (b)successful realisation of 62 Satellites (including 5 INSAT-1 Satellites built abroad to our specifications), (c) building of 2 satellites for foreign customers and (d) launching of 26 foreign satellites by PSLV.*

1.6. India has evolved as the role model for the world in the area of space applications; one amongst six in the world with capability to make satellites and launch them; one of the four with demonstrated capability for re-entry of spacecraft; presumably the first one to launch 10 satellites in one single mission and launched the CHANDRAYAAN-1 satellite that facilitated the major discovery of water molecules and water ice on the lunar surface.

1.7. The Indian Space Programme is poised for further accomplishments in its programmatic aspirations and taking the ISRO saga forward. The next decades appear more promising and challenging with increased number of missions and newer technology developments.

1.8. A comprehensive planning would determine where the nation's space technological capabilities are going over the next five years, how it's going to get there and what impact it would bring about for the benefit of the nation. The focus of such a strategic plan is usually on the entire gamut of activities that encompass a space system. There are a variety of perspectives, models and approaches that has been used in bringing out this planning document, considering the strategic nature of the department, culture of the department, complexity and size of the department in view of the blend of R&D and missions in the horizon of its activities.

1.9. This planning document accords all elements of the multi-dimensional ISRO activities, taking cognizance of the recommendations of several user communities or Strategy defining committees.

1.10. The Hon. Prime Minister of India outlined the future directions for the Indian Space Programme during his address of March 24, 2011 to the ISRO/DOS community. Excerpts are reproduced below:

"Having achieved so much, it is important that we look ahead and plan for the future.

Dr. Vikram Sarabhai had once said and I quote "Technology is not an objective to be aimed at, but a tool to be used for the benefit of the common man," unquote. I believe it is important for ISRO to concentrate its resources and evolve a perspective plan for its future development that is based on clearly defined objectives and benefits.

Large scale poverty is the foremost challenge facing our country. The unfortunate truth is that the fruits of our growth are not equally shared among different segments of our society. We have to be acutely conscious of regional disparities and imbalances within the country, and address the inequalities that exist.

Space based applications are a very potent means of bridging these divides in our society. It is therefore necessary that we work towards reducing the cost of access to space. This requires expediting the development of heavy lift launchers, advanced propulsion systems, including the cryogenic stage, and recoverable and reusable launch systems. We should pay greater attention to the Geosynchronous Satellite Launch Vehicle Programme.

Food security and self-sufficiency in agriculture, particularly paying special attention to the needs of the small and marginal farmers, remains yet another fundamental goal.

In such a scenario, managing the environment and tackling climate change will be major challenges. Our disaster warning and response capabilities will have a major impact on livelihood security for our people. The role of space based observation systems, development of newer class of environment and monitoring sensors and study of weather related phenomena assume great importance in this regard.

Taken together, the space programme has a vital role to play in making the concept of sustainable development a reality.

The other major goal before us is the socio-economic empowerment of our people. The Satellite Instructional Television Experiment, which was the brainchild of this Centre, demonstrated for the first time how space technology could be used for broadcasting and for reaching the benefits of education to the village level"

"Although we have come a long way since then, there is much more that needs to be done. Tele-education, tele-medicine and Village Resource Centre services deserve high priority. ISRO's contribution to the monitoring of programmes like the Mahatma Gandhi National Rural Employment Guarantee Scheme, the Accelerated Benefit Irrigation Programme and Bharat Nirman is laudable. "

Empowerment requires that we ensure space services are available to all sections of society. Access to information should be easy. In the years ahead ISRO should make a conscious effort to reach out to beneficiaries and consumers of space products so that they can extract maximum advantage from the technology that is available in the country.

The information and communications revolution is upon us. It is changing the lives of millions of our people across cities, towns and villages faster than we could have imagined. This transformation has been made possible in large measure due to the space infrastructure you have built. We should aim to master newer technologies for more sophisticated communication satellites. For example, satellite based broadband internet services could bring about a new technological revolution that directly benefits rural and remote areas.

I am glad that ISRO is aiming to achieve self-reliance in the area of navigation through the Indian Regional Navigation Satellite System. This will enable secure transport and better air traffic management and search and rescue operations.

I have referred earlier to the spirit of scientific inquiry. We will do all that is necessary to promote scientific discoveries, and for ISRO to remain at the cutting edge of technology. You will have the government's support in your quest to better understand the solar system and universe and in the continuing discovery of space"

As our economy expands, there will be growing pressure on our resources, whether it is land, water or minerals. Remote sensing applications for such purposes will be critical. Simultaneously, the processes of urbanization will gather speed and we will have to face the challenge of management of urbanization."

Expanding horizons of Indian Space Programme

1.11 In the years to come, India will look forward to sustain its rightful place as the leading space faring nation and to take leadership in a few niche areas. Today's knowledge based society demands information generation and dissemination to various strata of society to improve the quality of life. The space infrastructure would prove to be the ideal medium for meeting this

demand. ISRO would also engage and collaborate in Space science and Planetary exploratory missions guided by compelling scientific inquisition by pursuing breakthrough technologies, embracing the challenge of developing reliable, self-reliant and cost effective space infrastructure.

1.12 In the Expanding Horizons of Indian Space Programme (as depicted in Figure 1.1), the Space Based Application Programme remains the substratum of the entire gamut of activities supporting the National imperatives of social security. Also, there will be continued focus on Low cost access to space in a self-reliant manner. Operational space assets are to be maintained and protected for optimum operational lives while newer initiatives would be mounted in the domains of space exploration and inter-planetary mission in the quest of technology development and enhancing scientific knowledge-base in the country.

1.13 Under such ever changing scenarios, the priorities of the Space Programme would be -

(i) To contribute towards the national endeavours in food and water security, weather and climate, environment and ecosystem, education and health care, skill development, rural communication, infrastructure development, disaster management support, smart governance, sustainable development and related national imperatives through space application programmes;

(ii) To create, sustain and manage operational space assets with the participation of Indian industry as a risk-sharing partner for the production of such assets;

(iii) To develop newer capabilities towards (a) low cost access to space; (b) contribute to answering fundamental scientific quests; (c) scientific exploration of Earth as a total system, Moon, Mars and beyond in the solar system; (d) critical technologies related to human space flight programme, eventually leading to human presence in solar system ensuring synergy of national capabilities and international cooperation and

(iv) To facilitate advanced research in conjunction with academia on cutting-edge technologies with a target to make India a technology-leader in certain niches.

Figure 1.1: EXPANDING HORIZONS OF INDIAN SPACE ENDEAVOUR

1.10 Considering the importance of self-reliance, strategic technology like space and also considering the impact that it brings to the societal application programmes, feedback has been received from several stake holder agencies. Such feedback from user agencies (Planning Commission, National Natural Resource Management System, INSAT Co-ordination Committee etc.) has been given utmost priority in drafting this document.

The spill-over missions from the 11th Five Year Plan has been reviewed carefully before including into the 12th Plan. Some of these missions have also been assigned priority for completion within the 12th plan.

Under 12th Five Year Plan, 25 launch vehicle missions and 33 spacecraft missions are envisaged with a number of facility/infrastructure developments and technology demonstrating missions. The total proposed outlay for the 12th plan is ₹ 55,000 Cr with a Plan component of ₹47,500 Cr and non-Plan component of ₹ 7,500 Cr.

2. Performance Appraisal of 11th Five Year Plan

Programmatic targets

2.1 The overall direction of the Indian Space programme during 11th Plan was to sustain and strengthen the already established space based services towards socio-economic development of the country. Major thrust areas have been development of next generation heavy lift launch vehicle GSLV-MK III; critical technologies for the human spaceflight programme; Competitive and state-of-the-art space segment augmentation in INSAT/GSAT system; ensuring continuity of data with enhanced capabilities through constellation of earth observation satellites; undertaking space science and planetary exploration missions; strengthening space-based disaster management support; atmospheric research programme and societal applications.

A total of 60 missions were planned during the 11th plan period which included 32 satellite missions and 28 launch vehicle missions. Figure - 2.1 gives an overview of the targets in terms of new technologies to be developed, capacity augmentation and missions to be accomplished during the 11th Plan.

Accomplishments during the 11th Plan

2.2 During the first four and half years of the 11th plan, Indian space programme witnessed several major successes and achieved greater heights. The successful launch of Chandrayaan-1 on-board PSLV-C11, a historic feat of placing Indian tri-colour on lunar surface and detection of water molecules on Moon surface were the most significant events.

2.3 The other important space endeavours were launching of TEN satellites (including CARTOSAT-2A and IMS-1) in a single launch of PSLV-C9, launch of Microwave Radar Satellite (RISAT-2) and Mini Satellite ANUSAT on-board PSLV-C12, OCEANSAT-2 and six nano-satellites onboard PSLV-C14; CARTOSAT-2B, ALSAT-2A, NLS 6.1 & 6.2 and STUDSAT on board PSLV-C15, RESOURCESAT-2, YOUTHSAT and X-SAT on-board PSLV-C16. The INSAT/GSAT system was further augmented with the launch of INSAT-4CR (on-board GSLV-F04), GSAT-12 (on-board PSLV-C17) and

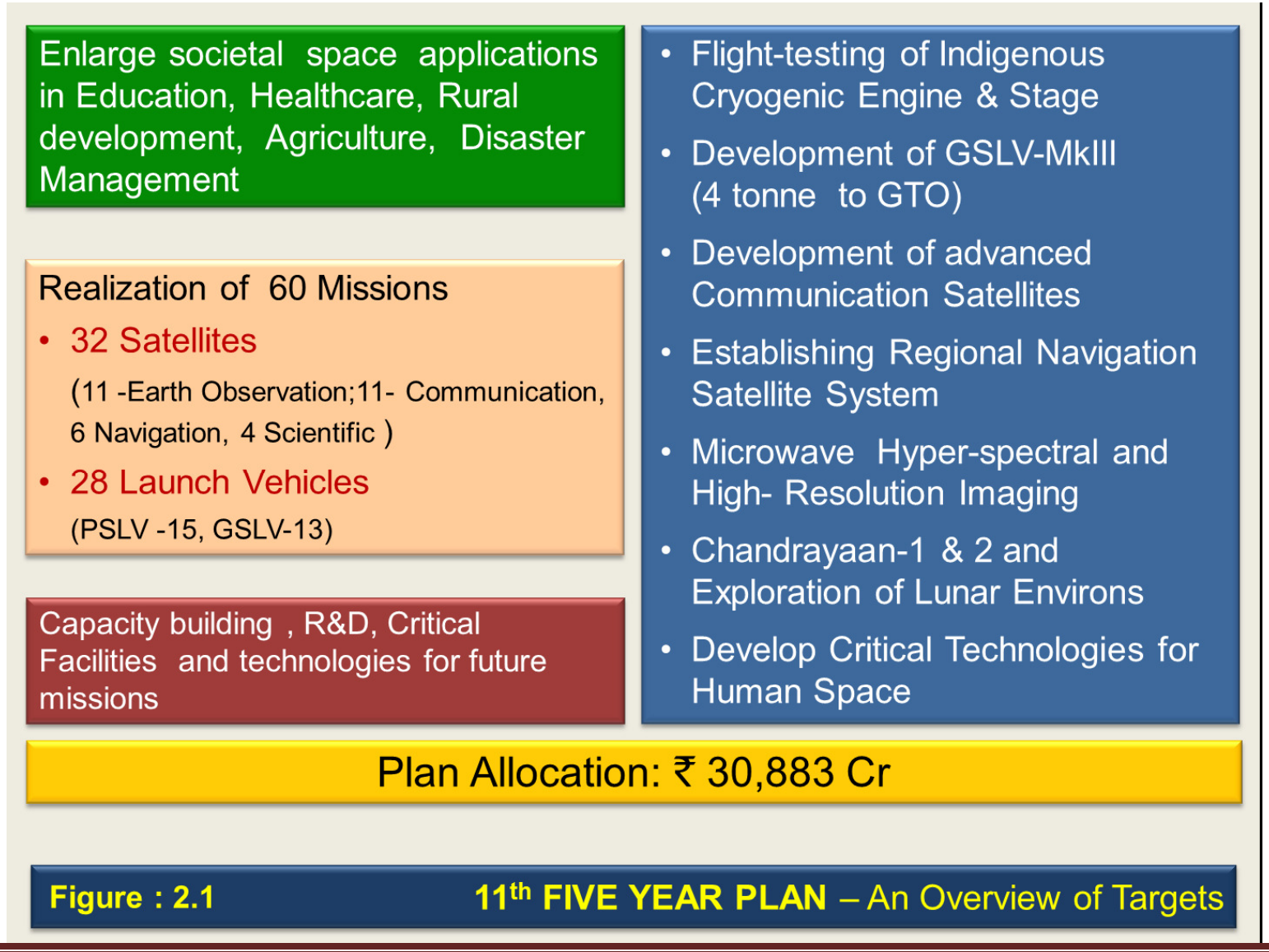


Figure : 2.1 **11th FIVE YEAR PLAN** – An Overview of Targets

GSAT-8 (Procured Launch). Two satellites for international customers (AGILE and TECSAR) were launched on commercial basis by PSLV-C8 and PSLV-C10. In addition two state-of-the-art communication satellites (W2M and HYLAS) were built for European customers. Further, two major on-going missions are getting ready for launch before the closure of the 11th Plan viz. PSLV-C18/Megha-Tropiques and PSLV-C19/RISAT-1.

2.4 During 11th Plan, a total of 27 missions have already been accomplished (15 spacecraft missions and 12 launch vehicle missions). Keeping in view the progress of on-going missions, another 4 missions (2 spacecraft missions and 2 launch vehicle missions) are realizable before March 2012. Hence a total of 31 missions are likely to be achieved during the 11th Plan Period. As compared to 20 missions accomplished during 10th Plan, there was a 55% increase in number of missions accomplished during the 11th Plan. Figure 2.2 depicts the missions accomplished upto September 2011 and missions planned to be achieved during the remaining period of the 11th Plan.

2.5 The work on other on-going missions projected for 12th Plan such as INSAT-4/GSAT-series, INSAT-3D, INSAT-3DR, GSAT-11, GISAT, CHANDRAYAAN-2, ASTROSAT, IRNSS, SARAL, SRE-2 and ADITYA-1 is in various stages of realization. These missions are expected to be accomplished during the early phases of 12th Plan.

2.6 The work on establishment of GEO Aided GPS Augmented Navigation System (GAGAN) has been initiated in collaboration with Airport Authority of India to provide Satellite-based Navigation services and better air traffic management over Indian air Space.

2.7 Besides this, the development of next generation advanced launch vehicle, GSLV Mk III, has made significant progress during the plan period with the successful commissioning of a world class Solid Propellant Plant (SPP) and other specialized test and fabrication facilities required for the programme. Static tests have been conducted to qualify Solid (S-200), and Liquid (L110) stages. The development of C25 Cryogenic stage, which is critical for the development of GSLV-MK III, is also progressing well.

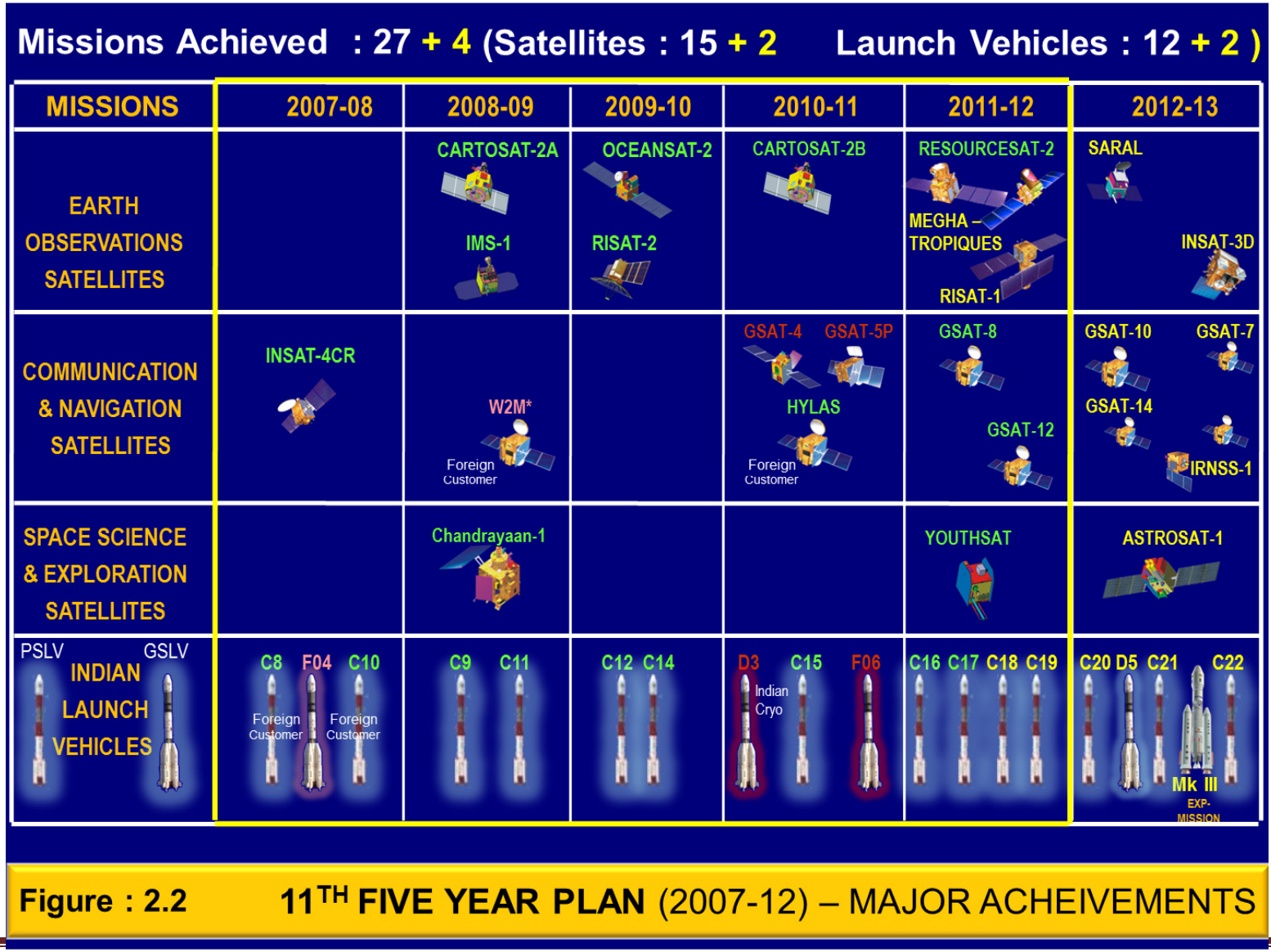


Figure : 2.2 **11TH FIVE YEAR PLAN** (2007-12) – MAJOR ACHEIVEMENTS

2.8 The development of higher thrust Semi-cryogenic engine (with Liquid oxygen as oxidiser and aviation grade Kerosene as fuel) which forms the core stage of future vehicles has also been initiated. The design of the engine, development of a single element pre-burner and demonstration of ignition, design of test facilities have been completed during this Plan.

2.9 In the area of Space Science and Planetary exploration, a study report on the feasibility of undertaking a planned Mission to Mars has been completed. As per the study report, it is feasible to undertake Indian's first mission to Mars during the 12th Plan.

2.10 Detailed feasibility studies on undertaking indigenous human spaceflight mission have been carried out. During the mid-term appraisal of the 11th Plan, it was felt prudent to implement the programme in a phased manner considering the magnitude of complexities and developmental efforts involved. The Department will continue the activities related to development of critical technologies required for the successful culmination of the programme which envisages carrying humans to low earth orbit and their safe return to earth.

2.11 R & D activities on advanced launch vehicle technologies including Air breathing propulsion and Reusable Launch Vehicle Technology Demonstrator have been initiated during the 11th Plan.

2.12 Realisation of Hypersonic Wind Tunnel (HWT) facilities consisting of 1m HWT and 1m shock tunnel for aero thermal and aerodynamic characterization of advanced launch vehicles such as RLV, TSTO and re-entry vehicles has been accomplished.

2.13 During the 11th Plan, Indian Institute of Space Science & Technology (IIST) has been set-up at Trivandrum, Kerala in order to create quality scientific human resource tuned to suit the requirements of state-of-the-art space research programme.

2.14 As envisaged during the mid-term appraisal, Remote Sensing Data Policy 2011 has been brought out enabling dissemination of high resolution data to concerned users in a timely manner.

2.15 This apart, several initiatives on the societal applications of space technology such as Tele-education (over 55,000 EDUSAT classrooms established), Tele-medicine (382 Hospitals provided with Tele-medicine facility), Village Resource Centres (set up in 473 locations), space based Potential Fish Zone mapping benefitting the fishermen community of coastal areas, locating drinking water sources using IRS imageries covering more than 2 lakh habitations in ten States, Wasteland mapping and time series analysis to reclaim wastelands and improve productivity of the whole country using IRS data for development of waste lands, Space technology based Disaster Management Support etc. have made significant contributions to the National Development.

2.16 A detailed account of accomplishments of the Department vis-a-vis the targets set for the 11th Five Year Plan is given in Appendix-1.

Mission failure& recovery plan

2.17 During the 11th FYP there were failures of 2 Geo-synchronous Satellite Launch Vehicle (GSLV) flights viz. GSLV-D3 with Indigenous Cryogenic Stage during April, 2010 and GSLV-F06 with Russian Cryogenic Stage during December, 2010.

2.18 The GSLV-D3 mission failed as the Indigenous Cryogenic engine after its ignition couldn't sustain the combustion beyond 1 second. Based on the recommendations of the Failure Analysis Committee, comprehensive test procedures to verify the health of all flight systems/ components of the Indigenous Cryogenic Stage have been introduced.

2.19 The reason for the unsuccessful launch of GSLV-F06 has been the untimely and inadvertent snapping of a group of 10 connectors located at the bottom portion (shroud) of the Russian Cryogenic Stage. Based on the recommendations of the Failure Analysis Committee, redesign of the shroud, revisit of the connector mounting scheme, additional wind tunnel testing etc. are being addressed.

2.20 In addition, a seven member "GSLV Programme Review and Strategy Formulation Committee" under the chairmanship of Dr. K. Kasturirangan, was constituted to look into the future of the GSLV Programme and the strategies for meeting the demands of communication transponders in the

immediate future. The recommendations of this committee are getting implemented in the 12th plan formulation.

Mid-Term appraisal

2.21 During Mid-Term Appraisal of 11th Plan in September 2009, the following mid-course corrections were effected:

(a) Considering the technological complexities involved and the magnitude of efforts required in realising the Human Spaceflight Programme (HSP), it was planned to realize the HSP in phases with focus on developing critical technologies in the first phase.

(b) In order to facilitate the Department of Space to provide high resolution data in time to concerned users, it was planned to put in place suitable mechanisms and to revisit the policy frameworks to consider whether high resolution data (at least up to 2.5 metre resolution) can be made available to users in a timely manner.

(c) For ISRO to retain an R&D character at the organization level, it is important to farm out production jobs to industries in the wake up enhanced throughput requirement of satellites and launch vehicles (From 20 missions in the 10th Plan to 60 missions during 11th Plan). In this direction, strategies to achieve a quantum jump in Industry participation may, therefore, be worked out in the coming years.

(d) Space science research/planetary exploration programme has been an important component of the Indian Space Programme and several missions including Chandrayaan-2 and ASTROSAT have been planned in the coming years. Akin to this, a major challenge lies in creating a human resource base in the country for analysing the enormous amount of scientific data that would be available from these missions. There is a need to adopt aggressive measures in this direction to ensure availability of scientists in the area of space science and planetary exploration.

Spillover Missions to 12th Five Year Plan

Owing to the development complexity, realization of some of the mission planned for 11th Plan, have spilled over to the 12th Plan. These primarily relate to navigation satellites, development of new generation launch vehicle GSLV Mk III, operational flights of GSLV, Chandrayaan-2 etc.

(a) One of the major targets for 11th Plan was to establish Indian Regional Navigational Satellite System with a constellation of seven satellites. Considerable progress has been achieved in realizing the various subsystems of these satellites. However, the delay in realizing this satellite system were mainly attributed to the procurement of the Atomic clocks from foreign sources and the technological complexities of the system requiring several levels of qualification and testing. This resulted in spillover of 7 satellites and 7 PSLV missions to the 12th Plan.

(b) During the 11th plan 13 GSLV missions were planned of which only three were attempted. This was primarily due to the failure of two GSLV missions (GSLV-D3and GSLV-F06) which necessitated corrective actions related to redesign and additional testing of some of the vehicle level elements.

(c) Similarly, due to technological complexities involved in realizing the new generation launch vehicle GSLV Mk-III, the first developmental flight could not be taken up. However, considerable progress has been made in realizing two major propulsion modules (S200 and L110) and various elements of the launch vehicle.

(d) Another important target was the realization of India's second mission to moon - Chandrayaan-2. However, the important discoveries made by Chandrayaan-1, necessitated a revision of the final selection of scientific instruments to be flown in this mission.

Financial Performance

2.22 The total Indicative Outlay for Space programme for 11th five year plan was ₹ 34,883 Cr with a plan component of ₹ 30,883 Cr and non-Plan component of ₹ 4,000 Cr. However, based on the annual plan outlay allocated to the Department, the final plan outlay likely to be made available for the department during 11th plan would be around ₹ 21,580 Cr (Plan: ₹ 18,100 Cr; Non-plan: ₹ 3,480 Cr). Accordingly, some of the activities related to programmes/projects such as Manned Mission Initiative, Chandrayaan-2, Resourcesat-3, Cartosat-3, GSAT-13 & 14, IRNSS etc. have been phased out to 12th Five Year Plan.

Performance appraisal of 11th plan
Highlights of achievements

- **Chandrayaan-1** - The successful launch of Chandrayaan-1, first Indian Lunar Mission. Scientific data from Chandrayaan-1 led to breakthrough discoveries - detection of Hydroxyl (OH) and Water (H2O) molecule on lunar surface.
- **Indigenous Cryogenic Upper Stage** - In-flight testing in GSLV-D3 flight.
- **Missions Accomplished** - 27 accomplished, 4 more targeted before end of 11th Plan. A total of 31 missions likely to be achieved during 11th Plan – 55% increase compared to 10th Plan.
- **Space Transportation** - 11 PSLV and 3 GSLV launches accomplished – PSLV-C9 mission carried TEN satellites in a single launch.
- **Development of advanced heavy lift launcher GSLV Mk III** - Commissioning of large solid propellant booster plant, Static tests of Solid Stage (S-200) and Liquid stage (L-110). Realisation of C25 subsystems in progress.
- **IRS system** – Six Remote Sensing Satellites added
- **INSAT/GSAT System** - 3 communication satellites added – present transponder capacity- 187
- **Satellite Navigation System**- Technology Demonstration Phase of GAGAN (GPS and Geo Augmented Navigation) system successfully completed. Position accuracies of better than 10 meters demonstrated.
- **Advanced technology initiatives** – Development of critical technologies for Human Space Flight programme, Reusable Launch Vehicle - Technology Demonstrator (RLV-TD), Semi-cryogenic engine development, Air-breathing propulsion system.
- **Capacity Building** - Indian Institute of Space Science and Technology (IIST) established during the academic year 2007-08. The first batch of graduates from IIST was inducted into various ISRO centres in August 2011.
- **Space Application** - Nation-wide land use / land cover mapping for Natural Resources Census, creation of Natural Resource Data Base, Thematic mapping for National Urban Information System, Wasteland mapping and monitoring, locating potential drinking water zones, Potential fishing zone advisories for fishermen, Crop area and production forecasting.
- **Space commerce** - two communication satellites (W2M and HYLAS) realised for foreign customers; Launch of 20 satellites for international customers on a commercial basis using PSLV.
- Information portal – **BHUVAN** operationalized.

