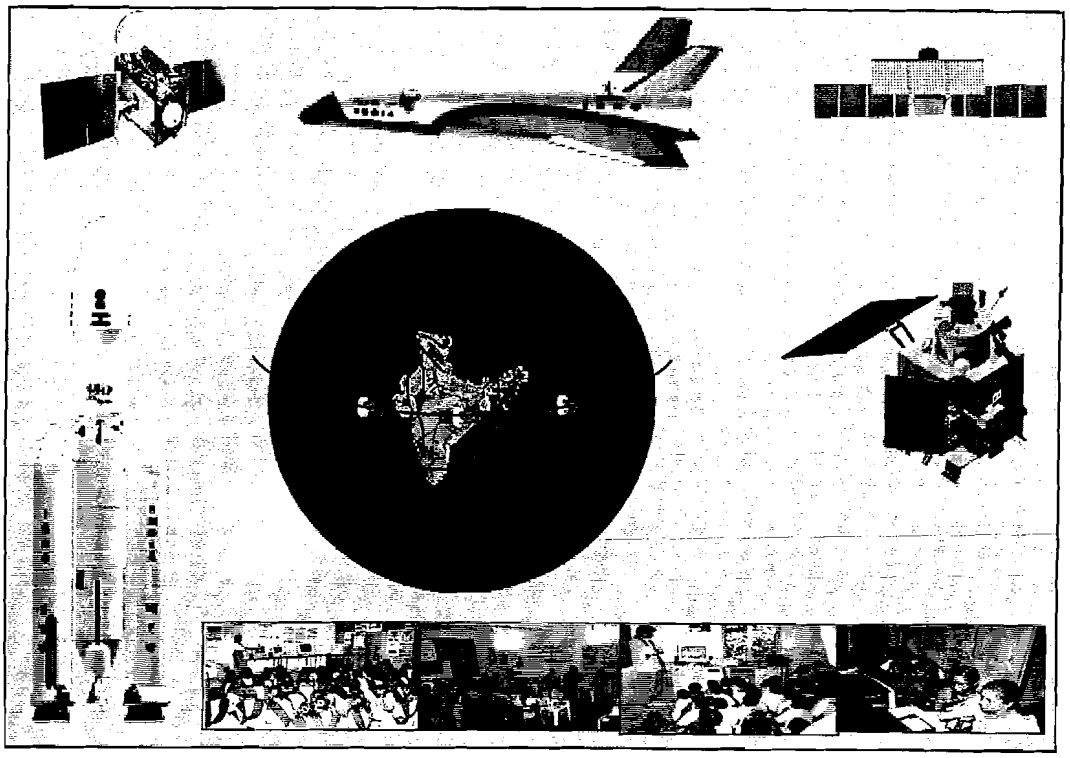
REPORT OF THE WORKING GROUP ON "SPACE" on the

ELEVENTH FIVE YEAR PLAN PROPOSALS 2007-12

for

INDIAN SPACE PROGRAMME



Indian Space Research Organisation
Department of Space
Bangalore – 560 094

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Department of Space

ELEVENTH FIVE YEAR PLAN 2007-12

Preface

Planning Commission have constituted a National level S & T Steering Committee in the context of formulation of Eleventh Five year plan 2007-12. During its first meeting held on 4th April 2006, the Steering Committee have formulated a Working Group for Department of Space under the Chairmanship of Dr. G Madhavan Nair, Secretay, DOS / Chairman, ISRO with the following terms of reference.

1. To review and assess the progress made during Tenth Five Year Plan (2002-07) identifying the achievements, weaknesses / shortfalls and gap areas.
2. To suggest plans and programmes for the Eleventh Five year plan 2007-12 including thrust areas.
3. To suggest an optimum outlay for the Eleventh Plan keeping in view the overall resource position in the country.

Based on a preliminary analysis of the national development scenario, trends in Space technology and other relevant aspects, the Department of Space has identified some of the major thrust areas of Space programme to be pursued during Eleventh five year plan and circulated the same in May 2006 to all the Members of the working group for their views, comments and any other specific inputs.

Further, this document is prepared which highlights the achievements vis-à-vis targets of 10th five year plan, the vision for Space programme the Decade 2010-20, national needs for space services and proposals for Eleventh Five Year plan 2007-12 in order to assist the deliberations of the working group, planned for August 23, 2006.

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Formulation of 11th Five Year Plan

Members of the Working Group on "Space"

1.	Secretary, Department of Space	...	Chairman
2.	Dr P S Goel, Secretary, DOD, New Delhi	...	Member
3.	Smt Radha Singh, Secretary,DAC(M/o. Agri.)N.Delhi	...	Member
4.	Shri D S Mathur, Secretary, DOT, New Delhi	...	Member
5.	Dr R R Navalgund, Director, SAC, Ahmedabad	...	Member
6.	Prof J N Goswami, Director, PRL, Ahmedabad	...	Member
7.	Prof P Venkatarangan, VC,AVV, Coimbatore	...	Member
8.	Prof M S Ananth, Director, IIT, Chennai	...	Member
9.	Shri Kiran Karnik, President, NASSCOM, New Delhi	...	Member
10.	Shri K U Limaye, Chief Controller (R&D), DRDO	...	Member
11.	Lt.Gen.H S Lidder, CISC, HQ IDS (M/o. Defence)	...	Member
12.	Shri B Lal, Director General, IMD, New Delhi	...	Member
13.	Dr A K Bohra, Director, NCMRWF, New Delhi	...	Member
14.	Dr M Gopal Rao, Surveyor-General, SOI, Dehradun	...	Member
15.	Shri P G Dhar Chakraborthy, ED, National Institute of Disaster Management (M/o Home Affairs), New Delhi	...	Member
16.	Shri V S Sampath, Director-General, NIRD,Hyderabad	...	Member
17.	Dr A K Singh, Director, IAR, New Delhi	...	Member
18.	Shri R Jayasheelan, Chairman, CWC, New Delhi	...	Member
19.	Director, Town & Country Planning Org., New Delhi	...	Member
20.	Planning Adviser, NEC, Shillong	...	Member
21.	Prof P Tandon, VC, NEHU, Shillong	...	Member
22.	Shri M K Prasad, Addl.DG, Forests (M/o.Env.&Forest)	...	Member
23.	Shri R R Prasad, Chief Engineer, AIR, New Delhi	...	Member
24.	Shri M C Agarwal, Chief Engineer, DD, New Delhi	...	Member
25.	Shri A K Chaturvedi, Adviser, HRD, DOT, New Delhi	...	Member
26.	Shri Agit Singh, CGM, DC, DIT, New Delhi	...	Member
27.	Shri Sunil Kumar, Joint Secretary, HRD, New Delhi	...	Member
28.	Shri Deepak Gupta, AS, Dept. of Health & Family Welfare	...	Member
29.	Chairman & Managing Director, HAL, Bangalore