3. PROGRAMME DIRECTIONS 2025

3.1 The guiding vision for the Indian Space Programme, from the very inception has been to be *'second to none*' in the development of space technology and its applications to solve the real problems of man and society. The emphasis on self-reliance has been an important component of the vision, with which India undertook development of satellites, launch vehicles and associated ground segment indigenously in a progressive manner. Today, India's core competence in space is its ability to conceive, design, build and operate complex space systems and use them in various frontiers of national development. India today has developed two operational space systems namely IRS (Indian Remote Sensing) and INSAT (Indian National Satellite System) satellites and capability to launch them through PSLV (Polar Satellite Launch Vehicle) and GSLV (Geo-stationary Satellite Launch Vehicle). India has used the space systems for development of the country through application programmes such as Tele-education, Tele-medicine and Village Resource Centers (VRC). India has also taken initiatives in space exploration missions such as Chandrayaan-1. The space technology institutions/centres created in the country and the overall system/project management practices evolved in the course of implementation have been vital outcomes of the space programme.

3.2 With the maturity and self-reliance in space technology achieved by ISRO, the next phase of vision of space for India for 2025 has been laid out.

- Operational services in communications and navigation.
- Enhanced imaging capability for natural resource management, weather and climate change studies.
- Space science missions to better understand the solar system and universe.
- Planetary exploratory missions
- Development of heavy lift launcher
- Reusable launch vehicles – technology demonstrator missions leading to Two Stage to Orbit (TSTO)
- Critical technology development for Indian Manned Space Mission.

3.3 Space technology is a powerful catalyst for social development in the areas of natural resource management, food security, rural development, education and literacy, health-care and environment. Innovations in space based communications and earth observations will be perused to achieve faster delivery of information to remote areas and finer observation of planet earth.

3.4 Operational services in communications and navigation.

3.4.1 Satellite communication continues to play a key role in broadcasting, VSAT communication, last-mile connectivity in remote locations and islands, etc. Advance coding and compression technologies are making the satellite communication very reliable and cost effective. Satellite bus technologies are also seeing major improvements with the adaptation of technologies like Ion propulsions, unfurlable antennas, multi-beams, spot-beams, higher frequency bands, etc. ISRO is taking a lead role in developing advanced technologies for both satellite and ground systems and generate an extensive R&D base in the country through the participation of industry and academic institutions. Specific agenda are set to transform India into a vibrant satellite communication and navigation industrial base in the world and invite international participation.

3.4.2 **Continuity of Services:** The satellite communication shall provide for continuity of traditional services like Broadcasting, Telecommunication, Broadband, Satellite Navigation, Meteorological Imaging and Data collection etc. through INSAT, GSAT and METSAT Missions and shall also meet the broad objective of reaching the un-reached.

3.4.3 **Enhancement of Satellite Capacity** through

(a) Moving to higher frequency bands like Ku, Ka and V/Q bands and high power transmissions through multi-beams with spectrum reuse to meet the fast-growing demand for the bandwidth.

(b) Adoption of regenerative transponders capable of on-board switching and multiplexing and increasing the data carrying capacity by several orders (about 15 to 20 times) by advanced coding techniques.

(c) Separation of satellite system into bus-module and energy-modules so that the energy-modules periodically replaced and the life cycle of the bus-module is increased substantially.

(d) Satellite as major switching station with multiple spot beams and large unfurlable/reconfigurable antenna systems, making the satellite communication a highly reliable, ubiquitous and cost effective option.

(e) Independent satellite navigation constellation and exploitation of the existence of a large number of navigation satellites over the Indian sky.

(f) Adoption of technologies for jam-proof and encrypted communications.

(g) Use of ion thrusters to enhance the on-orbit life of satellites.

(h) Inter-satellite communication between GEO - GEO to achieve inter-continental connectivity and between GEO - LEO to address the requirements of remote sensing satellites data to be brought to a centralized processing facility without establishment of multiple ground stations.

(i) Aero-mobile communication to provide internet and telecom access to air passengers.

(j) Efforts to secure required orbital slots and spectrum assets for the country.

3.4.4 **Satellite Communication Applications**

(a) Direct To Home (DTH) and triple play (high speed internet, high speed multimedia, high speed broadband wireless access) services, with personalized access to the entertainment user-segment; stationary and mobile.

(b) Anytime and anywhere connectivity to provide access to emerging business applications with encryption to meet the demands of business user-segment.

(c) Facilitate enhanced meteorological data dissemination to support disaster management and mitigation through high performance meteorological payloads/satellites. Achieve enhanced capability in satellite aided search and rescue operations through increased international participation.

(d) Provide low cost telecom, weather and Geographical Information Systems to all villages and remote areas of the country to meet the emergency and disaster management communications without loss of time, using space platforms.

(e) Provide high accuracy satellite based positioning, navigation and timing service over the Indian sub-continent, through Indian and other Navigation Satellites over the Indian sky by integrating their performance in a state-of-the-art GNSS receiver. Integrate the Position, navigation and Timing (PNT) service into low cost mobile handsets with indoor positioning capability.

(f) Medium earth orbit (20,000 km) based search and rescue ground systems development.

(g) Ground based observation system for GEO satellite surveillance

(h) Expand developmental programmes including tele-education,tele-medicine and Village Resource Centres to the entire country by providing self-sustaining satellite based countrywide education and training network through the realization of dedicated satellites for societal applications.

3.5 Enhanced imaging capability for natural resource management, weather and climate change studies.

3.5.1 The relevance of Earth Observations (EO) from space has become more pertinent in recent years in view of growing concern on global well-being. There has been wider recognition that an improved understanding of the Earth System and its processes, particularly in understanding the non-linear land-air-ocean interactions in the light of anthropogenic interventions is important. A variety of instruments employing various measurements technology and techniques, both active and passive sensing have been flown on many space missions. There is a need to evolve constellations of small satellites, formation flights, autonomous missions, intelligent networking, event driven observations, sensor web, data mining/ fusion, on-board processing, quantitative remote sensing etc. to meet such requirements.

3.5.2 With the ever-increasing advances in EO technologies and techniques, ISRO recognizes the importance of seamlessly integrating them with applications covering in the public good, commercial and strategic needs of the country. Vision for the Indian EO programme envisages “developing a self-reliant, multi-dimensional programme, providing operational services to the community, and striving to make these services as part of everybody’s day to day life.”

3.5.3 Strategy for Payload and Application

(a) Development of hyper-spectral sensors, atmospheric chemistry instruments, earth radiation budget radiometers, temperature and humidity sounders, cloud profilers, rain Radars, Lidars, synthetic aperture radiometer, multi-angular/polarization instruments, imaging microwave radiometers, advanced ocean color instruments, radar altimeters, scatterometers as well as various gravity magnetic field and geo-dynamic instruments.

(b) Monitoring global scale activities, sparsely populated deserts, mountains**,** forests, and polar regions; the mid and upper troposphere and stratosphere; measure the solar output, earth radiation budget, vegetation cover, ocean biomass productivity, atmospheric ozone, stratospheric water vapour and aerosols, greenhouse gas distributions, sea level and ocean interior, ocean surface conditions and winds, tropical precipitation and many more.

3.6 Atmospheric Observation Payloads

3.6.1 Atmospheric Science Programme envisages significant contribution to the national system by way of advanced satellite missions, institutionalize a fully automated ground observation network providing real time *in-situ* observations and develop fully evaluated modelling packages in the areas of now-casting, local weather forecast, cyclone track and intensity prediction.

(a) Development of hyper-spectral sensors for monitoring atmospheric dynamics, minor constituents etc.

(b) Active microwave systems such as rain radar, cloud radar, multi-channel radiometer, active optical systems such as Spaceborne Lidar, Differential Interferometer Active Lidar that will provide vital observations on atmospheric water vapour, profiles, wind and rainfall.

(c) A GPS occultation system with a constellation of satellites to generate adequate upper atmospheric profiles in the tropical region.

(d) Development of an advanced instrumented aircraft for in-depth study of cloud-development and related atmospheric processes.

(e) Developing a fully automated observation network integrating space and ground systems.

(f) Development of SMART sensors in future satellites that can detect severe weather events and trigger maximum observations from space and ground systems for monitoring and forecast

(g) A networked system to automate observations, monitoring and real-time warning by suitable integration of meteorological and communication satellites

(h) Establishing data centers for disseminating real time data from multiple sensors.

(i) Advanced modelling activity for development of operational packages for data assimilation from ground and space systems including direct assimilation of radiance in models towards improvement in now-casting, local specific forecasts and cyclone track and intensity prediction.

3.7 Environment and Climate

Development of combination of air and space borne LIDAR systems along with different types of ground and space based microwave radars to generate models for climate/global change phenomena using multi-platform observations and new technologies.

3.8 Satellite System and Services

- Deployment of polar orbiting RESOURCESAT/RISAT, CARTOSAT and OCEANSAT, experimental polar orbiting SARAL and Megha-Tropiques with low inclination orbit;
- Geo-stationary Metsat, Geo Imager and Sounder sensors on INSAT. It has also been planned to supplement these with improved geostationary imaging capability, technology experimental missions especially for microwave in L-band and millimeter wave, polarimetric radiometer, hyper-spectral, stereo-viewing and supplemented with aerial sensor delivery for disaster applications (X & C band SAR).
- Services like improving weather forecasting and warning, understanding and adapting to climate variability and change, periodic mapping of natural resources at various scales, information system and database creation for various natural resources, crop acreage and production estimation, soil moisture mapping, watershed development monitoring, command area monitoring, potential fishery zone mapping, monitoring of accelerated irrigation benefit programme, potential drinking water site identification, creation of spectral library for rocks & minerals, inter-linking of rivers, ocean salinity sensing,

monitoring of extreme events, support for urban and rural governance, rural road connectivity, etc.

3.9 Ground Systems

- Development of new applications combining imaging and non-imaging sensors and the geophysical parameters derived from them using suitable algorithms.
- Calibration and validation of sensors and optimum information extraction from the combined datasets are some of the emerging areas of interest. Advanced techniques in data fusion and in the data mining solutions are thrust areas for developments.
- Making use of advanced modelling techniques combined with advances in geo-spatial technology, for emerging EO applications.

3.10 Space Sciences

3.10.1 Space science missions to better understand the solar system and universe. The space science aims mainly to find solutions to numerous unresolved questions about the

(a) Evolution of the universe, galaxy, stellar and planetary systems and also the origin of life and intelligence,

(b) Effect of solar variability (solar wind, UV/EUV radiation) on the climate and weather of space and also direct or indirect impact on earth's meteorology/environment related processes.

In addition, the unique opportunities provided by the space platforms to conduct in-situ measurements or under the zero-g conditions of space would be used for understanding basic science related questions in plasma physics, material science, phase transitions, etc.

3.10.2 **Astronomy:**

- Continuation of ASTROSAT programme
- Advanced sensor/ detector development programme for fainter objects detection with better angular resolution.
- Small Satellites to carry out dedicated scientific research in the field of Astronomy and solar science

- Coordinated observations with a solar coronagraph and ground-based optical telescopes, radio telescopes such as the GMRT, ORT and the low frequency telescope at Gauribidanur for study of coronal mass ejections and the consequent space weather.
- The space borne solar coronagraph ADITYA-1in visible and near IR bands with polarimeter and spectrograph to study
    - Coronal waves and heating of the corona
    - Dynamics of Coronal loops: formation and evolution
    - Temperature diagnostics of the corona (using line ratio techniques)
    - Development and origin of CMES
    - Space weather Prediction
    - Topology of magnetic fields
- New initiatives related to X-ray astronomy with multi wavelength astronomy for development of
    - Soft X-ray, high-resolution spectroscopy with focusing optics and bolometer (5-10 years from date).
    - X-ray polarimeter (4-8 years).
    - A sensitive X-ray sky monitor (~5years).
    - A black hole monitor (~4-6 years).
    - High sensitivity hard X-ray experiment (6-8 years)

3.10.3 **Space Weather and Solar-Terrestrial Physics:** Space Weather is a manifestation of Sun-Earth relation. It refers to the conditions on the Sun and in the Solar Wind that can cause disturbances in the outer layers of the Earth's atmosphere. The main objective of this area is to achieve better quantitative estimates of influences of solar variability on the earth.

- *Small Satellites for Earth's Near-Space Environment (SENSE):* a twin-satellite mission to probe the electromagnetic environment of the Earth's near-space region. The mission proposes launch of two small satellites, namely, SENSE-P and SENSE-E, at low Earth orbits (~500 km), one with high inclination (~80º) and the other with an inclination of ~30º in order to realize multiple scientific goals such as study of the ionosphere-thermosphere system including electric field, current

system, ionospheric irregularities, ionospheric disturbances and neutral atmospheric structure and energetics.

- A dedicated mission to explore the inner Magnetosphere, Ring current zones, Plasmasphere, Plasmapause regions, etc.

3.10.4 **Micro-gravity science:** The SRE programme has been taken up as a series of launches catering to different types of small science/applications experiments which would provide the expertise and experience to carry out large scale experiments on-board Indian recoverable satellites.

- More experiments using μ-gravity capsule on the indigenous satellite system.
- Up-gradation of the balloon drop parachute system
- Development of advanced technologies to enable possible manned missions necessary for μ-gravity driven manufacturing projects.

3.11 Planetary exploratory missions

3.11.1 The primary focus of the planetary science / exploration programme beyond Chandrayaan-1 is governed by science aspects with the Basic theme of *"Understanding the Origin and Evolution of Solar System Objects"*. Additional objectives could be exploration of resources on Moon and Mars.

- Missions to Moon: Chandrayaan-2: To further our understanding of origin and evolution of the Moon with improved versions of Chandrayaan-1 instruments for imaging, mineralogy and chemistry; addition of alpha and neutron spectrometers in orbiter. Studies of lunar radiation environment including solar wind-magnetotail interactions.
- Mars Orbiter: with science goals of understanding Martian atmospheric processes and weather/dust storms; Martian ionosphere, effect of solar wind, surface magnetic fields, search for paleo-water and surface resources.
- Remote Sensing Asteroid Orbiter & Comet Flyby: with science goal of understanding evolution of asteroids and comets, early solar system processes, meteorite-asteroid connection, physical and chemical properties of asteroid and cometary material. Primary Target: 4 Vesta; Near-earth asteroid as an option.

- A Technology Demonstration Mission/ flyby to outer solar system
- Simulation experiments on processes to harness planetary resources for special minerals including deposits leading to energy generation, etc.

3.12 Space Transportation Systems

The currently operational expendable launch vehicles PSLV and GSLV are catering towards launching of 1.5 tonne class remote sensing and 2 tonne class communication satellites, for meeting the national requirements.

3.12.1 **Development of heavy lift launcher:** To reduce the cost of access to space, especially for communication satellites, it is required to launch satellites with large number of transponders. This requires development of space transportation system capable of keeping satellites in the order of 4 to 5 tonne in geo-transfer orbit. GSLV-Mk-III is being developed to meet this requirement. Besides meeting the requirements of the country, GSLV-MK-III, once developed and commissioned, will be able to fetch few International contracts, as 70% of the satellite-launches required globally fall in this weight-class.

3.12.2 Development of **Unified modular launch vehicle** to reduce the number of propulsion modules for all the three types of launch vehicles. This would mean that the core vehicle would be a standard configuration and depending on the payload mass to be delivered in orbit, the solid strapon-motors with different propellant loadings could be added.

3.12.3 Development of **semi cryogenic propulsion stage** as the first stage of the Unified modular launch vehicle and the heavier cryogenic stage as the upper stage to reduce the cost of launch.

3.13 Reusable launch vehicles – technology demonstrator missions leading to Two Stage to Orbit (TSTO)

3.13.1 The launch cost of the present expendable systems, is roughly in the range of 12,000 –15,000 $/ kg. To make the space exploitation more affordable, the cost of access to space needs to be substantially brought down by an order of magnitude.

- Development of technologies to make the systems recoverable and reusable and adopting advanced and efficient propulsion systems like air-breathing propulsion, use of semi-cryogenics are envisaged in order to bring down the per kg cost of the payload (vehicle hardware contributes 70% of the total cost of the launch vehicle).

- Development of newer Reusable Launch Vehicle technologies like aero thermodynamic characterization of wing body configuration at hypersonic speeds, reusable thermal protection systems, advanced lightweight materials, autonomous navigation, guidance and control systems, landing mechanisms, etc. are envisaged.

3.14 Human Space Flight

3.14.1 Indian Human Space programme is another very important initiative that has been taken up. Human spaceflight programme is a highly complex technological venture demanding multi-disciplinary expertise. This programme envisages design, development, validation of the space capsule and development of indigenous launch capability for carrying two member crew to low earth orbit and to return them safely to a predetermined destination on earth. This initiative will involve number of technical challenges like crew module design, environmental control and life support system, mission management with human in loop, crew escape system, launch pad related facilities and establishment of dedicated astronaut training facilities.

3.14.2 The understanding of the effect of human physiology and psychological systems under reduced gravitational force, atmospheric pressure and temperature in the space environment are very crucial to this mission. Space environment will induce short term and long-term harmful defects on the human body. The effective way of managing this is to design a capsule, which will negate this harmful effect. Crew safety is one of the important aspects which are to be addressed at every phase of the mission. The launch vehicle will have to be suitably human rated to be reliable and efficient.

3.14.3 This programme envisages setting up of large facilities for production of hardware, testing and qualification and this is expected to give a big

boost to the Indian industries. Basic research activities needed for the programme will benefit the R&D institutions and academic community of the country. Thus this programme will lead to development of a host of new technologies and programmes which will benefit the various scientific, academic and industrial community. Human Spaceflight programme presents an opportunity for demonstration of a national effort to place our country in the exclusive club of space fairing nations with human mission capability.

3.15 12th Five Year Plan proposals of the Department is a step towards establishing India's leadership position in the area of Space Science and Technology. They are primarily towards:

i. Undertaking the entire gamut of space related activities from designing and building of satellites and launch vehicles, socially relevant application programmes to developing cutting edge technologies including capacity building all under a single umbrella

ii. India being the only country having a multi-wavelength space based observatory capable of monitoring of intensity variations in a broad range of cosmic sources with the realisation and launch of ASTROSAT mission in the first year of the 12th plan.

iii. Retaining the position of being the only provider of Scatterometer data by launching SCATSAT-1. Globally, data from scatterometer is in high demand owing to its usage in predicting sea state forecasting, coastal zone studies and inputs for weather forecasting and climatic studies. This mission will further augment service provided by Oceansat-2 satellite launched during 11th Plan.

iv. Positioning India's Polar Satellite Launch vehicle in the international market as the most preferred option for launching small/mini satellites.

4. 12th PLAN – PROGRAMME PROPOSALS

4.1 Approach and Methodology

4.1.1 From time to time, efforts have been made to refine the futuristic directions and thrust areas for Indian Space Programme. "Space Vision India 2025" presented during 110th Space Commission meeting laid out the vision for India's Space Programme till 2025. Detailed exercise has been carried out in bringing out the "Earth Observation Strategy2025" identifying the critical future missions keeping in view the developmental needs of the country and harnessing the latest technologies available in the area of remote sensing. The PC-NNRMS, during its meeting held in July 2011 deliberated on the EO data requirements for the 12th plan. Constitution of "Mars Mission Study Team" was another step towards exploring the possibility of undertaking a technologically challenging mission to Mars. "The GSLV/ SATCOM Strategy Review and Formulation Committee" constituted in Dec 2010 provided the future directions for the GSLV and the Satellite Communication programmes. The launch vehicle community through various level of discussions have come out with the critical technologies required for the future of space transportation systems. The inputs generated through these initiatives have provided valuable inputs for the formulation of the Plan proposals. In addition, the broad directions for the 12th plan brought out in the approach paper by Planning Commission have also been suitably taken into account in the plan proposals.

4.1.2 A plan drafting group, constituted by Chairman, ISRO / Secretary, DOS have synthesised the various inputs generated including those from ISRO Centres / Units and the Programme Offices in ISRO HQ and have generated the draft plan proposal which presented in this document.

12TH PLAN PROPOSALS IN A NUTSHELL

Launch vehicle programme

- Developmental Flight of GSLV Mk III – the next generation launch vehicle
- Evolve GSLV with Indigenous Cryogenic stage as a proven reliable vehicle.
- Develop critical technologies for Human Space Flight Programme and demonstrate the performance through unmanned flights.
- Realisation of total 25 launch vehicle flights – 17 PSLVs + 6 GSLVs + 2 GSLV Mk IIIs. (as against 14 flights during 11th plan)

Satellite based Navigation programme

- Establish the constellation of IRNSS with 7 satellites – 3 GEO and 4 GSO.
- Commissioning of ground segment – TTC & Uplink stations, SCC, CDMA ranging stations, Navigation control centre and data communication links.
- Implement Fully Operational phase of GAGAN - GPS Aided GEO Augmented Navigation.
- Introduce Satellite based Navigation services in the country – position, velocity and time services, precision agriculture, GIS, DMS, fishery, etc.,

Satellite Communication programme

- Augment the INSAT/GSAT capacity to ~400 Transponders in C, Ku, Ka, MSS and BSS bands.
- Realisation of advanced Ka band communication satellite with multi beam technology.
- Development and qualification of next generation 6K-20KW satellite bus
- Rejuvenate and expand the societal applications – Telemedicine, Tele-education, VRCs.

EO and Atmospheric Science

- Provide continuity of services with improved data with three thematic series of EO Satellites – Natural Resources, Cartography, Ocean/atmosphere
- Realisation of Geo-imaging satellite for DMS and resource survey applications.
- Newer Missions / payloads – enhanced cartography (0.25m resolution), advanced OCM for marine biology
- Thrust area of EO applications – Space based Information System for Decentralised Planning.

Space Science and Planetary Exploration

- Undertaking challenging Mission to Mars.
- Realisation of Chandrayaan-2 with Rover and Lander.
- Multi-wavelength Astronomy observational satellite - ASTROSAT
- Undertake X ray Astronomy satellite POLIX

Total of 58 Missions – 33 Satellites and 25 Launch Vehicles

(Against 31 Missions in 11th plan)

4.2 Satellite Communications

Global Trends

4.2.1 Satellite communication continues to play a key role in providing conventional communication services like broadcasting, VSAT communication and providing last-mile connectivity in remote locations & islands, etc. However, today the space industry is entering a new and exciting phase promising the huge growth prospects. Many traditional applications like Fixed Satellite Service(FSS), Broadcast Satellite Service (BSS) and Mobile Satellite Service(MSS) are morphing into newer and richer forms such as High Density Fixed Satellite Services (HDFSS), internet over satellite and mobile multimedia services. All these market scenarios are demanding generational shift in spacecraft payload and bus system configuration, architecture and design.

4.2.2 Broadcast and VSAT sector requirements are continuously increasing particularly from emerging regions in Asia, Africa & Latin America. The extent to which projected growth will materialize will depend to a large extent on the rate of expansion of new applications like broadband and mobile satellite services. Consumers in the emerging markets including India will rush to sign up for new TV platforms and higher definition services resulting in phenomenal growth.

4.2.3 It is estimated that satellite operators should provide more than 900 Gbps capacity to meet the emerging demand compared to what is available today. Such a future growth is mostly expected to come from realization of dedicated Ka-band spacecraft of a typical 100 Gbps capacity which will trigger a sea change in data bit cost and quality paradigms, facilitating space segment integration into terrestrial networks.

4.2.4 More and more international players are announcing new ventures to meet this demand and join information revolution bandwagon. Major satellite operators have announced launch of next-generation, high throughput satellite in near future to expand their rapidly growing broadband internet service. The multimedia mobile communication for handheld users is another emerging sector. Considering the scarce

spectrum availability for such applications, effective and efficient use of spacecraft based system is envisaged.

4.2.5 Satellite payload has to evolve from the present level of complexity that is suited for the TV broadcasting and telephone trunking to a level that is required for multimedia applications. These payloads should be capable to handle tens of spot beams and thousands of carriers in Ku and Ka band. The complexity is due to increase in number of access ways to satellite (from one or two beams to tens of spot beams) and decrease in processed information quantum i.e. elementary bandwidth processed by payload (large earth stations transmitting bulk of data being replaced by numerous small stations transmitting data bursts or packets). There has been renewed emphasis on providing satellite based services directly to the consumers. The emerging mobile and high bandwidth services demand greater performance from payload to support new applications with the use of low cost ground terminals. It calls for increase in payload power and bandwidth in the single platform. Increase in power allows reduction in ground terminal size or availability of larger capacities with the same terminals. Satellite throughput or bandwidth per spacecraft is also increasing as most of the commercial operators are delivering combined C and Ku band satellites with 80-100 transponders.

Approach to Plan Formulation

4.2.6 The approach to plan preparation for the 12th Plan for satellite communications will be to augment the INSAT capacity and to bridge the gap between the demand and supply of the transponders for meeting all the requirements of the country and also to maintain sufficient spares capacity to meet contingencies. Development of state of the art technologies and latest applications areas shall also be pursued.

4.2.7 There are important social programmes such as, Tele-education, Tele-medicine and Village Resource Centers that are to be given further expansion in the 12th Plan. In addition, keeping in view the changing national scenarios, newer implementation models for these societal programmes will also be considered. Development of critical technologies in all disciplines of satellite communication will be pursued. Continuation

of support to the strategic requirements of the country is another crucial area that would continue to be pursued during 12th Plan.

Thrust Areas

4.2.8 The main thrust areas of satellite communications during 12th plan are:

(a) Continuity of services provided by the INSAT system to be guaranteed.

(b) Building INSAT system capacity to meet increasing demands of Commercial, Government and Social sectors with adequate spares. Provide INSAT capacity to cover Asia, Africa and Eastern Europe in order to explore TV Market globally.

(c) Maintaining and securing sufficient orbit-spectrum resources for country's Satcom activities. Pursuing rigorously to secure spectrum for 100 additional Ku-band transponders and around 50 C-band/Ext C-band transponders in newer orbital locations.

(d) Develop satellite technologies to realize flexible payloads in terms of reconfigurable coverage, bandwidth and power.

(e) Build advanced communication technology High Throughput Satellite (HTS) in higher frequency band like Ka/Ku, Ka/Ka or any other band on I-6K platform.

(f) Realization of an advanced communication technology Ka/Ku-band I-4K satellite and development of ground segment for its optimum utilization.

(g) Realization of S-band multimedia satellite (S-BSS & S-MSS), which was envisaged in the 11th FYP, and realization of high power, high capacity multi-beam satellite (S-band MSS) to meet growing demand. Development of ground segment for their utilization along with developing Indian industry for production of ground user terminals.

(h) Study of Ka & V-band propagation effect and development of appropriate models and mitigation methods

(i) Continue to provide support and consultancy to established tele-education networks. Establish tele-education networks in the remaining states. Jointly promote the establishment of DTH based tele-education solution with State governments/UT/MHRD.

(j) Continue to provide support and consultancy for established telemedicine networks and expansion. Support satellite based Continued Medical Education(CME) programme through tele-medicine network.

(k) Tribal Area Development Project (TADP) with a special focus on the education & development of tribal areas starting with Gujarat and Rajasthan is to be initiated.

(l) Bringing synergy between communication & navigation systems by developing location based services for societal applications.

(m) Development of the ground segment compatible with MEOSAR based Search & Rescue system.

(n) Continuation of an effective support to space based disaster management system.

(o) Reviewing the Indian Satcom Policy and revise it, if necessary.

(p) Incorporation of a methodology towards assessment of authentication of demand of satellite transponders from various user segments.

Demand Scenario

4.2.9 The operational transponder capacity from INSAT/GSAT satellites at the end of 11th Plan is satisfying a demand of around 198 transponders. Apart from the operational transponders, the transponder demand during the 12th plan period is arising from (a) retiring of operational INSAT satellites (b) outstanding request from customers (c) to cater to the demands of the customers who are currently availing capacity from foreign satellites (d) expected growth in the industry due to the introduction of HDTV, expansion of TV channels, broadband VSAT services, satellite mobile communication etc. In addition there is a need for planning sufficient transponder back-up capacity for the operational services.

Users meet on GSAT-11 held in Aug 2010 at New Delhi and workshop on Communication Satellite technology held in Jan 2011 at SAC, Ahmadabad gave an understanding of the user requirements at a broad level. In addition, interaction with customers and correspondence with various government user departments has provided inputs for estimating the demand. During the Working Group Meeting for formulation of 12th Five Year Plan, the various user agencies like Doordarshan have expressed their future requirements for the expanding business scenario.

Taking these factors in to account, the total transponder demand during the 12th Plan stands at 794. This is a preliminary assessment of the Demand which needs to be firmed up in due course of time for planning

purposes. It is expected that the actual demand could be marginally less than what is indicated above.

The following table (Table 4.4.1) describes all the future communication satellite missions as envisaged for 12th Five Year Plan.

Table 4.2.1: Communication Satellite Missions for 12th Five Year Plan

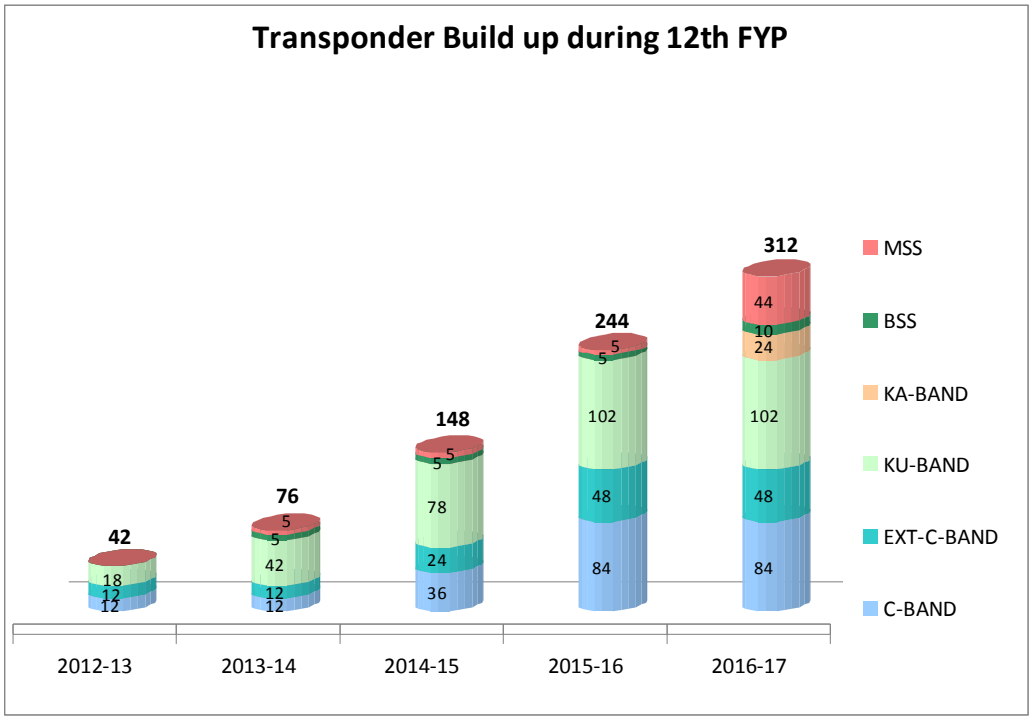
Satellites in 12th FYP (Platform)	Time Frame Launch Vehicle	Payload Configuration	Coverage
GSAT-10 (I-3K)	2012-13 Procured Launch	Ku Band: 12 Ext C band: 6 C band: 12	India Coverage and expanded coverage
GSAT-14 (I-2K)	2012-13 GSLV	Ku Band: 6 Ext C band: 6 Ka beacon: 1	India Coverage
GSAT-6 (I-2K)	2013-14 GSLV	BSS (C X S): 5 spot MSS (S XC): 5 spot	C band feeder link: India coverage S band user link: five spot beam over India
GSAT-15 (I-3K)	2013-14 Procured launch	Ku Band: 24 GAGAN	India Coverage
GSAT-16 (I-3K)	2014-15 Procured launch	Ku Band: 12 C Band: 24 Ext C Band: 12	India Coverage
GSAT-11: (ACTS-1)* (I-4K)	2014-15 Procured Launch	High Throughput Satellite (Ku/Ka) 24 Transponder Equivalent	India Coverage with 10 Gbps throughput capacity for VSAT application
GSAT-9 (I-2K)	2015-16 GSLV	Ku Band: 12	India Coverage
GSAT-17 (I-3K)	2015-16 Procured launch	C Band: 24 Ext C Band: 12	India Coverage
GSAT-18 (I-3K)	2015-16 Procured launch	Ku Band: 12 Ext C band: 12 C Band: 24	India Coverage

GSAT-6A (I-2K)	2016-17 GSLV	BSS (C X S): 5 spot MSS (S XC): 5 spot	C band feeder link: India coverage S band user link: five spot beam over India
GSAT-19E (I-3K)	2016-17 GSLV-Mk III	TBD	India Coverage
GSAT-11S (I-4K)	2016-17 Procured Launch	S Band multi-beam: 34	India Coverage with 10Gbps throughput
GSAT-Ka* (I-6K)	2016-17 Procured Launch	High Throughput Satellite (Ka/Ka) 24 Transponder Equivalent	India Coverage with 40 Gbps throughput capacity for VSAT application

*These high through put satellites come with multi-beam technology, primarily for VSAT/Broadband applications. Their throughput, in Giga Bits Per Second (GBPS) is very high compared to traditional bent-pipe transponders.

Figure 4.2.1 describes the Transponder build Up Scenario owing to the above mentioned satellite missions. In addition to the above mission work towards development of the following satellites viz GSAT-20, GSAT-21 will also be initiated in 12th plan which will fructify during the early phases of 13th Plan. Accordingly, it is assessed that the total transponders to be made available by end of 12th plan period would be 398 including minimum spare capacity.

Figure 4.2.1



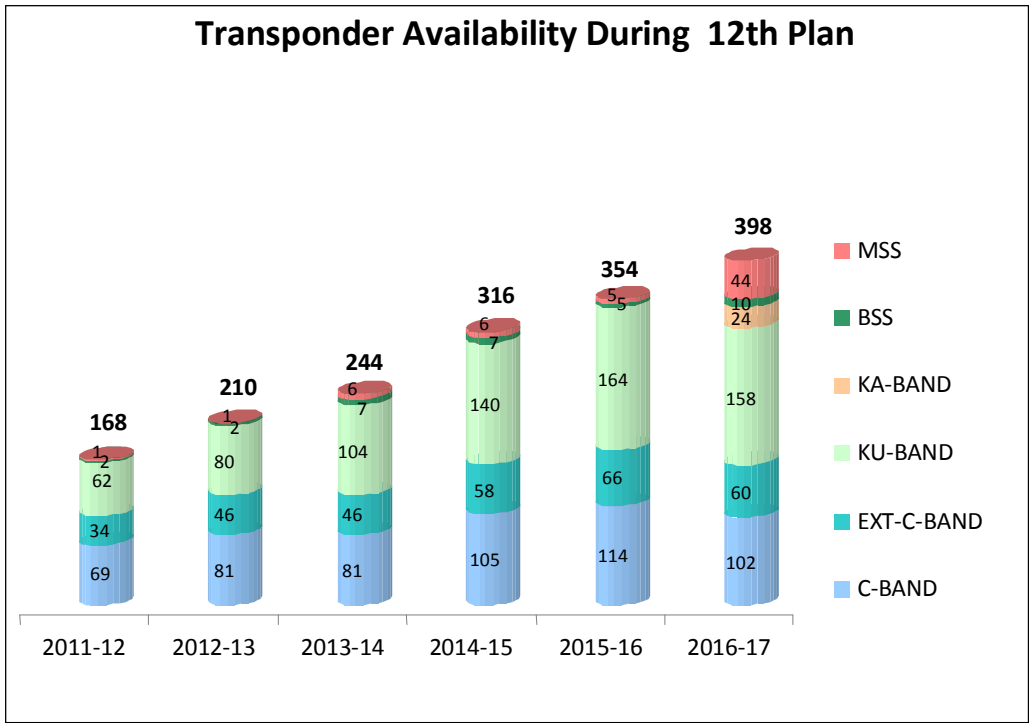
Communication Satellite Missions

4.2.11 During 12th Plan, 14 communication satellites are planned to (a) increase the transponder capacity (b) to introduce new generation broadband VSAT systems (c) introduction of Ka band systems (d) building high power S-band satellite mobile communications and (e) introduction of new generation geo-imaging satellite.

4.2.12 During 11th FYP seven satellites were realized and launched (INSAT-4CR, GSAT-4, GSAT-5P, GSAT-8, GSAT-12, W2M & Hylas). Work on realization of 5 satellites (GSAT-10, GSAT-14, GSAT-6, GSAT-9) is in progress and these satellites are in the advanced stage of completion. Realization of ACTS-1 (GSAT-11) has also been initiated. GSAT-11 satellite is the next generation I-4K satellite incorporating several emerging new technologies. This satellite is a high through-put satellite with multi-beam technology, primarily for VSAT/Broadband applications. Its throughput, in Giga Bits Per Second (GBPS) is very high compared to traditional bent-pipe transponders. Following table gives the new missions planned in the 12th FYP with replacement satellites in order to provide continuity to the existing services and new satellites to take care

of the additional requirements of users. The following graph depicts the build-up of the transponder capacity in various frequency bands during the 12th Plan. Figure 4.2.2 shows the availability of the transponders in various bands from end of 11th FYP to the beginning of 13th FYP considering the end of life of existing satellites during the period.

Figure 4.2.2



4.3 Space Based Navigation System

Approach to plan preparation

4.3.1 Satellite Navigation service is an emerging satellite based system with commercial and strategic applications. ISRO is committed to provide the satellite based Navigation services to meet the emerging demands of the Civil Aviation requirements and to meet the user requirements of the positioning, navigation and timing based on the independent satellite navigation system. To meet the Civil Aviation requirements, ISRO is working jointly with Airport Authority of India (AAI) in establishing the GPS based Geo Augmented Navigation (GAGAN) system. To meet the user requirements of the positioning, navigation and timing, ISRO is establishing a regional satellite navigation system called Indian Regional Satellite Navigation System (IRNSS).

Global Trends:

4.3.2 The satellite navigation services offered, or being offered in near future by the Global Navigation Satellite Systems (GNSS) are bringing benefits to users worldwide and also contributing to the gradual transformation of society. In the current scenario, the Global Positioning System (GPS) and its receivers are quite familiar and the receivers are available at the affordable price achieving the positioning precisions of a few meters. The applications fields are very wide, still emerging and not limited to transport, banking, environment, geology, oil exploration etc. The demand for the satellite navigation services and derived products around the world is growing at a rapid rate with generalization of its use in personal navigation in cars and its integration in the personal mobile communications.

4.3.3 The operation of a GNSS system is based on a time-difference-of-arrival concept. A receiver receives a signal from a satellite, containing the information about the position of the satellite and its clock. This receiver is then able to determine the distance between both by measuring the travel time of the signal. With the information of at least four satellites, the receiver will know its position using the triangulation method with an

accuracy ranging between centimetres and few meters, depending on various factors.

4.3.4 GNSS services are based on huge infrastructures which require a big effort and high investments for its development and maintenance. The infrastructure includes in-orbit satellites carrying high precision clocks, and a complex system of high capacity ground stations (basically big antennas and processing centres) worldwide distributed. Few governments or organisations are able to set up such a system. As a result, currently, there are only two global operative systems (GPS and GLONASS, although this last one has never been fully developed), both with a military origin. This scenario is expected to change considerably in the coming years, with the on-going development of the first civilian system (GALILEO), the improvement of the current existing systems (third generation of GPS, full deployment of GLONASS and enhancement from the regional system of Beidou-1 to global navigation system of Beidou-2), the availability of various regional augmentation systems, and other regional navigation systems.

4.3.5 This changing scenario, with an increasing number of available systems (both globally and regional) and the consequent gain in performances (positioning and time accuracy, continuity, integrity) will revolutionize the navigation applications and services at many different levels. Concepts like interoperability of the systems, security issues, or integration with other growing communications and information technologies are drawing a new landscape in the following decade for the applications and services of GNSS systems.

4.3.6 The status of various existing and currently under development GNSS and Regional systems other than Indian systems are as follows:

GPS (US):

- As on Sep 2011, 31 satellites are operational.
- GPS has achieved a RMS signal-in-Space User Range Error (URE) of 0.9 by 2009 in SPS service.
- The first block of IIF satellites was launched in June 2010 with operational service in L5 band and with best GPS clock performance.

- GPS has planned Civil Capability Improvements 24 satellites with L2C service by 2016, with L5 service by 2018 and with L1C service by 2021.
- GPS III integrity enhanced by SV reliability and on-board clock monitoring.

GLONASS (Russia):

- As on Sep 2011, 27 satellites are in orbit of which 23 satellites are in service.
- The 1st generation of GLONASS-K satellite was launched on Feb 26, 2011 with test CDMA signal in L5 band. GLONASS-K transmits 5 signals. Civil and military signals in each of the L1 & L2 & a new CDMA signal for civil applications in L5 band at a center frequency of 1202.025 MHz. As of now, extensive studies are being carried out for developing new CDMA signals in the L1 & L2 bands in addition to the L3 signal.

GALILEO (EU):

- Galileo will launch first two operational satellites in October 2011 and subsequent launch of operational satellites in coming years. Galileo plans to provide initial satellite navigation services in 2014 and complete constellation by 2019.

EGNOS (EU):

- EGNOS Open Service (OS) is available from 1st October, 2009 and Safety Of Life (SOL) service is available from 2nd March, 2011.

COMPASS / BEIDOU (CHINA):

- China started building its own satellite navigation system in 2000 and had set up a regional satellite navigation system after launching three Beidou geostationary satellites between October 2000 and May 2003. Beidou is the Chinese pinyin of compass.
- The Beidou-1 system could not meet growing demand, so a better functional Beidou-2 regional and global navigation system is being set up in two stages.
- Eighth COMPASS / BeiDou-2 satellite have been launched by April 10, 2011. Between the early part of 2011-2015 period, 12 to 14 navigation

satellites will be launched to provide navigation, timing and short message services in the Asia and Pacific region. By 2020 a global navigation system comprising more than 30 satellites will be in place.

QZSS (JAPAN):

- First satellite of QZSS was launched in September 2010.

Thrust areas for the current plan

4.3.7 The major thrust areas of Satellite Based Navigation Programme are:

(a) Implement the final operational phase for satellite based augmentation system (SBAS) GAGAN over the Indian Airspace jointly with Airport Authority of India and providing position, navigation and timing services through an integrated receiver.

(b) Implement an independent Indian Regional Navigation Satellite System (IRNSS) over Indian region and encourage the growth of user segment in Indian Market.

(c) Develop indigenous expertise in applications of Global Navigation Satellite System (GNSS) for critical National applications, identify specific application software development areas and work towards development of receivers for IRNSS including Global Navigation Satellite System (GNSS) through participation of Indian industry.

(d) Secure sufficient orbit-spectrum resources for country's Sat-Nav Programme activities.

(e) The IRNSS constellation to be increased from 7 to 11 satellites, to meet the user's requirements of the extended service coverage.

(f) There is a need to formulate the Indian Satellite Navigation Policy as ISRO is implementing and going to provide Satellite based Navigation services in India.

Programmatic Target of 12th FYP

4.3.8 The Satellite Navigation Program (SNP) has the primary objective of establishing a space based infrastructure, ground segment for satellite based position, navigation and timing services. The SNP also has an objective for the user segment, the task of developing the receivers for IRNSS including GNSS indigenously through participation of Indian industry.

4.3.9 Currently, the SNP has the responsibility of realizing two space based navigation systems viz., GAGAN and IRNSS.

4.3.10 **GPS Aided GEO Augmented Navigation (GAGAN)** is a Satellite Based Augmentation System (SBAS) implemented jointly with Airport Authority of India (AAI). The main objectives of GAGAN are to provide Satellite-based Navigation services with accuracy and integrity required for civil aviation applications over Indian Air Space and to provide better Air Traffic Management over Indian Airspace. The system will be interoperable with other international SBAS systems like US-WAAS, European EGNOS and Japanese NSAS and provide seamless navigation across regional boundaries. The GAGAN project is implemented in two phases viz., (i) Technology demonstration phase (TDS), (ii) Fully operational phase (FOP). Currently GAGAN-FOP phase is under progress. Most of the ground segments are realized. When commissioned for service, GAGAN-FOP will provide a civil aeronautical navigation signal consistent with International Civil Aviation Organization (ICAO)'s Standards and Recommended Practices (SARPs).

4.3.11 GAGAN made significant progress during 11th plan period.

(a) The first GAGAN payload is available on GSAT-8 launched in 2011 and in-orbit tests were conducted successfully. The second GAGAN payload on GSAT-10 is planned to be launched in the end of 11th Plan. The third GAGAN payload on GSAT-15 is planned to be launched in 12th Plan.

(b) Ground segment consisting of 15 INRES stations with redundancies, 2 MCC and 2 INLUS are ready in 11th Plan. The third INLUS is in progress and made available in 12th Plan.

(c) High available Data communication network with OFC as primary network and VSAT as secondary network is expected to be completed by the end of 2011. The second OFC as tertiary network will be established in the 12th Plan.

(d) Development of regional Ionosphere ISRO GIVE Model – Multi Layer Data Fusion (IGM-MLDF) is completed and the software based on DO-178 will be completed in 12th Plan.

(e) Overall system Integration, validation and stability test will be done in 12th Plan.

(f) System Documentation, studies and analysis of Hazardous Misleading Integrity (HMI), Certification of the GAGAN system will be done after the availability of all GAGAN payloads in the 12th Plan.

4.3.12 The major milestones for the GAGAN during the 12th Five year plan are given in Table 4.3.1 as follows:

Table 4.3.1

Milestone	Year
Availability of 2nd GAGAN payload	2012.
Availability of 3rd GAGAN payload (In orbit Spare)	2013-2014
The certification and Operation of GAGAN system for Civil Aviation	2013-2014
Applications other than Civil Aviation	2012 – 2016 and Beyond

4.3.13 GAGAN is planned to get into operation by the year 2014. Maintenance of the Space segment, maintenance of INLUS RF portion and exploring the possible applications will be a continuing process and will extend beyond the 12th Plan period.

4.3.14 **Indian Regional Satellite Navigation System (IRNSS)** is an independent and indigenously developed Indian Satellite based positioning system for critical National applications. The main objective is to provide Reliable Position, Navigation and Timing services over India and its neighbourhood, to provide fairly good accuracy to the user and to provide Integrity and Ionospheric correction messages to user. The IRNSS will provide basically two types of services viz., (i) Standard Positioning Service (SPS); (ii) Restricted Service (RS)

4.3.15 Space Segment consists of seven satellites, three satellites in GEO orbit and four satellites in GSO orbit with inclination of 29° to the equatorial plane. The 3 GEOs will be located at suitable orbit slots and the 4 GSOs have their longitude crossings at two suitable orbit slots (two in each plane). All the satellites will be visible at all times in the Indian region. Ground Segment is responsible for the maintenance and operation of the IRNSS constellation. It provides the monitoring of the constellation status, computation of the orbital and clock parameters and navigation data

uploading. The Ground segment comprises of TTC & Up-linking Stations, Spacecraft Control Centre, IRNSS Timing Centre, CDMA Ranging Stations, Navigation Control Centre and Data Communication Links. User segment mainly consists of a single frequency receiver for Standard Positioning Service (SPS), dual frequency IRNSS receiver for both SPS & RS service and a multi-mode receiver compatible with other GNSS providers.

4.3.16 Both the navigation systems will provide position, velocity and time (PVT) to the users with the specified accuracies and will be compatible and interoperable with other Global Navigation Satellite Systems (GNSS).Both the systems are being established to meet the societal applications such as precision agriculture, Geographic Information Systems (GIS), disaster management, fishery, Location Based Services (LBS), Intelligent Transport Systems (ITS) etc.

4.3.17 The IRNSS first satellite was to be launched in 2008 and constellation to be completed by 2012 as per the 11th Plan. Now the launch of all these satellites has spilled over to 12th Plan with first launch scheduled in 2012 and the seven satellite constellation to be completed by 2015-16. IRNSS activity is entirely new development program in ISRO and new technology elements had to be developed in Space segment, Navigation payload design and Ground segments. This necessitated new design and implementation. This new design and implementation required several new simulation, facility development, augmentation and experimentations. In addition some of the contracts have taken more time to be signed after resolving technical and commercial aspects. These aspects lead to a delay in implementation of IRNSS programme.

4.3.18 The ground segment is being realized in two phases. In first phase, 1 IRNSS Navigation Centre (INC), 1 IRNSS Network Timing centre (IRNWT), 4 IRNSS CDMA ranging stations (IRCDR), 6 IRNSS Laser Ranging Stations (ILRS), 10 IRNSS Range and Integrity Monitoring Stations (IRIMS), 2 IRNSS Data Communication Network (IRDCN) and 2 Satellite Control Facility (SCF) will be established and in the second phase 2nd INCC, 2nd IRNWT and 7 IRIMS will be established. In the 11th FYP, Phase 1 will be completed except for the spill over of establishing 1 IRCDR station at Jodhpur, reference receivers in all 10 IRIMS to the 12th Plan. Infrastructure for the 7 IRIMS of the 2nd phase will be completed in the

11th Plan with a spill over of reference receiver in all 7 IRIMS to the 12th Plan. The 2nd INC and 2nd IRNWT will be realized in 12th Plan.

4.3.19 The major milestone for the IRNSS during the 12th Five year plan is described in Table 4.3.2 as follows:

Table 4.3.2

Milestone	Year
IRNSS-1	2012-13
IRNSS-2	2013-14
IRNSS-3	2013-14
IRNSS-4	2014-15
IRNSS-5	2014-15
IRNSS-6	2014-15
IRNSS-7	2015-16
Operations of Ground Segment	2012-13
IRNSS network time characterization	2012
Initiation of the establishment of second Navigation Control Centre	2012-13
User Receiver Development	2012
Integrated GNSS receiver	2013
Constellation Expansion and Ground spare satellites	2016-17 & Beyond

4.3.20 The project has an approval for 2 ground spare satellites in addition to 7 satellite constellation. To meet the user's requirements of the extended service coverage, it is required to increase the number of satellites in the constellation from 7 to 11. These additional 4 satellites will be ready in 12th FYP and will be launched in the beginning of 13th Plan.

4.3.21 The Constellation Expansion, Ground spare satellites, Maintenance of Space Segment, Maintenance of Ground Segment, Modernization of the existing navigation system, exploring of possible and potential satellite navigation applications will be a continuous process and will extend beyond the 12th Plan.

4.4 Earth Observation Systems and Atmospheric Science Program

Global Trends

4.4.1 A variety of instruments employing various measurements technology and techniques, both active and passive sensing have been flown on many space missions. As per Committee on Earth Observation Satellites (CEOS), where 30 space agencies are members, around 100 new satellite missions will be launched upto 2013. CEOS agencies are operating or planning 261 individual satellite Earth Observation missions carrying 775 instruments (416 distinct instruments, some being repeats) on their EO missions in the next 15 years (2010-2025 period). Most of the space faring nations and space agencies such as, NASA, NOAA, CSA, ESA, CNES, DLR, JAXA and China are working on constellations of small satellites, formation flights, autonomous missions, intelligent networking, event driven observations, sensor web, data mining/ fusion, on-board processing, quantitative remote sensing etc.

4.4.2 The Key global trends in Earth Observation are observed as:

- Significant rise in number of satellites in medium to high resolution (~2.5m), funded by govt. and Scientific payloads development
- New government participants in EO is increasing like Nigeria, Malaysia, Thailand, Turkey, Taiwan, Indonesia, and others
- Era of constellations like RapidEye (5), GeoEye (2), DigitalGlobe (3 in Q3/09), COSMO-SkyMed (4), SAR-Lupe (5), DMC (5), and others
- Constellations addressing need for coverage and revisit time
- Surge in radar satellites like TerraSAR-X, COSMOS-SkyMed, SAR-Lupe, Radarsat-2, TecSAR – total of 11 operational satellites
- Less sophisticated platform, mini & micro-satellites driving down satellite costs
- Increased funding – Private investment (RapidEye), Public Private Partnerships (TerraSAR-X), and dual-use programs (Cosmo-SkyMed)
- Ease of data access

- Emphasis is on commercialization and privatization of high resolution satellite programmes.

The Thrust Areas

4.4.3 The thrust areas of EO for the 12th Plan have been identified based on detailed deliberations in the inter-centre committee of ISRO. The points considered are:

(a) providing continuity of services for mapping, monitoring, and inventory of natural resources including processed products for ocean and atmosphere applications;

(b) addressing gap areas and new emerging requirements, specifically identified by user ministries (PC-NNRMS outcome) under the NNRMS umbrella;

(c) global trends, current status, Indian capabilities and planned research and development.

4.4.4 The above points have also been discussed in the Inter-Ministerial platforms and the feedback has been incorporated appropriately. Considering the above, the following prioritized areas have been identified:

i. Continue with three thematic series of Indian EO satellites (Natural resources, Cartography and Ocean & atmosphere, including all-weather capability) with specific improvements wherever essential.

ii. Develop new payloads to meet the user requirements involving state-of-the-art technologies in the areas of electrical, electronics, software and mechanical systems.

iii. Provide spacecraft platform stability by implementation of advanced technologies, like, control moment gyros and fiber optics gyros. This will enable reliable and performance-rich observation system with operational data products.

iv. In parallel, undertake ground segment, calibration & validation, assimilation & modeling and large demonstrative studies for effective utilization of the various sensors.

v. Special emphasis in the areas of agriculture, environment, large scale mapping, infrastructure planning, oceanography, climate and atmospheric studies.

Requirements Analysis for 12th FYP

4.4.5 Based on the user inputs (a) A series of meetings of NNRMS Standing Committees; (b) PC-NNRMS meetings with participation of user Ministries; (c) Prof. Vaidyanathan Committee report, a detailed analysis was carried out to identify gap areas in applications, keeping in view the current capabilities of payloads and proposed activities for new payload development. This has resulted in arriving at a set of missions which addresses user requirements and possible newer areas of applications in the coming years. Specific focus has been on the user requirements, based on which, functional characteristics of payloads have been considered while defining the future missions (**Table-4.1**).

Table 4.1: User Requirements analysis

Theme	User Requirements	Proposed Sensor Configurations
Optical Sensors		
Agri.	• Repeat coverage (< 10 days) • Multiple crop area identification (~ 2 m Mx) • Drought damage quantification • Crop Inundation • Damage assessment • Quantification growth parameters & condition	**1. GISAT Mission** Frequent Monitoring ~50m Mx ; 500 m HySI (VNIR and SWIR); ~1.5 km (Thermal Bands) **2. Resourcesat-3 series** 20 m Mx/ 740 km swath; 5 days **3. Cartosat 2C/ 2D Mission** 0.64 m PAN/ 2.5 m Mx/ 9.6 km swath **4. Cartosat 3 series** 0.25 m PAN, 1m Mx , 5m (MIR), 16 km swath **5. Cartosat 1A/1B/1C Mission** 1.25 m Stereo PAN ; 2.5 m Mx; 25 m HySI (VNIR and SWIR) / 60 km swath
Water	• Irrigation planning • Irrigation Infrastructure	
Bio-Res.	• Forest Cover, Glacier/ Snow, Vegetation Type • Primary productivity/ carbon balance	
Geology	• Mineral identifications • Lithological information	
Rural	• Land Information System	
Carto-Urban	• Cartographic mapping, High resolution DEMs, 3D city models and urban flooding	
Environment	• Green house gases (CO_2, AOD, CH_4, NOx, SO_4, O_3)	**R & D Satellite**(IMS Bus): Spectrometer

Theme	User Requirements	Proposed Sensor Configurations
Ocean Biology	Continuity of ocean colour measurements, Atm. correction, algal bloom detection, SST	**Oceansat-3/3A/3B** Mission 13 Channels (400-1010 nm range) ;2 Channels (11 and 12 µm)
Ocean and Atmospheric	Atmospheric Motion Vector, Outgoing Long Wave Radiation, Upper Tropospheric Humidity, Temperature & Humidity Profile, SST	**INSAT-3D/3DR/3DS Mission** 6 Channel Imager, 19 Channel Sounder
Microwave Sensors		
Agri. Water	• Kharif season crop assessment • Flood damage • Soil Moisture	**1.** RISAT -1 A (C-band) Mission **2.** RISAT -2 A (X-band) Mission **3.** RISAT – 3 (L-band) Mission
Ocean & Atmosphere	Wind vectors with improved Repetivity	**Scatsat- 1 Mission** Ku Band Pencil beam Scatterometer
	Temperature and humidity profile	**Microwave Sounding Unit**
	Tropical water cycle and radiation budget : Microwave radiometers and sounders	**MeghaTropiques Mission** MADRAS, ScaRab, SAPHIR, ROSA
	Sea Surface Altimetry	**SARAL Mission** Ka Band Altimeter

Spill over Missions from 11th Plan

4.4.6 It was planned to have eight (8) new missions (Resourcesat-2, Resourcesat-3, DMSAR-1, GEO-HR (GISAT), TES-HYS, Cartosat-3, SARAL, Megha-Tropiques) in the 11th FYP, in addition to the three (3) carry-over missions (INSAT-3D, RISAT-1, Oceansat-2) from the 10th FYP. A total of eight (8) missions were realized in 11th FYP, which included four (4) of the planned missions, namely, Oceansat-2, Resourcesat-2, Megha-Tropiques, RISAT-1 (likely by Jan 2012) and four (4) unplanned missions (Cartosat-2A, IMS-1, RISAT-2, Cartosat-2B). Remaining five (5) missions (INSAT-3D, Resourcesat-3, GISAT, Cartosat-3, SARAL) are being carried over to the 12th FYP and two (2) missions (DMSAR-1, TES-HYS) are not being pursued further.

4.4.7 The carried over five (5) missions would provide operational observation capabilities with respect to atmosphere, natural resources, near real-time monitoring of disaster, high resolution imaging and physical & biological oceanography, respectively. The missions that are not pursued further are addressed through RISAT series with microwave imaging and Cartosat-3 satellite for hyper-spectral observations.

Programme Proposals - 12th Plan

4.4.8 There are 8 missions planned for 12th Plan (including special projects) that covers observation in the area of natural resources, ocean & atmosphere, climate and environment, all weather and high resolution imaging. With the realization of these missions, there would be significant improvements in the areas of short term weather and ocean state forecasting, natural resources management, high resolution cartography, large scale mapping, space based Essential Climate Variables (ECVs) with enhanced spatial, spectral, radiometric and temporal resolution, which are summarized in Table-4.2.

Table 4.4.2: 12th Plan EO Mission Profile

Year	Satellite	Orbit & weight	Sensors	Applications
2012-13	**INSAT-3D**	GEO/2050 kg	Imager & Sounder	Cloud images, Atmospheric observations on Temperature & Humidity profiles, Sea surface Temperature
	SARAL	800 km / 450 kg	Altimeter & ARGOS	Sea Surface Height, Ocean Waves & Winds, Date relay applications
2014-15	**Cartosat-2C**	500 km / 700 kg	< 0.64m Pan & 2.5m MX with 10 km swath	Enhanced Cartography

Year	Satellite	Orbit & weight	Sensors	Applications
2015-16	**Resourcesat-2A**	817 km/1200 kg	AWiFS, LISS-III & IV	natural resources mapping & monitoring
	Cartosat-2D	500 km/700 kg	< 1m Pan & 2m MX with 10 km swath	Enhanced Cartography
2016-17	**Oceansat-3**	720 km / 450 kg	13 band OCM and 2 band TIR	Advance OCM for Marine Biology
	CARTOSAT-3	500 km/1500 kg	0.25m Pan; 1 m MX; and 5m MIR	Enhanced Cartography; Resource Mapping applications
	GISAT	GSO/855 kg	4 MX in VINIR; TIR; HySI in VNIR to SWIR	Geo Imaging in with high temporal res. For natural resources and disaster management

In addition to the above mission work towards development of the following satellites viz CARTOSAT-1A, RISAT-3, INSAT-3DR, CARTOSAT-1A/1B, SCATSAT-1 and MEGHA-TROPIQUES-1A will also be initiated in 12th plan which will fructify during the 13th Plan and beyond.

New Initiatives

4.4.9 Essentially, INSAT-3D/3DR, SARAL and GISAT represent the missions spilled over from 11th plan. Several new initiatives have been planned during 12thPlan, which include:

- Medium resolution and Hyperspectral imaging from Geo platform
- Millimeter wave humidity and temperature sounder
- Fourier transform spectrometer for GHGs sensing
- Ocean Colour and Sea Surface Temperature from same platform
- Development of Optical filters like wedge filters, Offner gratings and strip filters

- Development of ultra-light weight telescope optics with physical diameter ~1m.
- Ka-band transmission system to transmit the voluminous data from spacecraft in a limited time period of ground station visibility, configurable onboard Data handling system with advanced algorithms of Data compression.
- Dissemination of ocean and atmosphere data to the global user community in near real time
- L-band Microwave radar
- ASIC based advanced data handling, storage and encryption system for future IRS Missions.
- Indigenous development of Infrared focal plane arrays and novel IR imaging systems based on Quantum Well/ Quantum Dot/ Dot In Well structures belonging to Nano-technology class of devices.
- Advanced on-board computer which will exploit the miniaturization technologies in electronics.
- Rigid, Light weight structure development for spacecraft bus
- MEMS thrusters for small satellites
- Rendezvous and Docking (RVD): Space Docking Experiment based on the low impact docking concept (Berthing Scheme) using two small satellites (IMS-1 class ~ 100 kg).

4.4.10 Besides the missions planned for realisation in 12th plan as elaborated above, it is also planned to initiate work during 12th plan on (a) Precipitation Radars; (b) Space borne LIDARs; (c) Altimeters and (d) Radio Occultation Experiments using IRNSS Platform for atmospheric parameters, which would fructify during 13th plan period.

Thrust Areas for EO Applications – 12th FYP

4.4.11 While ensuring continuity of services in the areas of Natural Resources Census (1:50000 & 1:250000 scale), Ground water potential mapping, snow and glacier studies, coastal zone management, PFZ, Ocean State forecasting, weather forecast, Space based Information Support for

Decentralized Planning (SIS-DP), Accelerated Irrigation Benefit Programme (AIBP), India-Water Resource Information System (India-WRIS), National Urban Information System (NUIS), including the initiative to help user Ministries in the institutionalization process for remote sensing based services (with MoEF, MoES, MoA, MoWR, already in the forefront), the following initiatives in different application sectors are also proposed.

4.4.12 **Land use Zoning**

Use of NRC outputs for Land use Zoning & as input to Land use Planning and Policy Preparation, as a newly emerged requirement, in light of National Land Acquisition and Rehabilitation and Resettlement Bill, 2011, passed by Govt. of India.

4.4.13 **Geology**

- Hyper spectral studies will continue for some more mineralized belts in association with GSI. RISAT data will be utilized for protrozoic belts of India for structural mapping.
- Use of field remote sensing equipment like Ground Penetrating Radar (GPR) for sub surface geology, Glacial ice thickness etc.

4.4.14 **Water Resources**

- National water resources assessment in all the river basins as a national programme, in consultation with CWC.
- Snow melt runoff modeling for planning of water distribution in irrigation projects and hydropower generation

4.4.15 **Agriculture**

- Operational use of RISAT data for crop inventory and condition assessment,
- Polarimetric SAR for improved crop discrimination
- Hyper spectral data for crop condition assessment and Integrated pest & diseases management
- Crop specific drought and its impact assessment for major crops

- Multistage national crop production forecasting for Horticultural and additional crops under FASAL
- Soil moisture observation system in rain-fed and drought prone states
- Field studies on crop simulation models and retrieval of crop biophysical parameters
- Impacts of climate variability and change on crop phenology and growth

4.4.16 **Cartography, Urban Environment & Infrastructure Planning**

- Large scale mapping and High resolution DEM
- 3D Urban modeling and information systems

4.4.17 **Atmospheric Sciences**

- Operational parameter retrieval for forthcoming missions (INSAT-3D, MT, SCATSAT-TSU, Radio occultation)
- Mesoscale modeling for improved weather forecasting
- Contributing to observation infrastructure through Indigenous development/ design of ground based network.
- Study of atmospheric chemical transport using chemical transport modeling
- Initiatives towards the development of rain radar.

4.4.18 **Ocean Sciences**

- Operational and improved high resolution coastal forecast
- Location specific ocean forecast
- System studies on advanced sensors
- Phytoplankton physiology using Fluorescence response, organic carbon and fluxes and underwater light field
- Estimation of Ocean Heat Content using SARAL / Altika derived Sea surface heights and impact on cyclone generation

4.4.19 **Forest& Environment monitoring**

- Forest change alert system using IRS sensor data twice in a year for indicating the hotspots of changes in forest cover for efficient forest

monitoring and planning conservation strategies and implementation.

- Desertification status monitoring
- Coastal Processes, Coastal Eco system and Coastal Zone Management

4.4.20 **Climate Change**

- Continuity of aerosol radiative forcing over India, atmospheric GHGs and Trace gases, Energy, water and mass exchanges in vegetative systems, atmospheric boundary layer characterization
- The multi-spatial thematic datasets will be used for identifying areas suitable for greening for Green India Mission.
- Polar Science Studies
- Green House Gases Monitoring from space
- Paleo-climatic research to understand present and predicting future change in the Earth system functioning.
- Modeling energy and mass exchange in vegetative system
- Monitoring the drivers of global warming like trace gases, greenhouse gases, aerosols, characterization of atmospheric mineral dust, carbonaceous aerosols, emission sources, chemistry and transport over Indian region
- Modeling the Impact of Climate Change on agricultural system Productivity, horticultural crops and hydrology
- Study of oceanic nitrogen cycles, the carbon dynamics of ocean and its role vis-à-vis global climate change
- Vegetation carbon pools and fluxes assessment in soil and vegetation
- Carbon biogeochemical cycle and Net Carbon balance
- Carbon-cycle modeling and simulation by integrating all the ground based and satellite measurements into a coupled surface (land and ocean) and atmospheric model Impact of Black carbon and debris cover on glacial ice melting
- Impact of Climate change on natural ecosystem

4.4.21 **Web based Data and Information services**

- Unified ISRO Portal as a common gateway for data and services through distributed geoportal environment.

- Bhuvan to provide enhanced services, multiple timeline datasets, distributed services
- As per the new policy, coarse resolution datasets of some latency would be made freely available as a web service.
- Thematic maps would be made available through WMS standards.
- The services of MOSDAC would be expanded

4.5 Disaster Management Support Programme

4.5.1 The Disaster Management Support (DMS) Programme of ISRO is intended to provide near real time support and services from imaging and communication satellites towards efficient management of disasters in the country.

Overview of the accomplishments in 11th FYP

4.5.2 The major focus of the DMS Programme in the 11th Plan was to implement essential support services in terms of value added data products and information and communication support for the major natural disasters. The Decision Support Centre (DSC) established at National Remote Sensing Service Centre (NRSC) Hyderabad as a single window for all services has responded comprehensively to all the major disasters such as flood, cyclone, drought, landslides, earthquakes and forest fires. All the flood events were monitored and the flood inundation layer super imposed with base details were disseminated to the concerned Relief Commissioners, Ministry of Home Affairs, and Central Water commission in near real time (5-6 hrs).

4.5.3 **National Database for Emergency Management (NDEM)** is conceived as a GIS based repository of data to support disaster/ emergency management in the country, in real/ near real time. The NDEM will contain datasets at different scales/ details: (i) National level core geo-spatial data at 1:50,000 scale; (ii) Hazard specific data for multi-hazard prone districts at 1:50,000 scale; (iii) Data for multi-hazard prone cities/ towns at 1:10,000 scale; and (iv) Data for major cities at 1:2,000 scale.

4.5.4 An NDEM server is established at NRSC and the data base available with ISRO in 1:50K, 1:10K and 1:2K were loaded on to the server. The design of Decision support systems for flood, drought, landslides and radiological disasters are completed. A mobile device based software solution has been developed to collect field data including geographic location coordinates, field photos and scientific parameters and transmit the collected information in near real time to the central server where the data is organized and utilized. Civil works related to NDEM building is in the final stages. The architecture and specifications of the NDEM infrastructure are

being reviewed based on the suggestions of inter departmental technical Group.

4.5.5 Development and deployment of fail-safe **emergency communication** equipment is an important component of the DMS System. ISRO/DOS has developed on-site deployable emergency communication equipment. Presently 4 WLL VSATs (2 vehicle mounted and 2 container based), nine INMARSAT Mini-M terminals and eight INSAT Type-C terminals are available for emergency communication. Further, 50 numbers of INSAT Type-D terminals have been procured and distributed to various ISRO centres for use during emergency situations.27 terminals are being used by CRPF for its emergency operations. A Distress Alert Hub has been set-up at Chennai, and around 1850 Distress Alert Terminals (DAT) for fishermen have been procured and distributed to fishermen through Indian Coast Guard. ISRO/SAC had conceptualized DTH based Disaster Warning system. In the DTH based warning system, individual or group of DTH receivers could be selected and sent with siren warning followed by voice message. Satellite link is being established from IMD cyclone warning centre and Doordarshan using DMS network for bringing full operational mode through Doordarshan.

4.5.6 ISRO/DOS has undertaken the task of setting up a **satellite based Virtual Private Network (VPN)**, at the behest of MHA, as a part of the overall, fail-safe disaster/ emergency communication network in the country. The National Emergency Operation Centre (NEOC) of MHA, Cabinet Secretariat, NDMA, PMO, other key data providing agencies (IMD, CWC, GSI, SOI, INCOIS, NIDM), and the Decision Support Centre (DSC) of NRSC are connected with 20 multi-hazard prone State Emergency Operation Centres (SEOCs).

4.5.7 The **Airborne Laser Terrain Mapper (ALTM)** and Digital Camera have been procured to strengthen the monitoring capability for disaster management. ALTM DC data acquisition for over 30000 sq. km was completed. Data processing of 8800 sq. km (Orissa and AP – sabari) was completed. Data processing of 21600 sq. km (Bihar and Assam Phase I) is in progress and will be delivered during the 11th FY period.Using ALTM camera 50 cm contour is being generated with about 20cm accuracy.About

₹ 200 cr has been earmarked during 12th plan for procurement of new aircraft.

4.5.8 Considerable progress has been achieved in developing **Early warning systems** for flood, cyclone and drought. A prototype for flood early warning using high resolution DEM for forecasted discharge is being attempted on pilot scale in Godavari basin. The results were shared with CWC and the validation exercises are going on. Another model is developed for north east region based on the meteorological inputs. This also has shown considerable promise to the entire NE region. Further a Flood Hazard atlas was prepared for Assam region considering the flood events in the last 10 years. Flood hazard mapping based on existing embankment breach points are also being carried out.

4.5.9 **Airborne Synthetic Aperture Radar (ASAR):** The cloud cover during the disaster events, especially during flood season was a major hurdle to have observations using optical sensors. Hence development of Aircraft versions of SAR payloads was pursued during 11th FYP for easy deployment during disasters. The development model of C-band SAR has been realized and had extensive experimental flights. The flight model is realized and undergoing T&E for operationalization. Similarly the X-band SAR is being developed and the developmental model will be realized in this financial year itself.

4.5.10 **Hydrometeorological networks:** Monitoring the extreme weather based disasters sucha s cyclone, floods, drought, etc. need real time observation of the associated parameters. Towards this the Automatic Weather Stations (AWS) enabled with satellite based real time data transfer was pursued in 11th FYP. More than 1000 AWSs has been established in various parts of the country. The data from these AWS are made available through the ISRO web site (www.mosdac.gov.in) in near real time.

4.5.11 For the surveillance and monitoring of severe weather systems such as cyclones development and establishment of Doppler weather Radars were planned. In the 11th FYP, four S band DWRs are made ready through industry participation. Efforts are on to install these radars. Further a C-

band DWR is being planned at Trivandrum to study the onset of monsoon, and is in the final stages of development.

4.5.12 **Constellation of EO satellites for DMS**: Currently 9 Remote Sensing Satellites (Resourcesat-2, Oceansat-2, Cartosat -1, 2, 2A & 2B, TES, IMS-1 & RISAT-2) are providing EO data. INSAT-3A and Kalpana satellites in the geosynchronous orbit provide data in support of weather monitoring. These data are being effectively used for disaster management purposes. Further GISAT, INSAT-3D in the GEO orbit and RISAT-1 in the LEO orbit will further augment the data availability for continuous monitoring of natural disasters, weather observation and all weather capabilities respectively.

Thrust Areas of 12th Plan

4.5.13 The major thrust areas of DMS programme in 12th Five Year Plan are:

(a) Operationalization of National Database for Emergency Management (NDEM)
(b) Continue impact mapping and monitoring of natural disasters with improved turnaround time and with newer capabilities
(c) Risk evaluation and reduction
(d) Acquisition of close contour data through ALTM
(e) Extension of the communication network to the District Emergency Operation centres
(f) Geo-location based services such as Search & Rescue and distress alerts
(g) Operational dissemination of the information and products directly to the affected areas
(h) Operational utilization of early warning systems
(i) Extension of the Hydro-meteorological network
(j) Key areas of research and development
(k) Continued participation in international initiatives

Programmatic Targets for the 12th Plan

4.5.14 The DMS programme is driven by EO satelliltes and communication satellites to support DMS activities. DOS plans to provide necessary bandwidth in the communication satellites including in S-band,

Navigation systems such as GAGAN and IRNSS, in addition to EO satellites such as RISAT-1 and GISAT for observation for enhanced observation capabilities. These initiatives would further improve disaster related services under DMS.

4.5.15 **Operationalization of National database for Emergency Management (NDEM) with multi thematic, multi-scale database and relevant Decision Support Systems:** The NDEM as envisaged with multi-tier database will be operationalised. National level core geo-spatial data at 1:50,000 scale; Hazard specific data for multi-hazard prone districts at 1:10,000 scale; Database for multi-hazard prone cities/ towns at 1:10,000 scale; and Database for major cities at 1:2,000 scale will be organized in association with other participating organizations. Development of Decision support tools for addressing emergency management within national disaster frame work will be taken up. Institutional mechanism for sharing & updating database on continuous basis, mirroring / replica of databases at Ministry of Home Affairs with suitable access/security mechanism and dissemination during Emergency would be implemented.

4.5.16 **Impact mapping and monitoring of natural disasters with improved accuracy and turnaround time:** As the satellite based observation is getting augmented with new and improved sensors, the data availability for disaster management support purposes will be improved. The Decision Support System (DSC) at NRSC who is engaged in providing services for DMS will strive to improve the turnaround time of products. The planned GISAT in the geosynchronous platform will provide data of any region of interest, every 5 minutes and for the Indian landmass at every half an hour. The RISAT satellites will ensure all weather data availability.

4.5.17 **Early warning system** for drought monitoring and assessment, spatio-temporal distributed water balance models, quantitative impact of drought on production, agricultural drought assessment from geostationary platforms will be taken up. Daily forest fire alerts during forest fire season is being provided presently. Further, identification of forest fire pockets in various regions, fire prone zones, fire frequency analysis, studies on burnt area analysis, and causative factors for forest

fire will be carried out. The satellite based inputs will be used for effective integration of forest working plan management. In the 12th FYP emphasis will be given to customize the early warning systems for different geographical regions and operationalise them.

4.5.18 **Risk evaluation and risk reduction:** As the DMS programme has considerably advanced in generating the database and monitoring the impacts, the emphasis in the 12th FYP will be towards risk mapping and risk mitigation measures. The risk involved in a disaster is disaster specific and region specific. The advancement in knowledge and realization of database such as NDEM will help in risk evaluation. Towards this as the first step a North Eastern Regional Node for Disaster Risk Reduction (NER-DRR) will be established for assessment of disaster specific risk and mitigation methods for the North Eastern region. The DSC at NRSC will address the other part of the country in a phased manner.

4.5.19 **Acquisition of close contour data through ALTM:** During the 12th FYP ALTM-DC data acquisition of 48000 sq. km area of the major flood prone regions are planned. These data will be processed and the close contour information will be passed on to other groups for flood modelling and other activities. Further to increase the efficiency of data acquisition, replacement of the old ALTM-DC system, GPS receivers and processing systems are also planned during the 12th FYP.

4.5.20 **Extension of the communication network to the District Emergency Operation centres:** The satellite based communication network for Disaster management, set up at the behest of MHA at present connect 20 State Emergency Operation Centres with knowledge providing nodes and decision making nodes. This network was planned to be extended to the other states of country and to 241 multihazard prone districts of the country in phases. This could not be completed due to the bandwidth crunch. As DOS is planning to increase the number of transponders in this FYP, the second phase of extending it to the multihazard prone districts will be taken up in association with MHA.

4.5.21 **Geo-Location based services:** The realization of IRNSS will be made operational in the 12th FYP. Eventhough it is primarily meant for civil aviation, it will give opportunity to give a wide opportunity to devise

position based services such as search and rescue services and distress alert services.

4.5.22 **Connectivity and information reach out:** The information reaching the region and people directly exposed to the immediate risk is most important in reducing the casualties. This will also help in coordinating rescue operations in the remote areas. The development of deployable communication equipment, DTH based disaster warning systems etc., are efforts towards this. The advancement of communication systems and improvement in satellite technology such as S-band transmission will give opportunity to test and develop efficient and cost effective communication devices which could be used at the disaster sites. Integration of mobile communication technology with the DMS servers could improve the information dissemination to directly to the person in the danger zone.

4.5.23 **Extension of hydro-meteorological network:** The in-situ observation network in support of extreme weather phenomena needs further extension of the networks such as Automatic Weather Stations and Doppler Weather Radars. Two Polarimetric S-band Doppler Weather radars (DWRs) are to be installed in the North East region. The first system will be installed at Cherrapunji, Meghalaya and site for 2nd DWR in NE region is to be finalized. Additionally two more similar DWRs are projected by SASE/DRDO, Chandigarh to cover the Himalayan region. One location is identified as Banihal pass in J & K and site for 2nd system is to be identified. The total cost of system and civil works will be shared equally by ISRO and DRDO. One C band polarimetric DWR is under development as a technology demonstrator and for rainfall measurements and will be installed at TERLS, Thiruvananthapuram. These systems will be commissioned in the12th five year plan.

4.5.24 **Key areas of Research & Development:** R&D in the areas of early warning and efficient dissemination mechanisms will be continued. The R&D for early warning covers flood, cyclone, drought, earthquakes and landslides. While there has been some advancement in the early warning in case of flood, cyclones and drought further refinement is required. Improvement in the Tropical Cyclone Track, intensity and landfall prediction will be attempted using INSAT-3D and Megha-Tropiques

Mission based automated system, development of wind-hazard model for land falling cyclones, prediction of tropical cyclogenesis using Numerical Weather Prediction model and advanced satellite observations are the key areas of research related to cyclones. In the case of landslides, improvements in rainfall threshold and slope instability based models for early warning of landslides will be attempted. Early warning of Earthquakes is yet another challenging area, not completely understood by the scientific community. There are various precursors identified for earthquake. Crustal deformation mapped through InSAR techniques, study of ionospheric perturbations, land surface temperature anomalies, gravity anomalies etc will be studied as a possible precursor for predicting the earthquake. Similarly, assimilation of temperature, humidity profile and winds in mesoscale models using historical data of extreme rainfall events for possible predictions, flash flood monitoring/ prediction, and developing techniques for using satellite data in conjunction with field data for avalanche forecasting are some of the other areas envisaged.

4.5.25 **Participation in international initiatives:** There has been various efforts from specialized professional bodies/organizations such as Inter-Governmental Oceanographic Commission (IOC), Global Earth Observing System of Systems (GEOSS), Integrated Global Ocean Service Systems (IGOSS), World Meteorological Organisation (WMO), Coordination Group on Meteorological Satellites (CGMS) towards efficient management of disasters. DOS has been in close association with International Charter 'Space and Major Disasters' and Sentinel Asia programme. This association will be continued and strengthened by providing data and products from IRS satellites, secretarial support and supporting the capacity building.

4.6 Space Transportation System

4.6.1 The main focus of the Space Transportation Systems during 12th plan period will be towards achieving self-sufficiency in launching our satellites, developing launch vehicles for enhanced pay load capability, adopting appropriate outsourcing strategies for assuring productionisation of launch vehicles, enhancement of infrastructure for launch vehicles and developing technologies for the future programme of ISRO will be the focus during the upcoming plan period.

Global Trends

4.6.2 Global trend for Space Transportation systems among space faring nations is currently focused towards expendable launch vehicles with wide range of payload capability that is achieved through optimum stage selection. The reusable launch vehicle programme world-wide is given lesser thrust, because of the increased cost and lower reliability with the current technologies. The grounding of the space shuttle is a case in point. Also focus on human in space programme has marginally decreased and in contrast the scientific missions and communication satellite launches are given more thrust. Hence a global shift in the concept of low cost access to space is emerging with focus from reusable launch vehicles to expendable launch vehicles.

Indian Scenario

4.6.3 In the Indian scenario, reduction of launch cost, and achieving self-reliance in launch vehicle technology will be given maximum thrust. To meet the payload requirement up to 4 tons in a cost effective way, the existing class of PSLV,GSLV MK-II and GSLV MK III would be utilized. To further reduce the cost of launching, development of Unified Launch Vehicle with semi-cryogenic engine will be given due attention. Also technology development programmes for evolving a cost effective and reliable Reusable launch vehicle and also human in space mission would be given sufficient thrust. Novel scientific missions to Mars, moon and other interplanetary missions are envisaged.

Major Thrust Areas

4.6.4 The major thrust areas of Space Transportation System during 12th plan period would include:

(a) Enhanced level of production of PSLV Vehicle systems with vigorous industry participation to meet the projected launch requirements.

(b) Complete the qualification of indigenous Cryogenic Upper Stage (CUS)

(c) Complete the development flights and operationalise GSLV MK II with indigenous Cryogenic Upper Stage

(d) Complete development and qualification of C25 Engine & Stage

(e) Complete the first developmental flight of GSLV Mk III with 4.0 T GTO capability

(f) Enhancement of infrastructure to meet the launch vehicle requirements and advanced mission requirements.

(g) Demonstrate critical technology related to RLV & DMRJ through technology demonstration

(h) Develop the critical technology & subsystems related to Human Space flight programme

(i) Develop and demonstrate the critical technologies that will make ISRO's launch vehicle more cost effective and more capable.

(j) Continue the technology development efforts to improve the present capabilities and to contribute for long term Space Research.

Programmatic Targets:

4.6.5 The mission profile for meeting the satellite launch demand includes 17 PSLV missions, 6 GSLV MK-II missions and 2 GSLV MK-III missions (this also includes one experimental mission). This demands increased stage and system production rates, expanding human infrastructure and test facilities and substantial technological achievements in cryogenic stage elements.

4.6.6 **The Polar Satellite Launch Vehicle (PSLV)** is a reliable work horse designed and developed for launching satellites in the Sun Synchronous low earth orbits and GTO. It has a maximum capability of 1750 kg payload into a 622 km Sun Synchronous polar orbit (SSPO) and 1100kg in GTO. PSLV has a pedigree of 2 developmental and 16 operational flights. During the 12th plan, 17 PSLV launches (as against 11 PSLVs in 11th plan) are planned with suitable productionisation program and participation from Indian industry.

4.6.7 **Geosynchronous Satellite Launch Vehicle (GSLV)** is developed by ISRO towards achieving indigenous launch capability of 2000 kg class satellites such as INSAT, GSAT etc into GTO. The GSLV is a three stage vehicle. It adopts the flight-proven solid and liquid stages of ISRO's Polar Satellite Launch Vehicle (PSLV) and a cryogenic upper stage. GSLV had three developmental flights and four operational flights. Out of seven flights, GSLV D1, D2 and F01 were successful. GSLV F04 was partially successful and GSLV F02, D3 and F06 could not meet mission objectives.

4.6.8 Several measures have been undertaken to enhance the reliability of GSLV.The wealth of flight data and system performance information are harnessed from the previous 7 flights are analysed in detail. Corrective steps are identified and design modifications are implemented wherever required and necessary re-qualification of systems are also undertaken. The technical aspects are being reviewed by a panel drawn from national expertise comprising of members from research institutions, academia and industry. Their technical inputs are being incorporated in the design. Further, additional characterisations addressing all possible failure scenarios are undertaken and robustness of the system is enhanced with increased design margins.

4.6.9 It is targeted to realize 6 flights of GSLV during 12th plan period to meet the projected launch requirements including Chandryaan-2. Some of the important milestones of GSLV in the months to come are:

(a) Completion of modifications on Fuel booster Turbo Pump as per GSLV D3 FAC recommendations and completion of tests.

(b) Finalization of design improvements in the Cryo stage lower shroud as per GSLV F06 FAC recommendation.

(c) Demonstration of 4 m diameter payload fairing for larger payloads.

(d) Qualification of the Indigenous cryo stage in the next developmental flight of GSLV and productionise CUS.

(e) Demonstration of reliability of GSLV by successful future flights

(f) Suitable productionisation strategies and enhanced infrastructure to meet the commitment

4.6.10 **Cryogenic upper stage project** envisages the development and delivery of indigenous cryogenic upper stage (CUS) for GSLV MK-II programme. The major accomplishments during the 11th Plan were successful stage hot tests, structural qualification tests, stage propellant mock up trials, realization of first flight stage and flight testing in GSLV D3 mission. In the flight the main engine and two vernier engines successfully ignited. However due to anomaly in the LH2 booster turbo pump, the mission could not be accomplished. Based on accumulated wealth of ground hot test data and flight data, necessary improvements are incorporated in fuel booster turbo pump and qualified. The CUS stage with improved turbo pump will be flight tested in GSLV D5 in 2012.

4.6.11 **GSLV Mk-III** is intended to be a cost effective launcher for placing 4 ton class spacecraft to GTO. The major accomplishments in the 11th plan were the completion of S200 static tests, L110 stage hot tests, subsystem tests of CE20 engine, and structural testing of major elements. Though the progress in realization of subsystems have been substantial during the previous plan period, the targeted milestone of first development flight was not achieved due to time taken for new technology development and constraints of facility sharing. Though extensive analysis and tests are performed to validate the new technologies, flight test is the best confidence builder. Considering the complexity of the vehicle design and also the maturity and readiness of S200 and L110 stages, it is proposed to have an experimental mission of LVM3 with a passive C25 stage to demonstrate the critical atmospheric phase of flight and build up the required confidence prior to the use of C25 stage in LVM3 D1 flight.

4.6.12 Accordingly, in the 12th plan, it is proposed to undertake flight test (LVM3-X Mission) by last quarter of 2012. The launch complex facilities will be made operational with mock up activities. With the completion of qualification of C25 by 2014, the first development mission of GSLV Mk-III, i.e. LVM3-D1 mission will be scheduled during 2016-17 followed by LVM-D2 and one operational flight LVM3-M1 during the early phase of 13th plan period.

4.6.13 The payload capability of GSLV Mk-III can be further enhanced by 500 kg, if Two Burn Option for C25 stage is available. After the successful development of C25 and flight testing, the development of two burn option can be initiated, which require additional hardware design, engine and stage. The improvement in the performance of S200 is proposed by changing the grain geometry of head end segment.

4.6.14 **Semi-cryogenic project** envisages the design and development of 2000kN semi-cryogenic engine for the future heavy lift unified launch vehicle (ULV) and re-usable launch vehicles (RLV). Semi cryogenic engine uses a combination of liquid oxygen and Isrosene as propellants which are eco-friendly and cost effective. The major accomplishments in the 11th FYP were completion of engine design, development of a single element pre-burner and demonstration of ignition, initiation of materials procurement and development of strategic materials, design of test facilities. In the 12th FYP, the facilities required for production, assembly and testing will be established and engine developmental tests will be carried out.

4.6.15 A **Semi Cryogenic Stage** (SC160) with 160ton propellant loading powered by 2000kN semi-cryogenic engine is planned to be used in place of L110 stage of GSLV Mk III. This will enhanced the GTO pay load capability from 4 T to 6T. In the 12th FYP this stage development will be initiated.

4.6.16 For the atmosphere studies, scientific payloads are regularly launched by **Rohini series of sounding rockets** from TERLS and SDSC SHAR. Sounding Rocket programme also caters to development and flight testing of low cost sub systems and for technology demonstration of new

systems. Twenty six RH200 rockets were successfully launched during 11th plan period, the five-year MIDAS campaign. 165 RH200 flights were undertaken from TERLS Range during the 11th five year plan period. Two RH300 MkII flights were undertaken for Mesospheric Airglow Emission Studies with scientific payloads from PRL, Ahmedabad. For studying the middle and upper atmosphere during solar annular eclipse, eleven sounding rocket flights were conducted for SooyaGrahan-2010 Campaign viz. two RH560 MkII, five RH300 MkII and four RH200 during 14 – 17, January 2010 and data received handed over to scientists of PRL, Ahmedabad and Space Physics Laboratory, VSSC.

4.6.17 In the 12th plan, regular flights of RH 200 vehicle are planned from TERLS Range. In addition RH200 and RH300 Mk II flights are planned for several scientific studies. Developmental flights of RH 300 Mk III vehicle for 160 km altitude with 60 kg payload and RH 560 Mk III vehicle by replacing 560 booster with 560 M motor for 560 km altitude with 100 kg payload are being planned and the vehicles are planned to be operationalized. A new RH560 launcher will be made operational at SDSC SHAR to meet the increased launch frequency. As a part of academic collaborative programme, RH 200 Technology Demonstrator flights are also planned under Indian Institute of Space and Technology (IIST) student rocket programme during 2012. This totally accounts to more than 150 flights in the 12th plan.

4.6.18 **Space Recovery Capsule Experiment-II** Project has been formed in April 2008 with the main objective of realizing a fully recoverable capsule and the associated technologies. The first orbital reentry and recovery mission of India, Space Capsule Recovery Experiment (SRE-1), was successfully carried out on 22nd January 2007. SRE-1, after completion of micro gravity experiments in orbit, re-entered earth's atmosphere and was recovered safely at Bay of Bengal near Chennai. SRE mission and its success was the culmination of the systematic effort by a large number of expert teams from ISRO centres as well as other Govt. of India organizations, academic institutes and industry.

4.6.19 **Advanced Technology Vehicles Project** was formed to support the new technology areas especially Dual Mode Ram Jet Engine and Scram Jet Engine flight test demonstration. The first development flight of ATV D01(using RH 560 sounding rocket) was a 100% successful flight in which all the vehicle parameters were measured and vehicle characterization was done. The requirement to dwell the vehicle in the defined M-q window for a minimum of 5s was also demonstrated. In the 12th plan, five numbers of ATV development flights are scheduled to be flight tested with Dual Mode Ramjet-Scramjet Engine Modules from 2012 to 2015 and developmental flights of ATV-EX vehicle, improving ATV-D01 configuration with sustainer fins in cruciform configuration to achieve 600 km altitude with 200 kg payload.

4.6.20 A series of the **Reusable Launch Vehicle** technology demonstration missions have been envisaged to realize fully re-usable Two Stage to Orbit (TSTO) vehicle. For this purpose a winged Reusable Launch Vehicle Technology Demonstrator (RLV-TD) has been configured. RLV-TD will act as a flying test bed to evaluate various technologies required to qualify re-entry mission viz. hypersonic flight, light weight structures, control surfaces, control actuators under hypersonic flight environment, thermal protection systems, autonomous navigation, guidance and control, landing, powered cruise flight etc. and air breathing propulsion. RLV-TD activities that spill over to 12th plan period include Carbon-Carbon nose cap realization, fabrication of all structural components for proto/flight, structural testing and accomplishment of HEX-01 flight. Scheduled activities could not be completed as per plan due to constraints of resource sharing and time taken for new technology developments to meet the stringent mission requirements. In the 12th plan, hypersonic experiment flights (HEX1 & HEX2) are planned and developmental works will be initiated for HEX3, Landing Experiment, Re-entry experiment. The additional launch base infrastructure like jetty, air strip is planned for realization at SDSC SHAR for the Reusable launch vehicles.

4.6.21 **Air Breathing Propulsion** will play an important role in an advanced TSTO Reusable Launch Vehicle enabling cost reduction and improving

vehicle operability. Starting with Dual Mode Ramjet-Flight Technology Demonstration (DMRJ-FTD) programme for 0.1-ton class ram-scramjet engine, development of air breathing propulsion is envisaged in a progressive manner. One-ton class of turbojet, ramjet and scramjet engines are planned to be used in Reusable Launch Vehicle Technology Demonstrator (RLV-TD) programme. This would pave the way for subsequent development of bigger air breathing engines (of 10 ton class and above) for advanced TSTO-RLV. Vehicle characterization flight has been successfully carried out. Scramjet/Ramjet flights have spilled over to 12th five-year plan due to development issues of the new technology and constraints in sharing of resources among other projects.

4.6.22 During the 12th plan period, the major activities planned under Air Breathing (AB) propulsion are to realize ramjet-scramjet engines for *DMRJ-FTD* programme (using Advanced Technology Vehicle), to initiate the air breathing propulsion development activities for RLV application, to have specific technology development activities unique to air breathing engines and to augment the Scramjet Propulsion Test Facility (SPTF) at Mahendragiri for '*near*' flight condition simulations.

4.6.23 For achieving technological pre-eminence and as the natural progression of its current endeavors, ISRO has been mooting the idea of an **Indian Manned Space Mission**. This was debated in various forums and a majority of experts nation-vide endorsed the programme, noting that this would enthuse the scientific community of the country and would be a pride to every Indian apart from the many technological achievements. It was decided that the entire programme will be split into three different phases with the first phase targeting design, development and performance demonstration of critical technologies leading to manned space missions. The second phase and third phase would establish the necessary infrastructure, do qualification tests including flight testing with test vehicles, PSLV, GSLV and GSLV Mk III and finally demonstrate the first Indian Human Spaceflight. Meanwhile, the first phase of the revised program with a total cost of ₹ 435.00 crores, was prepared as a Project Report and was submitted for Government approval. During the 12th plan period, it is proposed to develop and demonstrate all the major

technology elements and infrastructure essential for Human Spaceflight Programme (HSP) including pad abort test, Orbital Vehicle (OV), Crew Escape System (CES), Environmental Control and Life Support Systems (ECLSS) & Flight Suit, Human rating of Launch Vehicle and realizing essential facilities including third launch pad for the development and flight testing of these systems. Mission and configuration studies and technical developmental activities will also be initiated for the Human Lunar Missions.

4.6.24 **Unified Launch Vehicle** conceptualizes a generic launch vehicle configuration to be able to meet the varying requirement from mission to mission by varying the propulsion system with considerable cost advantage. Unified Launch vehicle with semi-cryo stage has the features of a world class expendable launch vehicle, with GTO payload capability of 6t and LEO payload capability of 15t. Studies and developmental activities of ULV will be initiated in the 12th plan period.

4.6.25 **The Human Rating process of GSLV Mk III** for meeting the requirements of HSP is to be initiated in the 12th plan period. The work contents are, redesign of vehicle structures including propellant tanks and motor cases if necessary, re-qualification tests including stage functional tests of S200, L110 and C25. Intelligent systems to monitor and identify the imminent failure of systems are to be developed. The redundancy schemes in all the avionics, control systems, pyro systems and mechanisms are to be re-looked and re-qualified. Additional facilities for structural test are to be developed for conducting these tests.

4.6.26 Studies will be initiated for identification of a suitable site for establishment of a **Second Launch complex** to meet the enhanced launch requirements with payload gain.

4.7 Space Sciences and Planetary Exploration

4.7.1 Space Sciences & Planetary Exploratory missions contribute significantly towards understanding the mysteries of the universe, our existence and provide an opportunity towards development of cutting edge technologies. Through space science investigations, we seek to understand the processes governing solar radiation, evolution of planetary system, formation of galaxies, evolution of stellar systems and the universe.

4.7.2 Successful launch and realisation of Chandrayaan-1, India's first Mission to Moon in 2008 has been a land mark achievement in Indian Space Programme. The major contributions of Chandrayaan-1 were the discovery of water on the lunar surface and exosphere, clear evidence for the production of energetic neutral atoms and the development of detailed Digital Elevation Model of regions mapped by its stereographic camera. The work on Chandrayaan-2, Astrosat-1 and Aditya, initiated during 11th plan, is in progress and all these missions will be realised in 12th plan.

Global Trends:

4.7.3 The international scenario in planetary exploration is primarily towards MARS & Moon exploration. However, International space agencies from USA (NASA), Europe (ESA), Japan (JAXA) and China are also contemplating solar system exploration mission to study Mercury, Jupiter, Saturn and Pluto. In addition some missions are also planned to reach Near Earth Objects and Asteroids.

4.7.4 As far as MARS is concerned, the scenario is for Lander/ Rover missions for in-situ measurements, characterization of Martian atmosphere, identification of life indicators etc. Missions that are planned by NASA are MARS Science Laboratory CURIOSITY(Rover mission), MAVEN (Orbiter). Also NASA/ ESA are jointly planning a mission called ExoMARS to study trace gases on the Martian atmosphere.

4.7.5 Some of the important scientific missions to Moon in future are GRAIL (Lunar gravity mapping), LADEE (lunar atmosphere and Dust studies), SunRise (Sample Return far side mission). All these missions are from NASA, USA.

4.7.6 In the coming decade, more than 50 research missions are expected to be launched by ESA/NASA/JAXA etc. to advance the understanding of the early universe in the field of astronomy. Many of them are aimed towards studying the earliest galaxies and some of the first stars formed after the Big Bang. Missions are also initiated to use X-ray polarization as the new tool to study neutron stars and black-holes.

Thrust areas / Initiatives during the 12th Five Year Plan:

4.7.7 The major thrust areas of Space Science and Planetary Exploration programmes during 12th plan period are:

(a) Undertaking a technologically challenging "Mission to MARS"

(b) Exploration of Moon (Orbiter, Lander, Rover mission) - Realization of scientific payloads to study Lunar surface composition, morphology, Lunar Polar Ice detection and regolith characterization

(c) Realisation of the first Indian space science mission to study the Solar Corona

(d) An X-Ray polarimeter (POLIX) to study the x-ray polarization from bright x-ray emitting objects

(e) Initiatives towards undertaking MARS orbiter and Lander mission during 2018 launch opportunity- Identification of scientific payloads etc. Exploration of MARS surface features viz. morphology, topography, mineralogy and martian atmosphere

(f) Initiatives towards Lunar sample return missions from the polar region of moon and a possible establishment of lunar observatory

(g) Studies towards undertaking mission to Near Earth Objects and Asteroids

(h) Feasibility studies for use of Nuclear propulsion systems (RTG's) for Interplanetary missions

(i) Initiatives towards next space based Astronomy missions – Development of Infra-Red Spectroscopic Imaging Survey experiment, Gas Electron Multiplier (GEM) detector, X-ray instruments based on Solid State Detectors etc.

(j) Astrobiology Laboratory – Studies towards understanding of growth factor and sustenance of life systems under space environment and

search for life on other planets. Establishment of laboratory to study this would feed into future space exploration and space habitats.

(k) Space Habitat - Some of the technologies to be developed towards this would be development of inflatable structures for human habitat and solar cells with higher efficiency

Programmes during the 12th Five Year Plan:

4.7.8 Besides the spill over missions of Chandrayaan-2, Astrosat-1 and Aditya, the newer mission that is planned to be realised during the 12th plan is MARS Orbiter Mission. In addition, POLIX mission to study the X-ray polarization from bright x-ray emitting objects will be pursued.

4.7.9 **Mission to MARS (during November 2013 launch opportunity):** Mars with its many similarities to Earth is an important planet to understand the origin and evolution of the solar system. India certainly cannot afford to be behind in its independent exploration of the red planet.

4.7.10 India's first Mission to MARS during the 2013 would be important more from the technological perspective viz. entire mission design, planning, management and operations, communication from a distance of nearly 400 million km. This mission will demonstrate ISRO's capability to undertake deep space planetary mission where the travel time from Earth to MARS is nearly 300 days. The Indian Mission to Mars would also provide an opportunity to the scientific community, to further understand the Martian Science.

4.7.11 The present plan is to launch an MARS orbiter using Polar Satellite Launch Vehicle (PSLV-XL) during the November 2013 launch opportunity. MARS orbiter will be placed in an orbit of 500 x 80,000 km around MARS and will have a provision for carrying nearly 25 kg of scientific payloads on-board. The launch is planned during 2013.

4.7.12 **Chandrayaan-2**: After the first lunar mission, ISRO has undertaken the lunar landing mission, Chandrayaan-2, comprising of an Orbiter Craft, a Lander Craft and a Rover. Chandrayaan-2 is an Indo- Russian mission with Orbiter and Rover supplied by India whereas the Lander module will be from Russia. The objective of this mission is to land at a suitable

site on the lunar surface and carry out in-situ analysis by extracting the regolith by a drill or robotic arm for scientific studies of the lunar surface including analyses / detection of water ice (H_2O) etc. The launch is planned during 2014.

4.7.13 **ASTROSAT-1** is the first Indian Astronomy mission which will conduct simultaneous multi-wavelength observation of celestial objects covering optical, Ultraviolet and X-ray bands. The payloads for ASTROSAT are realized by ISRO, Tata Institute of Fundamental Research (TIFR) and Indian Institute of Astrophysics (IIA). The launch ASTROSAT is expected to increase the user community in the area of space science. The launch is planned during 2012-2013.

4.7.14 **ADITYA-1** is the first Indian space borne solar coronagraph mission to observe the coronal mass ejections (CMEs). Study of CMEs is important to understand how the magnetic fields from the interior of the Sun emerge at the surface leading to large mass ejections from the surface. Mass ejections can lead to major increases in charge particle background even around the Earth. The launch is planned during 2015-2016.

4.7.15 **X-ray Polarimeter Mission (POLIX)**: X-ray astronomy missions undertaken so far have made detailed studies towards imaging, timing and spectroscopy. One of the areas so far not explored has been polarization measurements. Many celestial X-ray sources have neutron stars with magnetic fields as high as 10^9 to 10^{12} Gauss. Polarization measurement is the only method of directly measuring the magnetic fields in these objects (neutron stars). The X-ray Polarimeter Experiment (POLIX) aims to measure the degree and direction of the X-ray polarization of a few bright cosmic X-ray sources using the principle of anisotropic Thomson scattering in 5-30 keV energy band.

4.7.16 **Capacity Building**: Keeping in view the recent initiatives/missions undertaken in the area of Space science research and planetary exploration viz. Chandrayaan-1 & 2, Astrosat, Mission to Mars, Aditya-1 etc., efforts will be made in creating a human resource base in the country for analysing the enormous amount of scientific data that would be available from these missions. There is also a need to adopt aggressive

measures in this direction to ensure availability of scientists in the area of space science and planetary exploration during the 12th Plan period.

4.8 Space Technology Initiatives for NE development.

4.8.1.1 The North Eastern Space Applications Centre (NESAC) has the mandate of providing support to developmental activities in the North Eastern Region (NER) through establishing an operational remote sensing based natural resources information generation facility, an operational satellite communications application segment to assist education, health, social welfare and other developmental activities. NESAC has also the mandate of establishing a regional facility for undertaking research in space science, organize training/ lectures/ seminars and symposia and research in space applications. In this endeavour, NESAC is to cooperate and collaborate with other national and /or international institutions, and publish and disseminate information on activities and research conducted in the Centre.

4.8.1.2 NESAC has taken up during 11th plan several collaborative projects along with the Space Applications Centre (SAC), National Remote Sensing Centre (NRSC), Indian Institute of Remote Sensing (IIRS), Universities/IITs of NER and State Remote Sensing Agencies on identified problems of the NER States in the areas of Remote Sensing and GIS, Satellite Communication, DMS, Space Science and Atmospheric Sciences.

Projects proposed for implementation during the 12th FYP

4.8.3 During the 12th Plan period, NESAC will pursue the recommendations of the HPC constituted for identifying the areas of priority based on the inputs received from the eight NE states.

4.8.4 **Natural Resources Repository (NRR):** NESAC will be participating in LULC–50K updation project, database generation at 1:10K scale under SIS-DP project. NESAC will also carry out geomorphological mapping and ground water prospects mapping for entire NER in collaboration with NRSC and State Remote Sensing Centres. A DBT funded project on developing an early warning system for tea mosquito bug infestation in tea

garden will be completed. EOAM funded project on mapping of major vector borne diseases in NER will also be completed.

4.8.5 NESAC will focus on preparing the remote sensing and GIS based forest working plan inputs for the states of Arunachal Pradesh, Assam, Meghalaya, Nagaland, Sikkim and Tripura. Utilization of RISAT data along with other SAR data will be a major focus during the 12th FYP considering the problem of persistent cloud cover in NER. A major project is proposed under EO-A for use of hyper-spectral data in the region. Scope of studies related to Health GIS will be expanded to a large extent during 12th FYP. NESAC proposes to use LIDAR data for various applications in the areas like forest biomass and timber stock estimation. ALTM data for selected areas are proposed to use in developing flood inundation simulation models in Brahmaputra and Barak valley.

4.8.6 **Satellite Communication**: NESAC will expand the Telemedicine network to all the district hospitals in NER. EDUSAT network will be expanded to a large extent connecting large numbers of schools, professional institutes and training centres. NESAC will support establishment of ground control station for the IRNSS.

4.8.7 **Disaster Risk Reduction for NER – A new Initiative**: NESAC shall operationalize Flood Early Warning System (FLEWS) for all the flood prone districts in NER. North Eastern Regional Node for Disaster Risk Reduction (NER-DRR) cell initiated by Chairman, ISRO on 26th July' 2011 will be made operational during 12th FYP. Creation of digital database for disaster-prone areas (Flood, landslide, earthquake, etc.) in each State of NER is also planned during 12th FYP. Hazard Risk Vulnerability Assessment (HRVA) for selected areas in NER initiated during 11th FYP will be completed during 12th FYP. District-wise drought assessment will be continued for entire NER.

4.8.8 **Space and Atmospheric Science:** Specific Studies will be taken up to characterize the regional aerosol and Green House Gases (GHG) to generate inventory of their regional source and sink by means of field campaigns and estimate their radiative forcing. The cloud-aerosol interaction and its impact on cloud precipitation efficiency and monsoon modulation shall be studied. NESAC will continue the numerical weather

forecasting for NER by improving the resolution with assimilation of more parameters and will also conduct research towards appropriate physics parameterization of atmospheric process unique to the region. The weather advisory services shall be extended to entire NER. A laboratory for Space weather and Ionospheric studies under the CAWSES-India programme shall be established to study the Sun-Ionosphere interaction.

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5. 12th PLAN – TECHNOLOGY AND POLICY INITIATIVES

5.1 Technology Initiatives

5.1.1 Technological advancement, which is essential to maintain competitive relevance, will be an important thrust area for future space endeavors. The current level of technologies have to be upgraded to a higher magnitude and novel concepts have to be developed in order to achieve a much better and reliable space system. New technologies acquired will be the driving force for futuristic space missions. Towards this the following technological development activities are planned during the 12th plan period.

Launch Vehicle Development Area:

(a) Composite segmented booster case for large solid motors,

(b) Elastic memory composites and Carbon-carbon technology demonstrators including optimization studies of carbon-carbon processing through CVI furnace, multidirectional perform & Characterization of thermo structural products at elevated temperature

(c) Automated real time structural integrity evaluation through acoustic emission monitoring for weld quality & in-flight integrity evaluation of structural components

(d) Optimal Trajectory design for various Lunar and interplanetary missions

(e) Orbital debris tracking and collision modeling

(f) Close loop speed control system for turbine

(g) Thin film coating for realizing zero lock ILG

(h) Autonomous Navigation Systems for long duration missions and HSP mission

(i) Atom interferometer based gyro and accelerometer.

(j) High resolution optical encoder

(k) Miniaturization of systems incorporating ASIC, SMD intensive and COB technology.

(l) MEMS Tunneling Accelerometer technology with compact sensor electronics.

(m) CFD solvers and associated high performance computing platforms

(n) Advanced engine actuator systems

(o) Robotics for planetary missions

(p) Miniaturization of electronic components

(q) Development of new guidance, simulation and control algorithms for robotics, interplanetary missions and human in space missions

(r) Nano materials and composite, high temperature material and composite, special alloys, radiation shield materials.

(s) Lunar soft lander

(t) Design of seal for minimum wear and leak, development of ceramic ball bearings and non-conventional bearings

(u) Dual bell nozzle

(v) Supersonic film cooling technology

(w) Study on 10T thrust pump feed earth storable engine for application in PSLV.

Earth Observations and Atmospheric Sciences Area

(a) Design and development of bus systems with required positioning accuracy, attitude and platform stability

(b) Air borne imaging spectrometer covering larger spectral bandwidth

(c) Green House Gases and Trace gases sensors using hyperfine and ultrafine spectrometers

(d) Field based multi-frequency microwave Ground Penetrating Radar

(e) Sensors for new categories and applications such as sounding by millimeter wave, LIDAR based sensors.

(f) Grids/ Cloud computing for EO data processing and dissemination

(g) Online geospatial data processing and development of specialized packages

(h) Development of immersive data visualization techniques for cyclone tracking, floods and 3D city simulation

(i) Super resolution technique for enhanced spatial and spectral restoration

(j) Building antenna and RF acquisition processing for new frequencies like Ka band

(k) Reflective Optics with large diameter mirrors

(l) Indigenous Processor for space applications, customized for Indian satellites.

(m) Very High Resolution Optical Sensor enabling technologies

(n) Advance SiC Mirror technology for 2 to 2.5 M Optics

(o) Multi-Band spectral filter development

(p) Detector Development

(q) Deformable mirror segments using suitable materials / activators

(r) Printed phased array & Reconfigurable Planar Antennas

(s) High Speed - High Power RF Switches

(t) Reconfigurable – reprogrammable Micro-Controller based systems

(u) Stress free mounting/ holding for very large optical/antenna components

(v) Lightweight composite structure for electro-optics module

(w) CFRP and composite based telescope/ antenna structures

(x) Faster / efficient software for Data Product generation

(y) Platform independent emulators and hardware simulation

Satellite communications Area:

Spacecraft Related Technologies

(a) I-4K bus with modular design (Bus module & payload module)

(b) 10 KW power generation and handling

(c) Single fully regulated 70-volt bus with Modular high power Battery Discharge Regulators (BDRs)

(d) Higher capacity Lithium ion batteries

(e) Electric propulsion along with chemical propulsion

(f) Highly stable platforms, on-board optical/RF tracking system

(g) DTG based Inertial Reference Unit (IRU)

(h) Miniaturization – MMICs, ASICs, FPGAs, HMCs, BGAs based systems

(i) I-6K Unified bus with modular design ,multi EV panels and scalable structure (Bus module & payload module)

(j) 20 KW DC power generation and handling by deploying a scalable and modular configuration

(k) Development of a new SADA system to handle power upto 20 kW

(l) Thermal control system to handle power dissipation in excess of 8 KW using Deployable radiators and various types of heat pipes including flexible links

(m) High capacity electrical propulsion system

(n) Autonomous precision antenna pointing system using advanced tracking mechanism

(o) DTG based Inertial Reference Unit (IRU) with star trackers

(p) Ku band TTC RF system

(q) Inter-satellite communication links

(r) Design and development of New I-4 K SADA with 120 V capability to handle 20kW in 70V and delivery to GSAT -11E.

(s) Solar power Satellite -Proof of concept

Payload Related Technologies:

(a) C, Ku-band TWTA development

(b) Ku-band Microwave Power Module (MPM), (using SL-TWTA + EPC + MMIC based L-SSPA integrated in single package)

(c) Digital Beam Former

(d) Flexible payload by developing flexible TWTA, EPC and Agile receivers & converters, and flexible dynamic range ALC Driver Amplifiers

(e) 12m unfurlable reflector, adaptive reconfigurable antennas, advanced multi spot bean antennas, active integrated antenna, Electromagnetic and photonic band gap antennas (EBG & FBG), dielectric loaded horns, microstrip phased array antennas

(f) Multi-channel Waveguide Rotary Joint

(g) On-board processing payloads; On-board Transparent Bandwidth Processor and signalling demodulator; High Data Rage Modulator

(h) On-board RF tracking system and digital Tracking Receiver for APM of multi-beam satellite

(i) Development of sub-systems at V-band to be initiated

(j) Development of high data rate free space Optical link for LEO to GEO

(k) GaN Device based SSPA: C-band (63 W), L-band (150 W) & S-band (250 W)

(l) EPC for GaN based SSPA

(m) Multiport Amplifiers (MPA): Ku-band MPA and S-band MPA

(n) Design of MMIC (L to W-band) and MMIC + LTCC based Sub-systems for miniaturization

(o) LTCC based Passive Components (Filters, PD, Couplers etc.)

(p) Pre-distortion type IMUX Filters: C-band & S-band (Use of low Q Resonators, Size & mass reduction by 70% with Equivalent RF performance as that of DR based Filters) and Ku-band (Use of low Q DR)

(q) Ku-band Temp. Compensated Filter based OMUX (300 W / Ch)

(r) S-band Narrowband (2.5 MHz) High Power O/P Filters

(s) Development of Digital m-ary Modulator with suitable coding for increased throughput, Power and Spectral Efficiency

(t) Development of Automatic Modulation Recognition techniques for onboard adaptive demodulation systems to improve QoS and to establish secured & strategic communication

(u) Study of

- Translucent processor
- Adaptive Digital Beam former
- Indian Data Relay Satellites and
- Safety and security of satellites and to prevent unauthorized use of satellites

Ground Segment & Applications related technologies

(a) Development of Ground segment commensurate with GSAT-6, 6A, & GSAT-11 satellites.

(b) User terminals compatible to multi-beam satellite for mobile communication

(c) Broad-band miniaturized antenna technology in L & S-bands

(d) Mobile multi-media hand-held receiver technology

(e) Advanced R&D for miniaturized re-configurable IDU (baseband & Modem for satellite terminals) using ASIC

(f) Development of Portable Ku-band Tele-medicine Terminal

(g) Miniaturized version of Ka-band user terminals

(h) Development of Optical Communication Terminal to be continued.

(i) Ka& V-band propagation studies and development of mitigation techniques

(j) Satcom based Automatic Identification System (AIS)

(k) Development of two-way audio-data communication distress alert terminals for Fishermen

(l) Ground segment for MEOSAR based Search & Rescue System

(m) Development of CospasSarsat compatible low cost Position Locator Beacons for search& rescue operations

(n) GMR standards for SATCOM Terminals for future Geo- mobile satellite

(o) LTE / LTE Advance for seamless communication across terminals and satellite network

Satellite Based Navigation Area

(a) Development of Indigenous Space qualified atomic clocks & On-board time synchronization technology.

(b) GaN Device based SSPA for L-band (150 W) & S-band (250 W).

(c) Productionization of Navigation satellites

(d) Development of Block / Stream Cipher for Encryption

(e) Characterization of IRNSS Network Time

(f) Technology development for the for the following type of user receivers including Integrated IRNSS and GNSS receiver preferably with Indian Industry participation .

- Development of SPS and RS User Receivers
- Multi-GNSS User Receiver (IRNSS, GPS, Glonass, Galileo) for improved PNT Solution
- User Receiver based on Carrier Phase Measurement for centimeter level accuracy
- Low cost and compact User Receiver

(g) Indigenous Reference Receiver Development with Indian Industry participation.

(h) Development of GNSS Signal Generators and Simulators

(i) Monitoring of satellite navigation signals for Quality of Service (QoS) of IRNSS and also other GNSS signals for Interference Analysis.

(j) Study and Analysis for Global Indian Navigational System (GINS).

(k) Study & Development initiatives for All Optical Atomic Clock (Ultra Stable for IRNSS, Deep Space Communication)

(l) Study and assess the requirement of Pseudolite in Indian scenario.

(m) Study on the use of C-band for satellite navigation.

(n) Study and plan for Indoor applications using the local augmentation.

(o) Study for improving the Weather prediction model by using the constellation of Observing System for Meteorology, Ionosphere and Climate (COSMIC).

Technology Demonstrator/ Experimental Satellites

During the 12th plan period a number of small satellite (IMS class) missions have been planned to demonstrate the emerging newer technologies. One of the major missions being the technology demonstration related to Docking and Rendezvous. These satellites will be flown on the PSLV missions as auxiliary or co-passenger satellites.

In addition, opportunities will be provided to the Indian student community to fly their nano-satellites for technology demonstration purposes.

5.2 Policy Initiatives

5.2.1 **SATCOM Policy:** SATCOM Policy in the country was introduced during 1997-2000 time frame enabling use of INSAT system by Private parties and the procedures to be followed in allocating the transponder capacity. The INSAT Co-coordinating Committee, which is the apex committee to provide directions on INSAT system planning as well as the Technical Advisory Group (TAG) have been recently reconstituted. INSAT system has grown many folds since the formulation of the Satcom policy and number of users on INSAT systems has also increased remarkably. Taking into account the last decade experience and considering the current growth scenario of Satellite Communications in the country, theSatcom policy 2000 will be revisited and revised, if required.

5.2.2 **Remote Sensing Data Policy:** Government of India has recently approved Remote Sensing Data Policy (RSDP 2011), containing modalities for managing and/or permitting acquisition/ dissemination of remote sensing data in support of developmental activities. Department of Space has been identified as the nodal agency by the Government for all actions under this policy which includes (i) license and /or permission for operating a remote sensing satellite from India (ii) acquisition/distribution of remote sensing data within India and (iii) acquisition/distribution of remote sensing data for use in countries other than India.

5.2.3 The policy allows distribution of all satellite data of resolutions up to 1 m on a non-discriminatory and “as requested basis” to the user; and all data of better than 1 m resolution would be subject to screening and clearance by the appropriate agency prior to distribution.

5.2.4 The recent initiative of Vetting of Images and Geospatial Information for Licensing for National Security VIGIL (in planning stage) is an effort of the inter-Ministerial Committee lead by DST and supported by DOS to draft a Bill to regulate the dissemination of images (satellite & aerial), Geo Spatial Information and terrestrial photography through web-hosting and in physical form and subject to a transparent licensing conditionality and in consonance with prevailing National Policies. The VIGIL Act will provide sufficient 'teeth' to the Remote Sensing Data Policy of 2011 for its effective implementation

5.2.5 Currently, satellite images better than 1 m resolution data is already available for browsing, visualization and down-loading through internet/web based service in public domain by the global player like Google Earth and Wikimapia. Taking in to account of technological improvement and global trend, the policy will be reviewed from time-to-time by Government, as per the provision contained in the policy.

5.2.6 **Space Legislation:**Internationally the outer space activities are governed by the United Nations treaties on outer space activities namely Outer Space Treaty (1967), Rescue agreement (1968), Liability Convention (1972), Registration Convention (1975) and Moon Treaty (1979). India has acceded to these treaties. *(has ratified first four and signed only on last one).* India has been complying with certain requirements of these treaties, in terms of fostering of international cooperation, registration of space objects in UN Registry, sharing of experience and capacity building in space technology and applications amongst developing and third world countries etc.

5.2.7 Indian space activities were started in early 1960s, with a thrust to develop indigenous capabilities towards realizing space systems and applications for national needs. Space activities in India, were streamlined under the Department of Space in 1972, which was identified as the nodal department as per the Allocation of Business Rules of Govt. of India. Though, a dedicated legislation for pursuing space activities was not formulated, such activities have been guided by other supportive/ related legislations and policies. For example, Remote Sensing Data Policy, SAT Com Policy, Industry Participation Policy etc., are already in place.

5.2.8 It is also necessary that relevant domestic laws are required to be enacted or amended in order meet the obligations committed under international conventions and treaties. This has been emphasized vide a recent communication from the Cabinet Secretariat bearing No.1/13/2/2010-Cb Dt. August 23, 2011.

5.3.9 Internationally too, there exists a demand from UN Committee on Peaceful Uses of Outer Space (UN COPUOS) to all space-faring nations, to enact national legislations in order to fulfil the obligations under UN Treaties on outer space activities. Most countries are in the process of formulating national legislations.

5.3.10 As the programmes are expanding multi-dimensionally with participation of Indian industry/ private sector, international partners and commercialization ventures as well, there is a need to regulate these activities through an appropriate legislation, namely 'Space Act'.

53.11 ISRO on its part has made studies on these lines and got exposed to the requirements fairly well. Taking cognizance of the developing scenario, both nationally and internationally, a focused initiative is intended to be pursued towards formulation a Space Act, which would involve a thorough consultation with all stake holders concerned

5.3 International Co-operation

5.3.1 The 11th Five Year plan witnessed significant progress in international cooperative endeavours and initiatives. Chandrayaan-1 mission with multi-lateral cooperative mechanism, and Megha-Tropiques satellite, the Indo-French joint mission are the shining examples of India's global collaboration with major space agencies of the world.

5.3.2 Currently, India is respected as an emerging space power which can achieve its goals in a more cost-effective and time-efficient manner. Developed countries view India as a 'Safe Partner' and Developing Countries view India as a 'Leader' in space technology.

5.3.3 In addition to continuing, strengthening and establishing newer cooperation relations with space entities in other countries, the

international cooperative activities of ISRO would receive special impetus to enhance the presence of Indian space capabilities in the international forums.

5.3.4 Some of the vital initiatives in International Co-operation would include Joint development and launch of small satellites with United Kingdom; Sharing of satellite data with Association of South East Asian Nations (ASEAN) for disaster management support; Establishing a network of weather stations in SAARC countries to support severe thunderstorm predictions; Taking up joint activities in space science under International Space Exploration Coordination Group (ISECG); and Joint realisation of satellites for earth observation, earth system science with other space agencies like ESA, NASA, JAXA and CNES.

5.3.5 India would continue to share its expertise in capacity building and disaster management support with the needy countries through various international fora. ISRO would also continue to actively participate in the activities of Global Earth Observation System of Systems (GEOSS) and also support space based virtual constellation of satellites for various themes by committing its satellites and data products for global cause.

5.3.6 In the beginning of 12th Five Year Plan, India will be hosting two major global events, the COSPAR Scientific Assembly in July 2012 and Committee for Earth Observation System (CEOS) Plenary in November 2012.

5.3.7 Globally there is a paradigm-shift in international cooperative initiatives considering cost, time and spread. ISRO would be adequately geared-up to handle the same and play a meaningful role in international cooperation

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6. 12th PLAN – CAPACITY BUILD UP

6.1 Human Resource Development

6.1.1 The Department of Space, during the XI plan period ending 2012, pursued the research and development activities in cutting edge technologies of Space and continued to provide the operationalised space based services to the nation. Indian Space Research Organization, a prime Research and Development agency, under the Department has realized a good number of complex missions both in Launch Vehicles and Satellites and has been able to lay foundation to provide newer services in near future and leapfrog to handle more complex missions. The organization has been able to realize the complex goals within the technology denial regime on various critical technologies and is very well placed to make very useful contribution in many other areas by technical/scientific consultancy to different industries/ academia/autonomous institutions.

6.1.2 Since inception, ISRO has been very careful in planning its human resources for realization of its goals and objectives. The Organisation has evolved a unique model of developing core competencies within the system for realization of space systems involving development of critical technologies, utilizing Indian Industries for realization of matured technologies into flight worthy systems and tapping the research potential of Indian academia for long term technology development. ISRO has been highly selective in inducting the best and highly talented young mind from the academia to pursue career in Space. The Organisation has also developed extensive training and development schemes to impart many of the high technological knowledge which are essential for young engineers to take up challenges in Space. The Department of Space has started its own academic institution with an objective of developing and imparting highly specialized and customized curriculum to the bright students selected through all India selection and award degree at the end of successful completion of the academic requirements with set standards. All such successful students will be absorbed in ISRO as Scientist / Engineers. At present, the organization has sanctioned manpower strength of 17500.

6.1.3 During the 11th plan period, the Department of Space has been successful in containing the manpower growth to barest minimum in the most critical technologies areas. The Department has set up high level work study group for taking up a holistic review of human resources requirement required to realize the targeted objectives. With extensive work study approaches, the Department was able to contain the growth within the permitted levels through dynamic re-deployments and pro-actively develop systems which enabled utilization of resources in Industries and academia. The growth in Scientific and Technical manpower resources was limited to 425 posts only which is approximately 2.5 % of its total human resources. The Department also experienced high order attrition of nearly 800 Scientists/Engineers and support staff due to superannuation leaving behind a very high standard legacy. The Department has been able to overcome the impact of attrition of high caliber and experienced professionals through its pre-drawn and properly tuned succession plans for many of the key positions through internal re-deployments of second level personnel. The Department had been able to groom the second level professionals to take over techno-managerial responsibilities through series of training modules in academia and professional institutions.

6.1.4 The Department of Space has drawn up its planned objectives to be pursued during the 12th five year plan period which contemplates seamless continuation of space based services, provide newer services through development of new technologies and development of newer systems, embarking on development of new missions to achieve self reliance in launch vehicle and satellite systems. Apart from this, the Department has also drawn up plans to realize the first phase of developmental activities pertaining to its ambitious plan of Human Space Programme, which calls for dedicated and sustained efforts in development and qualification of critical technologies through extensive development and testing processes. Many of these activities will have to be developed exclusively by deploying in-house, experienced, skilled and bright Scientists/Engineers well complimented by support S & T staff. Few of the production jobs, involving high risks, security and strategic concerns will have to be realized by creating certain newer production facilities as well as augmenting existing infrastructure. In the present

assessment of the activities that are planned for the 12th five year plan, it is estimated that the internal HR needs to be augmented by 1100 posts (750 Scientist/Engineers, 250 S & T support staff and 100 Administrative and auxiliary services) during the first three years of 12th five year plan period. Continuous development of its Human Resources to take up technical, techno-managerial and administrative challenges will be the focus during the plan period through special training in professional institutions. Specialised training on skill development, knowledge enhancement and exposure on new vistas of technologies will also be planned through close participation of specialists in the field both from Industries and academia.

6.1.5 Towards improvising the organization and methods, development of digital workflow based computerized working in Administrative areas is already in progress. Taking the best advantage of IT and Communication, the system is aimed at moving towards near-paperless office. Improvements in work methods and simplification of administrative processes in all functional areas will be taken up on continuous basis to improve the efficiency as well as to optimize the human resources.

6.2 Facility and Infrastructure

6.2.1 Realization of operational space systems and development of advanced complex space technologies requires a host of technical facilities and infrastructure. Specialized technical facilities for supporting the development, fabrication, integration and testing of the satellite systems and launch vehicles systems as well as launch and mission management are an integral part of the space programme. Over the years, the ISRO Centres / Units have been developed with the state of art infrastructural facilities essential for realizing the space systems in a cost effective manner. While maximal use of the Indian Industry's capability is ensured, it is very essential to renew / refurbish the existing critical in-house facilities, augmenting the capacity of existing facilities to meet the throughput requirements as well as build up new technical facilities commensurate with the programmatic requirements.

6.2.2 The critical facilities to be considered amongst others during the 12th plan include,

- **Third Launch Pad at Sriharikota**: To support the increased launch frequency of PSLV, GSLV; and also to provide active redundancy to the existing launch pads; to support the requirements of the next generation launch vehicles – the third launch vehicle is being envisaged.
- **Multiple Object Tracking Radar**: This is being developed for tracking of a maximum of seven targets during nominal mission of launch vehicles and simultaneously tracking of more than 10 objects during non-nominal missions. It will also be useful in tracking the space debris to safeguard our space assets.
- **Second Vehicle Assembly Building:** On an average, during a launch campaign in the second launch pad, of PSLV or GSLV, the occupancy of the vehicle assembly building is nearly 40-45 days, where as the occupancy at the launch pad in 10-12 days only. At this, a second Assembly Building would immensely help improve the launch turn around. A second vehicle assembly building is conceived to provide for redundant assembly facility for GSLV Mk III also.
- **Second Cryogenic Main Engine and Stage Test facility at LMF, Mahendragiri**: Currently the main cryogenic engine test facility is shared between GSLV and GSLV Mk III projects – resulting into a schedule clash. This new facility is planned to test and qualify the indigenous cryogenic upper stage for the GSLV and the C25 cryogenic stage for the GSLV- Mk III programme both and acting as a redundancy.
- **Solar cell production facility:** Towards minimizing the dependency for solar cell from foreign sources, it is proposed to establish a solar cell production facility at ISRO Satellite Centre. This would also enable indigenization and further research towards increasing the efficiency of the solar cells.
- **Productionisation efforts:** Space Technology Parks at ISITE, Bangalore; SDSC – Sriharikota; Space Application Centre, Bopal (Ahmadabad), Satellite Production Centre at Chitradurga, Production Island at LPSC Valiamala etc.

6.3 Industry Interface

Industry Participation

6.3.1 In accordance with ISRO's policy of maximally utilizing industrial capability, the Indian industries took active part in realizing hardware and software services for space segment as well as ground segments. During the 11th plan period, the emphasis on capacity building in industries to meet the throughput requirements for proven satellites and launch vehicles subsystems and ground segment has been achieved to a large extent. Strategies adopted in 11th plan on standardization of subsystems and form out to industries with bulk ordering approach has paid rich dividends. ISRO has been able to strengthen the productionisation through industries by adopting vendor development, vendor qualification, documentation and quality control approaches.

6.3.2 During the 11th plan period, in the launch vehicle area and spacecraft segment, the magnitude of industry contribution has grown apace with needs of operational flights and reliable spacecraft subsystems. With projects such as human spaceflight mission and planetary missions beyond moon on the anvil in the near future, industry is expected to play a larger role in achieving the goals. Some of the major elements that are now being produced by industry include fabrication of spacecraft structures, solar array deployment mechanisms, heat pipes for spacecrafts, realization of VIKAS engines for L40/PS2/GS2 stage, battery fabrication and testing, solar panel fabrication, propellant production etc.

6.3.3 The share of industries in the space budget is expected to increase further in the coming years. The quantum of contracts to Indian industry is expected to grow significantly in view of expected growth in the magnitude of space transportation and satellite system during 12th plan period. The idea is to have industry as a risk sharing partner and this will be achieved by involving industry from the preliminary stage of development of space systems. In addition to this some other innovative business models for increased participation from industries will also be considered during this plan period.

6.3.4 With ISRO envisaging large volume of production and higher degree of R&D for future works, it is planned to further augment the role of Indian Industry. While considering, the industry participation aspects such as realistic production levels, enhancement of throughput of product on a demand basis, timely realization, strategic aspects, continued commitments, human resource factor, industry consortium, extent of use of ISRO's internal facilities in the contest of industry participation are thoroughly addressed.

6.3.5 The major facilities to be realized with industry participation in the 12th plan period include third work centre for S139 segment hardware fabrication, second work centre for production of 18 LPM Axial Piston Pumps (EGC System of PSLV, GSLV and GSLV Mk III), second work centers for PSLV core structures (1/2L, 2/3L and IS3/4), second 500 TPA Ammonium Perchlorate Plant , Air Separation Plant (20 TPD) , Second N2O4 production plant, Production of strategic materials i.e., Hafnium, Niobium , Magnesium recycling Plant at KMML, Production plant for Isrosene, augmentation of production facilities for GSLV MkIII tank-ages, second work centre for fabrication of Cryo engine etc.

6.3.6 Indigenization of strategic components/materials will continue to be pursued in this plan and also through industry participation to reduce the dependence on import. This includes Liquid Hydrogen storage tank, Cryogenic and high pressure flow components, Materials for Semi-cryo engine, Sensors for cryogenic application, SiC/SiC composites for satellite thrusters, Adhesives for solar cell, Ultra high purity chemicals

Technology Transfer

6.3.7 One of the main objective of space industry partnership is to provide industry with the technical wherewithal through technology transfer so as to enable Indian industries to cater to the needs of new market that are emerging from applications of space program. Technology Transfer from ISRO promotes the development of Spin Offs of space technology in other areas and enables industry to cater to diversified needs of society.

6.3.8 Right from its inception, ISRO as a matter of policy has been involved in the technology transfer to Indian industry, both to meet the space program needs as well as to disseminate "Spin Offs" for non space uses. Concentrated efforts were made during the 11th plan period to maximize the know how transfer from ISRO to Indian industries. A large number of technologies have been successfully transferred and productionised in industries in the fields of electronic and computer based systems, speciality polymer, chemicals and materials, electro optical instruments, mechanical equipment and ground systems related to satellite communications, broadcasting and meteorology. Industries in the large, medium and small scale sectors have largely been beneficiaries of the technology transfer scheme. During the 11th plan period , know how of varied technologies like Nickel Hydrazine Nitrate, Search and Rescue Beacon, Ternary Eutectic Chloride Powder, Umbilical Pads, ASIC based Demodulator, Indigenous GIS Software, Distress Alert Transmitter , MSS Type D Terminal, Monopulse Tracking receiver, H Digital Holographic Software etc. were successfully disseminated to Indian industry.

6.3.9 During the 12th plan, it is planned to place systematic efforts to maximize the number of know how transfers from ISRO. Greater thrust would be accorded for industry to take up "Spin Offs" developed by ISRO for societal applications. The strategy in 12th plan period would be to identify similar socially relevant technologies like Automatic Weather Stations, Search and Rescue Beacons, Distress Alert Transmitters etc. for know-how transfer to Indian industries.

6.3.10 Entrepreneurship must be encouraged and promoted for venturing venture into space industry. During the 12th plan period, promising entrepreneurs shall be identified and encouraged to take productionisation and commercialization of ISRO developed technologies. Drive towards technology incubation efforts and industry as a partner in joint development effort for "spin offs" is planned.

6.3.11 Efforts to identify IPR's that have potential for commercialisation have resulted in a number of technologies that have been identified for know-how transfer to industry in the 12th plan period.

Intellectual Property Rights Protection

6.3.12 ISRO has been investing in developing a patent portfolio and in this area, while ISRO's objective has been to safeguard the technologies developed in ISRO Centres, simultaneously the approach has been to enable maximal commercial exploitation of such resources through appropriate technology transfers or licensing schemes. During the 11th plan period, a large number of patents were granted for the various innovative products/ processes developed by ISRO. The resolute efforts put in by DOS/ISRO has resulted in the filing of large number of patents and copyrights new products / processes and software developed by ISRO/DOS during the 11th plan period. The 11th plan period also witnessed a number of PCT applications being filed for protection of innovations in other countries.

6.3.13 ISRO Scientists/ Engineers are being encouraged and sensitized about the relevance of obtaining IPR's for the innovative work being carried out by them. ISRO Scientists/Engineers are being constantly encouraged to obtain appropriate copyright applications for the software developed and being utilised for various applications.

6.3.14 During the 12th plan period, emphasis will be on to adequately strengthen the IPR portfolio consisting of patents, copyrights and trademarks. A strengthened IPR portfolio will add value to ISRO's endeavours apart from safeguarding use of novel technologies developed by us. The IPR's will further act as a cradle for potential technology transfer candidates to industries and will also help in analyzing the quality of innovations. During the plan period, the driving force for IPR protection will be to facilitate production and commercial exploitation of innovations.

Innovation Management

6.3.15 In the context of the national drive on declaring the next decade as "Decade of Innovations", the imperative for providing further impetus to the process of innovation in ISRO is well recognized and ISRO believes that it is essential to nurture organizational eco system to promote innovations. Towards this, in order to catalyze and facilitate the process

during the 11th plan period, an "Office of Innovations Management (OIM)" has been formed at ISRO.

6.3.16. Towards this, a document named "ISRO's Catalogue of Innovation (2005-10)" has been brought out capturing, essentially, vibrant spirit and innovations existing in ISRO. In this document, the statistical profile of innovation in different work centres has been presented. The next activity towards this would be identification of innovations that can be patented, indigenized or could be transferred to industry.

6.3.17. During the 12th plan period, efforts will be on to impart structured education in sustenance of innovation culture. Concentrated efforts will be put to identify innovative technologies, obtaining IPR rights for safeguarding innovations, providing platform for recognizing innovators and to create a health environment for sustaining innovation culture. During the 12th plan period, the goal of enhancement of innovation environment will be viewed and executed as an organizational initiative. The concentration will be on innovations which will facilitate space programs.

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7. 12th PLAN – MISSION PROFILE AND PLAN OUTLAY

7.1 Mission Profile

7.1.1 For 12th Five Year Plan 2012-2017, a total of 58 missions are projected to be undertaken which includes 33 satellite missions and 25 launch vehicle missions. Out of the 33 satellite missions, three missions viz. Cartosat-2C, Cartosat-2D and GSAT-7 are to be funded by user agencies. The mission profile of the Department for the 12th Five Year Plan has been evolved taking into account the national needs and requirements to maintain the continuity of services. The number of missions to be taken up during the plan period was optimized considering the projected internal production capacity, availability of spaceport infrastructure and throughput of the industry partners. Considering the immediate pressing need to augment the transponder capacity of INSAT/GSAT system and the availability of GSLV-MK II and development status of GSLV-MK III, the Department has opted for availing procured launch services for few communication satellites.

7.1.2 The overall Mission Profile envisaged during 12th five year plan and part of 13th five year plan is summarized in Figure 7.1 (including user funded missions).

7.2 12th Plan Outlay

7.2.1 The financial resource requirements for the missions planned for 12th Five Year Plan as well as for advance investments required for the missions to be realised during the early phase of 13th Plan works out to ₹55,000 Cr at current (2011-12) prices. Out of this, the Plan component for 12th Plan would be ₹47,500 Cr while the Non-Plan component would be ₹7,500 Cr approximately.

7.2.2 Broadly, the outlay projected for 12th Plan has six major components as detailed in the following table.

Table 7.2.1: Summary of 12th Plan Outlay

Sl. No	Components	Projected Outlay (₹inCrores)	%agew.r.t. Total Outlay
1	**COMPLETION OF MISSIONS INITIATED DURING 11TH PLAN PERIOD** (GSLV-MK III, GSLV/PSLV operational, INSAT-3/4 series, SARAL, GISAT, GSAT-11, Astrosat, Chandrayaan-2, Aditya-1 and IRNSS)	5,128	9%
2	**NEW MISSIONS TO BE INITIATED AND COMPLETED DURING 12TH PLAN** (GSAT-15-21, GSAT-24, Resourcesat-2A/3, RISAT-1A, Scatsat-1, Environmental Satellite -1, Oceansat-3, Cartosat-3, MARS-1, Polix and application missions)	17755	32%
3	**NEW MISSIONS TO BE INITIATED FOR REALIZATION BEYOND 12TH PLAN** (IRNSS-8 to 11, Semi-Cryo development, RISAT-3, Carosat-1A Environmental Satellite - 2, Mars-2, GSAT-22/25/27/28, RLV)	7,805	15%
4	**MANNED MISSION INITIATIVES**	1,147	2%
5	**TDPs/R&D/FACILITY REPLACEMENT & AUGMENTATION/ PRODUCTIONISATION/ INDEGENISATION ETC.**	11,165	20%
6	**ORGANISATION AND INFRASTRUCTURE MAINTENANCE, GRANT-IN-AID & OTHERS**	12,000	22%
TOTAL		**55,000**	**100%**

12th FIVE YEAR PLAN MISSION PROFILE (2012 -2017)

Total Missions : 58 (Satellites: 33 Launch vehicles: 25)

MISSIONS	2012-13	2013-14	2014-15	2015-16	2016-17	2017- 18
EARTH OBSERVATION SATELLITES	SARAL		CARTO-2C	RESOR-2A CARTO-2D	OCEAN-3 CARTO-3 GISAT	RISAT-1A SCATSAT-1
COMMUNICATION & NAVIGATION SATELLITES	IRNSS-1 GSAT-14 INSAT-3D GSAT-10	IRNSS-2 IRNSS-3 GSAT-6 GSAT-7 GSAT-15	IRNSS-4 IRNSS-5 IRNSS-6 GSAT-16 GSAT-11	IRNSS-7 GSAT-9 GSAT-17 GSAT-18	GSAT-6A GSAT– 19E GSAT-11S GSAT-Ka	GSAT-7A INSAT-3DR GSAT– 20 GSAT-21(P) (satellite procured)
Procured Launch Service						
SPACE SCIENCE & PLANETARY EXPLORATION SATELLITES		ASTROSAT MARS	CHANDYAAN-2		ADITYA	MARS-2
INDIAN LAUNCH VEHICLES	C20 C21 C22 D5 X1 Antrix Exp	C23 C24 C25 C26 D6	C27 C28 C29 C30 F08	C31 C32 C33 F09 Antrix	C34 C35 C36 F10 F11 D1	C37 F12 F13 D2

PSLV GSLV GSLV-MkIII

7.2.3 The detailed break-up of the 12th plan outlay is presented in the Appendix 3.

7.2.4 Space is inherently a technology intensive endeavour and long term technology development / R&D is crucial for its long term viability. Accordingly, it can be seen from the above that about 15% of the total outlay proposed for the 12th Plan (Sl. No. 3, 4 & 5) has been towards "Preparing for Future", which includes advance investments for missions planned for realisation in the early phases of 13th Plan, initiatives on technology development / R&D / capacity buildup, advanced propulsion systems development for next generation launch vehicles and Manned Mission initiatives.

7.2.5 The tentative annual phasing of expenditure and the plan component therein are given below

Table 7.2.2: Phasing of 12th Plan Outlay

(₹inCrores)

FinancialYear	Total Budget	Plan Component
2012-13	8,800	7,600
2013-14	9,900	8,550
2014-15	11,000	9,500
2015-16	12,100	10,450
2016-17	13,200	11,400
Total	**55,000**	**47,500**

7.2.6 The major objective of the Indian Space programme has been to provide space infrastructure for socio-economic development of the country in a cost effective way and achieve self-reliance in production and launch of satellites. A study carried out by Madras School of Economics has examined the tangible benefits and identified the intangible benefits vis-a-vis the investments made in space. A detailed study on economic costing of INSAT transponders with 10% cost of capital on investments and 5.5% discount factor on future returns has brought out the cost advantage of INSAT transponders by at least 25% of the prevailing international prices. The cost performance of INSAT system has been considered to be commendable keeping in view the relatively high capital cost in India and

the dependence on some foreign components in the production of the satellites.

7.2.7 In remote sensing, benefits are in the form of cost savings due to mapping, value added products/services and the social impact it has made in several sectors of national importance. The cost of mapping based on IRS data is found to be one-third compared with the conventional methods of mapping. Preparation of urban perspective plans, forest working plans, waste land maps, hydro-geomorphological maps for location of drinking water sources, bio-diversity atlas, water shed development plans, potential fishing zone advisories are some of the important applications of IRS data which has brought significant economic and social benefits to the country, far exceeding the investments made in remote sensing. The potential benefits are large and they occur over time.

7.2.8 The derivative benefits of space programme are in the form of application of space technologies in non-space projects, creation of critical manpower in the Industry, improved managerial efficiency, and access to new markets using successful execution of space contracts as credentials. The critical manpower developed in-house ISRO is an invaluable asset for the country. A host of indigenous technologies have been realized in the development process. In the era of control regimes and import restrictions in high technology field, it is difficult to attach a value for the technologies realized in-house. Moreover, the political good will generated due to collaborative missions such as Chandrayaan-1 & 2, Megha-Tropiques, SARAL, Youthsat are immeasurable in monetary terms. The success of Chandraan-1 mission and its detection of water molecules on the moon surface have elevated the position of Indian among the comity of nations.

7.2.9 Thus, in a nutshell, the Indian Space Programme has paved the way for creating cost-effective space infrastructure for the country in a self-reliant manner and the economic and social benefits brought in by the application of space technology to the national development have been significant. The Space Programme is poised to play a pivotal role in the national development in the forthcoming decade.

8. Next step in Plan Formulation

8.1 Twelfth Five Year Plan proposals of the Department have been prepared by considering the requirements of various user Ministries/Departments and the inputs received from various ISRO/DOS Centres/Units. The proposals were presented to the Working Group of Department Of Space (WG-14) meeting on 29th September, 2011. Based on the proceeding of the meeting, the plan proposals are now suitably modified and the report of the Working Group shall be presented to Steering Committee on Science & Technology for review on 18th October, 2011. After the proposals are reviewed by Steering Committee, final modifications will be carried out and the 12th plan proposals will be submitted to Planning Commission.

APPENDIX-1

Department of Space

DETAILED PERFORMANCE APPRAISAL OF 11th FIVE YEAR PLAN

MAJOR TARGETS /ACHIEVEMENTS IN A NUTSHELL

The overall thrust of the Indian Space programme during 11th Plan was to sustain and strengthen the already established space based services towards socio-economic development of the country. Major thrust areas of the space programme during the 11th Plan period has been on developing next generation advanced heavy lift launch vehicle GSLV-MK III; developing critical technologies for the human spaceflight programme; Competitive and state-of-the-art space segment augmentation in INSAT/GSAT system; ensuring continuity of data with enhanced capabilities through constellation of earth observation satellites; undertaking space science and planetary exploration; strengthening space-based disaster management support; atmospheric research programme and societal applications of space technology.

2. During the first four and half years of 11th plan, Indian space programme witnessed several major successes and achieved greater heights. The successful launch of Chandrayaan-1 and historic feat of placing Indian tri-colour on Moon's surface, detection of water molecules on Moon surface were some of the most significant events.

The Other important space endeavours included launching of TEN satellites including CARTOSAT-2A and IMS-1 in a single launch of PSLV-C9, launch of Microwave Radar Satellite (RISAT-2) and Mini Satellite ANUSAT onboard PSLV-C12, OCEANSAT-2 and six nano-satellites onboard PSLV-C14, CARTOSAT-2B, ALSAT-2A, NLS 6.1 & 6.2 and STUDSAT on board PSLV-C15, RESOURCESAT-2, YOUTHSAT and X-SAT onboard PSLV-C16. The INSAT/GSAT system was further augmented with the launch of INSAT-4CR (onboard GSLV-F04), GSAT-12 (onboard PSLV-C17) and GSAT-8 (Procured). Two commercial satellites of international customers (AGILE and TECSAR) were launched by using PSLV. Other achievements included building two state-of-the-art communication satellites (W2M and HYLAS) for an European customer, establishment of GEO And GPS Augmented Navigation System (GAGAN) and setting up of Indian Institute of Space Science and Technology. Besides this, GSLV Mk III, the next generation

advanced launch vehicle under development, has made significant progress in the last two years with the successful commissioning of a world class solid propellant plant at SDSC-SHAR, Sriharikota for manufacturing large solid stage booster segments (S-200) for GSLV Mk III vehicles

4. In terms of Missions, ISRO has successfully accomplished 25 missions which included twelve launch vehicle missions with PSLV and GSLV and thirteen satellite Missions, besides commercial ventures of realizing two communication satellites (W2M and Hylas) and launching 10 foreign small/micro/nano satellites onboard PSLV. Keeping in view the progress of ongoing missions, another 4 missions (2 spacecraft missions and 2 launch vehicle missions) are realizable before March 2012.

5. Besides this, several initiatives on the societal applications of space technology such as Tele-education (over 55,000 EDUSAT classrooms established), Tele-medicine (382 Hospitals provided with Tele-medicine facility), Village Resource Centres (set up in 473 locations), space based Potential Fish Zone mapping benefitting the fishermen community of coastal areas, locating drinking water sources using IRS imageries covering more than 2 lakh habitations in ten States, Wasteland mapping and time series analysis to reclaim wastelands and improve productivity of the whole country using IRS data for development of waste lands, Space technology based Disaster Management Support etc., have made significant contributions to the National Development.

6. Following is the brief summary of the plan programmes envisaged during the Eleventh Plan vis-a-vis the achievements in the area of Launch Vehicle Development, Earth Observation Systems, Satellite Communications & Navigation (INSAT, GSAT & IRNSS), Space Science Programme, Atmospheric Science Programme and Disaster Management Support:

Launch Vehicle Development:

11th Plan Targets:

In the area of launch vehicle development, the major target for 11th Plan is to complete the development and operationalisation of GSLV Mk III capable of launching 4T class INSAT satellite, improving the capabilities of workhorse missions PSLV and GSLV for launching IRS and INSAT (2T class) satellites, technology development and demonstration missions on Reusable Launch Vehicle including space recovery technologies and air breathing propulsion. Technology development and demonstration missions related to Reusable Launch Vehicle including space recovery technologies and air breathing propulsion were also planned.

Building up large space systems like space stations, servicing and refuelling of satellites in space and material processing are promising greater economic benefit to the nation. These require a large scale involvement of human beings in space for building and maintaining space assets. Space has emerged as the next frontier of human endeavour and manned missions are the logical next step to space research. Therefore, it was considered necessary to initiate the development of Manned Missions during 11th Plan period by development of critical technologies. The major objective of the Manned Mission programme is to develop a fully autonomous manned space vehicle to carry two crew to 400 km LEO and safe return to earth.

Achievements

a) Development of GSLV Mk III, has made significant progress during the plan period with the successful commissioning of a world class Solid Propellant Plant (SPP) at SDSC-SHAR, Sriharikota for manufacturing large solid stage booster segments (S-200) for the vehicle. Specialized test and fabrication facilities required for L 110 liquid stage and higher thrust cryogenic stage have also been commissioned at Liquid Propulsion Systems Centre. Two static tests have been successfully conducted to qualify S-200 stage. Similarly, L110 stages have gone through two static tests. The development of C25 Cryogenic stage, which is critical for the development of GSLV-MK III, is progressing well.

b) Operational flights of PSLV C8 carrying Italian Agile satellite (on 23rd April 2007), PSLV C9 carrying Cartosat-2A/IMS/Nanosatellites(on 28th April 2008), PSLV C10 carrying TECSAR satellite (on 21st January 2008), PSLV C11 carrying Chandrayaan-1 (on 22nd October 2008), PSLV C12 carrying RISAT-2/ANUSAT (on 20th April 2009), PSLV C14 carrying Oceansat-2/Nanosatellites (on 23rd September 2009), PSLV C15 carrying Cartosat-2B/ALSAT-2A/NLS 6.1 & 6.2/STUDSAT (on 12th July 2010), PSLV C16 carrying Resourcesat-2/Youthsat/X-Sat (on 20th April 2011), PSLV C17 carrying GSAT-12 (on 15th July 2011), GSLV F04 carrying INSAT-4CR (on 2nd September 2007), have been successfully completed. Preparations for PSLV C18/Megha-tropiques Mission and PSLV C19/RISAT-1 Missions are in advanced stages of realisation during 11th Plan.

c) Testing of indigenous cryogenic stage for the full flight duration of 720 seconds has been successfully conducted on 15th November 2007 at Mahendragiri. The indigenous cryo stage will replace the Russian supplied cryogenic stage of GSLV.

d) The Government have approved in Jan 2009 a project on development of higher thrust Semi-cryogenic engine (with Liquid oxygen as oxidiser and aviation grade Kerosene as fuel) which will be the core stage in future launch vehicles. The total cost of the project is₹ 1798 crores and the realisation schedule is about 5-6 years. Work on design of the semi-cryogenic engine and establishment of test facilities has been initiated.

e) The Government has approved PSLV Operational flights C14 to C28 (Cost: ₹1518 crores approved in March 2008) and GSLV Operational flights F11 to F16 (Cost: ₹ 1280.96 crores approved in August 2008). Production of the PSLV& GSLV hardwares in the Industry and the procurement of materials / components are in progress to meet the launch schedules of satellites planned for 11th plan and beyond.

f) Detailed feasibility studies on development of Manned Mission have been completed and the project report on Human Space Flight Programme (HSP) is formulated. The total estimated cost of HSP programme is ₹12,400 crores and the development lead-time is about 8-10 years. A High-level committee headed by Dy. Chairman, Planning Commission has reviewed the need and benefits and recommended the HSP programme for approval. During the mid-term appraisal of the 11th Plan, it was felt prudent to implement the programme in a phased manner considering the magnitude of complexities and developmental efforts involved. The Department has initiated the development of critical technologies required for the successful culmination of the programme which envisages carrying humans to low earth orbit and their safe return to earth.

g) R & D activities on advanced launch vehicle technologies including Air breathing propulsion and Reusable Launch vehicles have been initiated. As a first step towards realizing a Two Stage To Orbit (TSTO), a series of technology demonstration missions have been conceived. For this purpose, a winged Reusable Launch Vehicle Technology Demonstrator (RLV-TD) has been configured. Engineering/Structural model development of the RLV-TD and hardware realisation for the Air breathing Propulsion system is in advanced stages.

h) Realisation of Hypersonic wind tunnel (HWT) facilities consisting of 1m HWT and 1m shock tunnel for aero thermal and aerodynamic characterization of advanced launch vehicles such as RLV, TSTO and re-entry vehicles has been accomplished.

Earth Observation (EO) Systems

11th Plan Targets:

9. The **Earth Observation (EO) Systems** during 11th Plan are driven by two major considerations viz., ensuring continuity of EO data with improved quality duly addressing the current gap areas and the urge to maintain the global leadership in EO systems. The EO series of satellites, both in IRS and INSAT/METSAT series, addressed broadly the thematic applications in three streams viz., Resourcesat series, Cartosat series and Atmosphere series. An important specific target for 11th Plan is to realize the Microwave remote sensing satellite RISAT-1 (Radar Imaging Satellite) which provides all-weather remote sensing capability crucial for applications in Agriculture and Disaster Management. Strengthening ground segment to ensure and enhance effective utilization of the remote sensing data has been an important thrust area. Creation of Natural Resource Inventory and Data bases, Food security, Water security, Disaster Management support, Infrastructure development, Weather forecasting, Ocean State Forecasting, Environment protection, climate variability and change are some of the thrust areas of EO systems applications identified for 11th Plan.

Achievements:

a) Earth Observation system was augmented with launch of Six Remote Sensing Satellites viz. Cartosat-2A, RISAT-2 IMS-1, Oceansat-2, Cartosat-2B and Resourcesat-2.

b) Two major ongoing missions are getting ready for launch before the closure of the 11th Plan viz. PSLV-C18/Megha-Tropiques and PSLV-C19/RISAT-1. Megha-Tropiques is a joint ISRO-CNES mission aimed at understanding the life cycle of convective systems and their role in the associated energy and moisture budget of the atmosphere in the tropical regions. The spacecraft has been shipped to the Spaceport and is slated to be launched during October, 2011 along with one foreign satellite viz. VESSELSAT-1 from Luxembourg and two Indian university satellites namely JUGNU from IIT Kanpur and SRMSAT from SRM University, Chennai. Radar Imaging Satellite (RISAT-1), weighing about 1800 kg, is a microwave remote sensing satellite with day and night all-weather imaging capability is in the advanced stages of realisation. The Transmit-Receive Modules, one of the critical technology elements required for realization of the satellite has been realised successfully through Indian Industries. RISAT-1 is slated to be launched during first Quarter of 2012.

c) The Government have approved in Feb 2009 a new satellite project SARAL – Satellite for Argos and Altika at a total estimated cost of

₹73.75 crores. SARAL is a joint small satellite mission with French Space Agency CNES for oceanographic and climatic research. Subsystem realization of the satellite is in progress.

d) Detailed studies were completed for future EO missions such as Cartosat-3, Resourcesat-3, RISAT-3. Formulation of project reports for approval of the Government is in progress.

e) Over a period of time EO products and services have been effectively utilized to showcase varieties of applications in many areas of resources inventory and monitoring. In doing so, various technologies, with respect to satellite and aerial remote sensing; Geographical Information Systems (GIS) and Global Positioning Systems have been utilized based on requirements. These technologies are enabling decision making possibilities at local level as well as planning and decision making at regional and national scales for effective management of our resources. Various applications have been successfully demonstrated through a well co-ordinated effort of central government ministries and state remote sensing infrastructure at national level, state level and even in many cases at local level. Geospatial databases on a variety of natural resources themes have been prepared at various scales for resource monitoring. Major EO Application initiatives in the 11th FYP includes:

- Rajiv Gandhi National Drinking Water Mission (RGNDWM): Under Phase III A of the project, ground water prospect mapping work in 6 states has been completed. In Phase III B ground water prospects mapping has been completed for Arunachal Pradesh, Haryana, West Bengal (part) &U.P. (part) and ground water Quality mapping is in progress. Under Phase IV, mapping for the remaining states of the country including the UT's and Islands is initiated.

- 'India-WRIS', a web enabled single window water resources information system, is being developed with the available information (both spatial and non-spatial data). The ßeta version with some of the important databases was launched on December 7, 2010. Further development of the information system is underway having which consists of 107 layers and a large number of variables as per requirements of CWC.

- Accelerated Irrigation Benefit Programme (AIBP): Under AIBP scheme of Bharat Nirman, Irrigation Infrastructure mapping for 53 sites has been carried out. In Phase-II another 50 irrigation projects have been taken up with an Irrigation Potential target of 8.5 lakh ha across 14 States.

- National Project for Repair, Renovation and Restoration (NPRRR) Evaluation of irrigation tanks identified under NPRRR for about 742 tanks distributed in 9 districts of six states - has been completed.

- National Wetland Inventory and Assessment (NWIA): Wetland Atlases showing 19 categories of wetlands at 1:50,000 scale were prepared using pre and post monsoon season IRS P6 LISS III data (2006-07). The National Wetland Atlas and the State/ UT Atlases were officially released by Hon'ble Minister of State, Environment and Forests, Govt. of India on June 8th 2011.

- Snowmelt runoff forecasting in Sutlej river Basin (up to Bhakra Reservoir) over the last two decades (during April-May-June), has demonstrated and established the satellite data utility for deriving advance information on seasonal snowmelt runoff. As an extension and operationalization of this application, studies in five major Himalayan river basins, namely, Chenab, Beas, Yamuna, Ganga and Sutlej basins have been taken up at the instances of CWC. The study aims to develop seasonal and short-term snow melt runoff forecast models for these river basins.

- Snow and Glacier Studies (including inventory of glaciers of entire Himalayan region at 1:50,000 scale, snow cover monitoring for Indian Himalayas at 10 days interval, monitoring of glaciers for retreat/advance and mass balance for glaciers of selected basins) has been taken up at the behest of MoEF. Phase-I of the project has been completed and final technical report is submitted to MoEF. Phase-II of the project has been approved and work has been initiated. Snow cover mapping for 2008-09 has been completed for Chenab and Satluj basins.

- NUIS programme Under NUIS, NRSC/ ISRO is carrying out thematic Geodatabase Creation for 152 towns at 1:10,000 scale using Cartosat-1 and LISS-IV imagery, besides Aerial Flying for mapping at 1:2,000 scale. Till date, 102 towns (67%) covering an area of 34,580 sq. kms out of 152 towns (100%) have been completed and tested for quality of information.

- Monitoring and Evaluation (M&E) of 77 sub-watersheds (742 micro-watersheds) in 5 districts under Karnataka Watershed Development Programme (KWDP) - known as Sujala Watershed Development Programme. The project witnessed optimal utilization of technologies like remote sensing, GIS and MIS as a part of planning, management and monitoring. The impact assessments have indicated measurable impacts. The methodology developed under the project is being replicated under NWDPRA project for 120

watersheds in 3 states. Specific inputs were also provided during the formulation of Integrated Watershed Management Programme (IWMP) under DOLR. Also, the initiatives have been taken to help some of the neighbouring countries viz., Senegal, Bangladesh, Sri Lanka and Tajikistan, to utilize such technology in their own projects. Sujala Phase II is initiated for additional 6 districts in Karnataka based on the success of Phase I.

- Natural Resources Census (NRC) Under NRC project of ISRO/DOS, preparation of land use/land cover (LU/LC) mapping at 1:250,000 scale has been completed consecutively for the sixth year (2010-2011) and hosted on web portal of Bhoosampada, NRSC. Mapping activity for LU/LC and land degradation at 1:50,000 scale has also been completed. Seamless LU/LC database on 1:50000 scale for entire country has been generated. The spatial statistics are organized to present the LU/ LC data on 79 classes at national, state and district levels. Land degradation mapping at 1:50,000 scale has also been completed. National Geomorphological mapping at 1:50,000 scale is in progress.

- At the behest MoES, INCOIS along with NRSC, has generated DEM using Cartosat-1 stereo pairs along Indian Coast, to meet the immediate requirement of Tsunami Early Warning Center. The specification of the coastal DEM, 20 km buffer from the coastline towards land portion, includes posting interval of 10m, with planimetric accuracy of 10m; and vertical accuracy of 5 to 6 m. This project has demonstrated the potential of Cartosat-1 data to generate high-quality DEM.

- Natural disasters such as Cyclone, Flood, Drought, Earthquake, Tsunami, Landslide, and Forest Fire are being monitored under the DMS programme. The meteorological satellites, INSAT and METSAT, have distinct advantages with their capability to image on a continuous basis, which is essential for tracking the tropical cyclones and deriving atmospheric wind vectors over large oceanic areas. The IRS series of satellites captures disaster events, and has been helpful in providing valuable data for risk management related activities. The aerial survey systems, such as the Aerial Laser Terrain Mapper (ALTM) and Synthetic Aperture Radar (SAR) helps in filling the observational gaps. Further, under National Database for Emergency Management (NDEM), databases at different scales/ details viz., National level core geo-spatial data at 1:50,000 scale; Hazard specific data for multi-hazard prone districts at 1:50,000 scale; Data for multi-hazard prone cities/ towns at 1:10,000 scale; and Data for major cities at 1:2,000 scale are being organised.

- One of the major project, initiated in the 11th FYP is the Space based Information Support for Decentralised Planning (SIS-DP) at the behest of Planning Coming. Under this project, the resource information is being prepared mainly from four different sources (1) High resolution satellite images, (2) Village cadastral maps, (3) User departments data, (4) Existing resource GIS layers / databases generated by central / state centers. All the thematic layers will be created on 1:10,000 scale using ortho-rectified high resolution satellite images (Cartosat + LISS 4 Mx fused). Currently, generation of resources maps at 1:10,000 scale for 5 states (Andhra Pradesh, Assam, West Bengal, Haryana & Kerala have been taken up.

- ISRO/ DOS has developed many Web Enabled Geospatial Information Systems (viz., NRDB, Bhuvan, MOSDAC site on meteorology and ocean data, Bhoosampada, BIS, IBIN, WaLIS, UIS, PMO-GIS, WRIS, etc.,) to provide information services in the public domain. Efforts are also on to showcase all types of data and services through a simple design of unified geoportal of ISRO.

- Integrated Multi-mission Ground segment for Earth Observation Satellites (IMGEOS) was conceived and being implemented at NRSC, Shadnagar to realize faster processing and dissemination of data products to users, specifically to meet requirements of disaster and other emergency applications Specific objectives of IMGEOS are (i) Multi-mission Acquisition and Processing; (ii) Effective Delivery Mechanisms; (iii) Real time, Web-based Services; (iv) Mission oriented Out-reach Activities; (v) Populating Free-ware Tools for Data/ Products Access etc.

- Government of India has recently approved new Remote Sensing Data Policy (RSDP 2011), which allows distribution of all satellite data of resolutions up to 1 m on a non-discriminatory and "as requested basis" to the user; and all data of better than 1 m resolution would be subject to screening and clearance by the appropriate agency prior to distribution.

- Under the framework of NNRMS, 27 States have established Remote Sensing Applications Centres (SRSACs), which are supporting the state agencies for their needs of natural resources information and developmental support. These Centres are equipped with facilities for Remote Sensing and GIS (supported through EOS, ISRO) and are carrying out various application projects of relevance to their respective States. The State Centres also participate in the NNRMS national level projects/ missions coordinated by ISRO/DOS and other agencies.

- ISRO has been making concentrated efforts towards capacity building in the area of Remote Sensing and GIS by organizing regular multi-level, multi theme training programmes for the benefit of professionals engaged in natural resources management, environmental assessment, disaster management support; university faculty members; school teachers and school students. Indian Institute of Remote Sensing (IIRS), Dehradun, a premier training and education institute, is engaged in developing trained professional in the fields of remote sensing, Geoinformatics and GPS technology for natural resources, environmental and disaster management. The National Remote Sensing Agency (NRSC), Hyderabad also organizes regular and customized courses for the benefit of user organizations in the area of RS & GIS for the professionals.

Satellite Communications and Navigation:

11th Plan Targets:

10. The major emphasis in **Satellite Communications** during 11th Plan was towards meeting the growing demand for transponders, ensuring continuity of quality services, protectionof space systems, efficient spectrum management and continuous improvement in technology. Based on the demand, the INSAT system capacity was targeted to be progressively augmented to about 500 transponders by end of 11th Plan. Development of cost-effective 4T-12KW bus with capacity of more than 50 transponders and flexible enough to accommodate wide range of payloads was to be undertaken. The thrust areas of applications include expansion and growth of tele-education, telemedicine and village resource centers; strategies for operationalisation and institutionalisation with the involvement of Central Government Ministries / Departments, State Governments and NGOs; self-sustenance and large scale training.

    In the area of **Satellite Navigation,** besides completing the ground augmentation system of GAGAN (GPS Aided GEO Augmented Navigation), a major target for 11th Plan was to establish Indian Regional Navigational Satellite System with a constellation of 7 satellites. Co-operation and participation in global navigational systems were also planned to be pursued.

Achievements:

a) The INSAT-4CR satellite carrying 12 high power Ku band Transponders has been successfully launched by GSLV F04 on 2nd September 2007 and operationalised. The satellite has been realised in the fast track mode consequent to the launch failure of INSAT-4C / GSLV F02 mission in July 2006.

b) The development of advanced experimental low cost communication satellite GSAT-4 and GSAT-5P were also completed. However, the satellites could not be placed into their intended orbits due to failure of GSLV D3 and GSLV-F06 flights.

c) The INSAT/GSAT system were further augmented with the launch of GSAT-8 (procured) and GSAT-12 (on-board PSLV-C17). With this the current INSAT system capacity has become 187 Transponders which are used for telecommunication, TV broadcasting, DTH services, business communications, rural area connectivity, Tele-education, Tele-medicine, Village Resource Centres, Search and Rescue operations and Emergency Communications. GSAT-10 satellite with 12 Ku-band, 12 C-band, 12 extended C-Band and GAGAN payload under advanced stages of realization.

d) The Imager and Sounder payloads for the advanced meteorological satellite INSAT-3D have been realised. Integration and testing activities are under progress for launch during 2012.

e) The Government have approved four INSAT/GSAT followon satellites viz., GSAT-9 configured with 12 high power Ku band transponder(Cost: ₹ 140 crores approved in Jan 2008), GSAT-10 configured with 24 Transponders (Cost: ₹ 735 crores approved in August 2009); GSAT-11 configured as an advanced multi beam communication satellite (Cost: ₹ 500 crores approved in Aug 2009); GSAT-12 configured around 1K bus with 12 C band transponders. (Cost: ₹80 crores approved in Feb 2009). The work on these satellite projects has been initiated. Further, work on other on-going INSAT/GSAT projects viz. INSAT-4D/GSAT-5, INSAT-4E/GSAT-6, INSAT-4G / GSAT-8 is also in progress.

f) Technology Demonstration Phase of the GAGAN – GPS And Geo Augmented Navigation System – has been successfully completed and position accuracies of better than 10 meters has been achieved. GAGAN, a joint initiative of DOS and AAI, will augment the GPS based positioning services in the country for civil aviation and other services. The Final Operations Phase of GAGAN, funded by AAI, has also been initiated which will get a further boost with the on-orbit availability of 2-channel GAGAN payload on-board GSAT-8.

g) With a view to establish a regional satellite navigation system over Indian Region, the Indian Regional Navigational Satellite System (IRNSS) has been initiated. IRNSS is a constellation of 7 satellites – 3 in GEO and 4 in GSO orbit. The configuration of the space and ground segment of IRNSS have been finalised and the development work has been progressing well. The irst IRNSS satellite is targeted for launch in 2012-13.

h) Significant progress has been achieved in thrust areas of Space applications viz., Tele-Education, Tele-Medicine and Village Resource Centres. Under EDUSAT based Tele-education programme, about 55,000 class rooms in various parts of the country have been operationalised covering primary education, secondary education, professional education, informal education and training/development. Satellite based Tele-medicine connectivity has been established in 382 hospitals wherein 306 hospitals in remote/rural areas are connected to 60 super speciality hospitals in district headquarters. Village Resource Centres have been set up in 473 locations which are providing integrated space services to the rural community.

Space Science Research:

11th Plan Targets:

12. The interest in Space Science researchduring 11th Plan was focussed in four major areas viz., Planetary Exploration / Science, Astronomy and Astrophysics, Space Weather and Weather & Climate. The Space Science research in the country has gained impetus in the recent years with the undertaking of Planetary mission Chandrayaan-1, Multi-wavelength astronomy satellite ASTROSAT and climatic research satellite Megha-Tropiques and created special awareness and enthusiasm amongst the younger generation. A major target for 11th Plan, therefore, was to complete these ongoing missions and plan for followon missions Chandrayaan-2 and Astrosat-2 for continued investigations. Besides this, a number of small satellite missions have also been planned for studies in Solar Physics (Space borne Coronagraph "Aditya"), Earth's Near Space Environment (Twin satellite missions SENSE-P and SENSE-E), investigations on inner magnetosphere (ITM) and studies in atmospheric aerosol and trace gases (I-STAG mission). Akin to this, a major challenge lies in creating the human resource base in the country for analysis of the enormous amount of scientific data that would be available from these missions. It was also planned during the 11th Plan period to undertake technology development for newer missions such as Mars Orbitor, Asteroid Orbitor and Fly-by Missions to Comets and Outer Solar System with a primary interest to understand the origin and evolution of solar system.

Achievements:

a) Chandrayaan-1, India's first unmanned moon mission, has been successfully launched on 22nd October 2008 onboard PSLV C11. Subsequent to the launch, through a carefully planned complex orbital maneuvers, Chandrayaan-1 was placed in Moon's orbit which is about 4 lakh kms from earth. The deep space network with two large antennae

(18 meter and 32 meter dia) with associated ground segment was established in Bylalu, near Bangalore to provide TTC support for the Mission. The momentous task of placing the Moon Impact Probe instrument with Indian Tricolor painted on its surface carried by Chandrayaan-1 was accomplished on November 14, 2008. The excellent quality of high resolution data from all the instruments has led to identification of new lunar features and characteristics, excellent topography of lunar features and crater basins, an insight into the shadowed areas in the lunar polar regions and environmental factors around Moon.

b) The Government has approved in September 2008 undertaking Chandrayaan-2 with an Orbiter and Lander rover. The total estimated cost of Chandrayaan-2 is ₹ 425 crores. The work on realisation of payloads and spacecraft subsystems is in progress.

c) The Government has also approved Aditya-1 satellite project to measure solar coronagraph with a cost of ₹ 392 Crores. The development work of Solar Coronagraph, the instrument to be flown on Aditya-1, has already been initiated.

d) The development of multi-wavelength astronomy satellite Astrosat has progressed well. The payload instruments and the spacecraft subsystems are under fabrication.

e) A study report on the feasibility of undertaking a planned Mission to Mars has been completed. As per the study report, it is feasible to undertake Indian's first mission to Mars during the early phase of 12th Plan.

f) Detailed studies on various small satellite missions for space science research in the area of solar physics, space weather and environment and atmospheric sciences have also been undertaken. Based on the studies, specific scientific missions to be flown as piggyback payloads are planned to be initiated.

g) Research / Exploratory studies in the areas of Global climate change, infrared astronomy, astrophysics, planetary atmosphere, aeronomy, solar physics are being carriedout using ground based facilities.

Disaster Management Support:

11th Plan Targets:

13. **Disaster Management Support**, was intended to provide timely and reliable space inputs and services to the DMS in the country and was a vital area of space applications during 11th Plan period. The major initiatives planned during 11th Plan period includes realization of a National Data Base for Emergency Management, Impact mapping and monitoring support for Disaster events, Satellite based communication

support for Disaster Management, strengthening of early warning systems and development of tools and techniques for decision support systems for Disaster Management.

Achievements:

a) ISRO provided necessary information support for monitoring of Major Disasters during the plan period. All the flood events were monitored and the flood inundation layer super imposed with base details were disseminated to the concerned Relief Commissioners, Ministry of Home Affairs, and Central Water commission in near real time (5-6 hrs). The cyclones originating in Indian Oceanic regions were observed, tracked and intensity were forecast on a regular basis. As a part of the National Agricultural Drought Monitoring System (NADAMS) monthly reports on the crop condition are being prepared for 13 states and provided to Dept. Of Agriculture & Cooperation and concerned states. The Indian Forest Fire Response and Assessment System (INFFRAS) is deriving daily active forest fires twice daily and disseminated to the forest officers and updated on the website. A new methodology for semi-automatic detection of landslides is developed.

b) The work on realisation of a National Data Base for Emergency Management to support disaster/ emergency management in the country, in real/ near real time has been initiated. An NDEM server is established at NRSC and the data base available with ISRO in 1:50K, 1:10K and 1:2K were loaded on to the server. The design of Decision support systems for flood, drought, landslides and radiological disasters are completed. A mobile device based software solution has been developed to collect field data including geographic location coordinates, field photos and scientific parameters and transmit the collected information in near real time to the central server where the data is organized and utilized. Civil works related to NDEM building is in the final stages. The architecture and specifications of the NDEM infrastructure are being reviewed based on the suggestions of inter departmental technical Group. Besides creation of data layers, several application tools like river-watch tool, flood hazard information system, flood disaster decision support system, etc., have been developed.

c) An Airborne Synthetic Aperture Radar (ASAR) has been developed for aircraft based surveys as a part of disaster management support system and demonstration flights have been completed. The flight model has also been realized and undergoing T&E for operationalisation. Similarly the X-band SAR is being developed and the developmental model will be realized during the 11th plan.

d) Towards emergency communication for disaster management activities, a Virtual Private Network (VPN) has been set up with 29

Nodes networking the State and District level emergency control centres with Ministry of Home Affairs for near real time management of natural disasters.

e) The Government have approved setting up of dedicated aerial survey facilities (Cost: ₹ 179.86 crores approved in July 2009) to support Disaster Management System in the country.

f) The Airborne Laser Terrain Mapper (ALTM) and Digital Camera data have been procured to strengthen the monitoring capability for disaster management. ALTM DC data acquisition for over 30000 sq. km was completed. Data processing of 8800 sq. km (Orissa and AP – sabari) was completed. Data processing of 21600 sq. km (Bihar and Assam Phase I) is in progress and will be delivered during the 11th plan period.

g) Monitoring the extreme weather based disasters such as cyclone, floods, drought etc. need real time observation of the associated parameters. Towards this the Automatic Weather Stations (AWS) enabled with satellite based real time data transfer was pursued in 11th FYP. More than 1000 AWSs has been established in various parts of the country. The data from these AWS are made available through the ISRO web site (www.mosdac.gov.in) in near real time.

h) A new methodology for assessing the Area favourable for Crop Sowing (AFCS), has been derived from Shortwave Angle Slope Index (SASI) images and incorporated in the drought assessments. The AFCS values are useful to assess the intensity of early season/sowing-period agricultural drought intensity in terms of timeliness in the commencement of sowings, extent of delay or reduction in crop sowings.

Atmospheric Science Programme:

11th Plan Targets:

14. Considering the need to provide an impetus on studies and research in the critical area of atmospheric research, an Atmospheric Science Programme (ASP) has been planned with special emphasis on use of satellite and advanced observation tools, techniques of modelling and a mechanism for interactions with scientific departments and academia for initiating suitable projects, leading to operational end user products in different domains. The primary goals of the Atmospheric Science Programme was to pursue high quality research and development work in Meteorology, Atmospheric processes, Atmospheric dynamics with emphasis on use of satellite inputs.

Achievements:

a) Development of low cost Automatic Weather Stations (AWS) for improved data for weather forecasting has been successfully completed and the densification of the meteorological observation network with deployment of AWS is in progress. Over 1000 AWS have been deployed as on date in various parts of the country.

b) A project on Prediction of Regional Weather through Observation Network AndModelling (PRWONAM) has been initiated for improving regional weather prediction over Sriharikota to support the launches and the results are encouraging. This system is in operation during the last 10 PSLV/GSLV launches

c) Development and deployment of Doppler Weather Radar for North-East Region of the country for improved data for forecasting the weather phenomena is in advanced stages of realisation.

d) A major Field Campaign in Bay of Bengal was conducted for a period of 35 days from Dec. 27, 2008 to Jan. 31, 2009 in winter season. 30 scientists from 12 national institutions participated in the campaign and observations were made using nearly 90 instruments. Nearly 15,000km length of Bay of Bengal region was systematically covered for multi-platform observations. It is expected that this campaign would bring out the atmospheric structures over Bay of Bengal region in the winter season and many new observational findings for future weather modelling.

HRD, Indigenisation, International Co-operation, Industry Interface, Commercialisation & Others:

11th Plan Targets:

15. Human Resource Development, International co-operation, Industry and Academia interface, indigenous development of space materials and components and Space commerce were the priority areas during 11th Plan period. An important target during the Plan period was to set up Indian Institute of Space Science and Technology with a view to capture the talent at 'plus two' level in order to create quality human resources in the country for ISRO.

Achievements:

a) The Indian Institute of Space Science and Technology has been set up in Thiruvananthapuram and the Institute has started functioning from the academic year 2007-08. About 150 students in three streams viz., avionics, aerospace and applied science are admitted annually. Initially, the Institute made use of the ISRO infrastructural facilities in

Trivandrum for conducting the courses. Subsequently, the institute started functioning from its newly developed campus at Valiamala, Trivandrum since August 2010. The first batch of graduates from the institute has been inducted to various ISRO/DOS centres/units during August 2011.

b) The Government has approved the proposal for upgradation of VLSI fabrication facilities at SCL, Chandigarh from the current 0.8 micron capability to better than 0.25 micron capability at a total estimated cost of ₹ 920 crores. The upgradation activities of the facilities are under progress.

c) Two state of the art communication satellites viz. W2M and Hylas were built by ISRO under a contract between Antrix/ISRO and EADS/Astrium for a European customer. Both the satellites were launched successfully on Ariane launch vehicles from Kourou, French Guyana. As part of the contract, both the satellites were handed over to the customer after initial Launch and Early Orbit Phase (LEOP) operations carried out from Master Control Facility at Hassan.In addition, PSLV has launched two satellites with dedicated launch (Agile of Italy and TECSAR of Israel).

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No. 12016/3/2011-S&T
Government of India
Planning Commission
Science and Technology Division

Yojana Bhawan,
Sanasd Marg,
New Delhi-110001

Dated 18.04.2011

OFFICE MEMORANDUM

Subject: WG-14: Constitution of Working Group of the Department of Space

The Steering Committee on Science and Technology for the formulation of Twelfth Five Year Plan, during its first meeting held on 5th April, 2011 under the Chairmanship of Dr. K. Kasturirangan, Member (Science). Planning Commission has decided to constitute a Working Group for the Department of Space. The composition and Terms of Reference of the Working group are as under:

COMPOSITION

S.No.	Name & Designation	
1.	**Dr K Radhakrishnan, Secretary, DOS**	**Chairman**
2.	Secretary, Dept of Agriculture and Co-operation, Ministry of Agriculture, New Delhi	Member
3.	Secretary, Department of Border Management, Ministry of Home Affairs	Member
4.	Secretary, Ministry of Earth Sciences, New Delhi	Member
5.	Secretary, Ministry of Environment and Forests,	Member
6.	Secretary, Ministry of Information & Broadcasting	Member
7.	Secretary, Department of Information & Technology	Member
8.	Secretary, Department of Land Resources, Ministry of Rural Development, New Delhi.	Member
9.	Secretary, National Disaster Management Authority, Ministry of Home Affairs, New Delhi.	Member
10.	Secretary, Department of Science and Technology	Member
11.	Secretary, Department of Scientific and Industrial Research/ Director General, Council of Scientific & Industrial Research	Member
12.	Secretary, Department of Telecommunications.	Member
13.	Director-General, IMD, New Delhi.	Member
14.	Director, Town and Country Planning Organisation, New	Member
15.	Planning Advisor, NEC, Shillong.	Member
16.	Surveyor-General, SOI, Dehradun.	Member
17.	Chairman, Central Water Commission, New Delhi.	Member
18.	Additional Director General, Forests, Ministry of Environment and Forests, New Delhi.	Member

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19.	Chief Engineer, AIR, New Delhi.	Member
20.	Chief Engineer, DD, New Delhi.	Member
21.	Joint Secretary, HRD, New Delhi.	Member
22.	Additional Secretary, Department of Health and Family Welfare, New Delhi.	Member
23.	Dr P S Goel, Honorary Distinguished Professor, ISRO	Member
24.	Dr B N Suresh, Vikram Sarabhai Distinguished Professor, ISRO	Member
25.	Dr T K Alex, Director, ISRO Satellite Centre, Bangalore	Member
26.	Dr R R Navalgund, Director, Space Applications Centre, Ahmedabad	Member
27.	Shri P S Veeraraghavan, Director, Vikram Sarabhai, Space Centre, Thiruvananthapuram	Member
28.	Prof. J N Goswami, Director, PRL, DOS, Ahmedabad	Member
29.	Prof. M S Ananth, Director, IIT, Chennai	Member
30.	Prof R S Deshpande, Director, Institute for Social and Economic Change, Bangalore	Member
31.	Prof. J. Srinivasan, Professor, Centre for Atmospheric and Oceanic Sciences Indian Institute of Science, Bangalore.	Member
32.	Prof. P Venkata Rangan, VC, Amrita Vidyapeetham, Coimbatore	Member
33.	Chairman and Managing Director, HAL, Bangalore.	Member
34.	Shri. J.D. Patil, Executive Vice president-Defense & Aerospace, Larsen & Toubro Ltd.	Member
35.	Shri. S.M. Vaidya, Vice President & Business Head, Godrej Precision Systems Ltd.	Member
36.	Dr Ajay Parida, Executive Director, MSSRF, Chennai.	Member
37.	Shri A.K. Verma, Adviser (S&T), Planning Commission, or his Nominee	Member
38.	Dr V S Hegde, Scientific Secretary, ISRO	**Member-Secretary**

Terms of Reference

1. To review and assess the performance and role of the Department at the end of the Eleventh Five Year Plan. Identify priorities of the Department for the Twelfth Five Year Plan and suggest measures including policy initiatives for enabling India to emerge as a major global technological power by 2025
2. To suggest plan programmes for the Department by adopting a ZBB approach and keeping in view the priorities and goals for the Twelfth Five Year Plan as well as the agenda for the Decade of Innovations during 2010-20.
3. To define deliverables as well as goals for the Department for the Twelfth Five Year Plan period as well as Annual Plans, both in terms of tangible and non-tangible outputs and formulate guidelines for deployment of resources for relating inputs to the specified goals
4. To suggest an optimum outlay for the Department, comprising of the on-going commitment and new programmes proposed to be undertaken.

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5. The Chairman may co-opt any other member.
6. The expenditure towards TA/DA in connection with the meetings of this Working Group in respect of Official Members would be borne by their respective Ministries/Departments. In respect of Non-Official Members, the expenditure would be met by the Department of Space, as admissible to class-I officers of the Government of India. .
7. The report of the Working Group would be submitted to the Steering Committee on the S&T for the formulation of Twelfth Five Year Plan by 15th July, 2011

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(R.K. Gupta)
Joint Adviser (S&T)

Copy forwarded to:

1. Secretary, Department of Space
2. Chairman, all Members and Member-Secretary of the Working Group
3. PS to Deputy Chairman, Planning Commission
4. PS to Adviser to PM on PI[3]
5. PS to Minister of State (Planning)
6. PS to all Members, Planning Commission
7. PS to Member-Secretary, Planning Commission
8. All Principal Advisers/Sr. Advisers/Advisers/HODs, Planning Commission
9. Director(PC), Planning Commission
10. Information Officer, Planning Commission
11. Library, Planning Commission

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(R.K. Gupta)
Joint Adviser (S&T)

Department of Space
12th Five Year Plan
FINANCIAL OUTLAY PROJECTIONS
(Plan + Non-Plan)

(₹ in Crores)

Sl No	Mission	Total Cost (Projects)	12th Plan Projected Outlay (at 2011-12 prices)
1. Earth Observation Systems and Atmospheric Science Program - Missions			
	Approved and ongoing		
1.1	RISAT-1	378.49	0.25
1.2	Megha-Tropiques	81.60	0.40
1.3	INSAT-3D	200.00	5.00
1.4	INSAT-3DR (2 Nos)	140.00	77.85
1.5	SARAL	73.75	30.00
1.6	GISAT	392.00	360.00
	New Missions - to be realised during 12th Plan		
1.7	Resourcesat-2A	180.00	180.00
1.8	EnvSat-1	100.00	100.00
1.9	Oceansat-3	250.00	250.00
1.10	SCATSAT-1	150.00	150.00
1.11	RISAT-1A	425.00	400.00
1.12	Cartosat-3	700.00	650.00
1.13	Resourcesat-3	220.00	170.00
1.14	INSAT-3D Launch Services	450.00	300.00
	New Missions - to be realised beyond 12th Plan		
1.15	RISAT-3	500.00	350.00
1.16	Cartosat-1A	300.00	50.00
1.17	EnvSat-2	205.00	100.00
1.18	Scatsat-2	180.00	30.00
1.19	Megha-Tropiques-1A	100.00	10.00
1.20	Oceansat-3A	300.00	25.00
Subtotal – 1		**4865.75**	**3238.50**

Sl No	Mission	Total Cost (Projects)	12th Plan Projected Outlay (at 2011-12 prices)
2. Earth Observation Systems and Atmospheric Science - Application initiatives			
2.1	Remote Sensing Applications	85.00	85.00
2.2	National Natural Resources Manamement System (NNRMS)	475.00	475.00
	Subtotal - 2	**560.00**	**560.00**
3. Satellite Communication - Missions			
	Test Satellites to be flown on GSLV/GSLV-Mk III		
3.1	GSAT-14 (Ku-6, Ext-C-6, Ka-1) - ongoing	50.00	50.00
3.2	GSAT-19 - new	70.00	50.00
	Operational Satellites to be flown on GSLV/GSLV-Mk III		
3.3	GSAT-9 (Ku-12)	140.00	30.00
3.4	GSAT-6 (BSS-5 spot, MSS-5 spot)	269.00	40.00
3.5	GSAT-6A (BSS-5 spot, MSS-5 spot)	147.00	100.00
3.6	GSAT-12 (C-12; Launched by PSLV)	80.00	0.10
3.7	GSAT-17 (C-36; GSLV Mk II)	300.00	300.00
3.8	GSAT-26/GSAT-19E (C-36; GSLV Mk III)	140.00	100.00
3.9	GSAT-22 (C-36; GSLV)	250.00	100.00
3.10	GSLV-23 (Ku-4, C-2, UHF-3,S-1, GSLV)	260.00	100.00
3.11	GSAT-25 (Ku-12; GSLV)	160.00	60.00
3.12	GSAT-18 (3 Ton; Ku-12, C-36; GSLV)	320.00	250.00
	Operational Satellites - Procured Launch		
3.13	GSAT-11 -Adv Communication Satellite (4 Ton; Ku/Ka-24)	500.00	400.00
3.14	GSAT-8 (3 Ton; Ku-24, GAGAN)	300.00	2.40
3.15	GSAT-10 (3 Ton; C-18, Ku-12, GAGAN)	321.00	150.00
3.16	GSAT-15 (3 Ton; Ku-24, GAGAN)	278.00	250.00
3.17	GSAT-16 (3 Ton; C-36, Ku-12)	284.00	240.00
3.18	GSAT-21 (4 Ton; Ku/Ka-24 equivalent)	500.00	500.00

Sl No	Mission	Total Cost (Projects)	12th Plan Projected Outlay (at 2011-12 prices)
3.19	GSAT-24/GSAT-11S (S multi band-34, S-34)	1200.00	800.00
	6 Ton Ka-Band Satellites - Procured Launch		
3.20	GSAT-20 (Ka)	1000.00	1000.00
3.21	GSAT-27 (Ka)	1000.00	800.00
3.22	Procured Launch Services		6000.00
3.23	Service Charges for Leasing INSAT/GSAT Transponders	600.00	1200.00
3.24	Augmentation of Capacity through short-term Leasing of Transponders	1000.00	1000.00
3.25	Procurement of Heavier Class Satellite	1000.00	1200.00
Subtotal - 3		**10169.00**	**14722.50**
4. Satellite based Navigation System			
4.1	IRNSS (1 to 7) - ongoing	1420.00	740.00
4.2	IRNSS (8 to 11) - new	800.00	200.00
4.3	GPS Aided Geo Augmented Navigation (GAGAN) - Ground station augmentation	500.00	400.00
4.4	Satellite Navigation Applications	200.00	100.00
Subtotal - 4		**2920.00**	**1440.00**
5. Satcom Applications			
5.1	Tele-education	150.00	150.00
5.2	Tele-medicine	300.00	300.00
5.3	Other satcom applications	250.00	250.00
Subtotal - 5		**700.00**	**700.00**
6. Integrated Space Technology Services			
6.1	Disaster Management Support (including procurement of DMS Aircraft)	500.00	500.00
6.2	Village Resource Centres	90.00	90.00
Subtotal - 7		**590.00**	**590.00**
7. Space Sciences and Planetary Exploration - Missions			
7.1	Astrosat-1	177.85	10.00

Sl No	Mission	Total Cost (Projects)	12th Plan Projected Outlay (at 2011-12 prices)
7.2	MARS-1	350.00	350.00
7.3	Chandrayaan-2	425.00	335.00
7.4	Aditya-1	127.75	100.00
7.5	Polix	100.00	80.00
7.6	MARS-2	500.00	350.00
	Space Science and Planetary Exploration Research		
8.7	Sounding Rockets		45.00
8.8	Space Science Promotion and Outreach		25.00
8.9	ISRO Geosphere Biosphere Programme		150.00
8.10	Space Science Instrumentation		5.00
8.11	Multi-institutional Projects		6.00
8.12	Science Payload/Sensor Development		10.00
8.13	Planetary Exploration (PLANEX)		15.00
8.14	Microgravity Research		4.00
8.16	Atmospheric Science Programme		400.00
8.17	Science Data Utilization Plan		20.00
8.18	PRL Plan Component		150.00
8.19	NARL Plan Programmes		100.00
8.20	SPL Programmes		25.00
Subtotal - 8		**1680.60**	**2180.00**
9. Space Transportation System			
	Launch Vehicle Programme		
9.1	PSLV (14-28) - ongoing	1518.00	772.00
9.2	PSLV - New	1728.00	1425.00
9.3	GSLV-Operational - ongoing	3550.96	1275.00
9.4	GSLV-MK III - Developmental	2498.00	470.00
9.5	GSLV-MK III - Operational	3220.00	2700.00
	Advanced Space Transportation System		

Sl No	Mission	Total Cost (Projects)	12th Plan Projected Outlay (at 2011-12 prices)
9.6	HSP (Pre-Project) - Ongoing	145.00	62.00
9.7	HSP (Phase-I) - New	435.00	435.00
9.8	HSP (Phase-II) - New	6300.00	650.00
9.9	Semi-Cryo Engine Development - Ongoing	1798.00	1200.00
9.10	Semi-Cryo Stage Development Project - New	700.00	200.00
9.11	Reusable Launch Vehicle - Ongoing		400.00
9.12	Advanced Technology Vehicle - New		25.00
9.13	Air Breathing Propulsion System - ongoing		80.00
Subtotal - 9		**21892.96**	**9694.00**
10	**Small Satellite Systems**		**150.00**
11	**Technology Development**		**2500.00**
12	**Advanced R & D**		**1200.00**
13	**Technical Facilities - Replacement & Augmentation**		**6000.00**
14	**Development of Space Materials and Components**		**200.00**
15	**Industry Interface/ productionisation**		**800.00**
16	**Advance Procurement / Stockpiling of Critical Components**		**300.00**
17	**International Co-operation**		**25.00**
18	**Sponsored Research**		**140.00**
19	**Organisation & Infrastructure Maintenance, Facility Operation, HRD etc**		**10000.00**
20	**Land and General Civil Works**		**1750.00**
21	**Housing**		**250.00**
Grand Total		**40458.31**	**55000.00**
	Plan Component		**47500.00**
	Non-Plan Component		**7500.00**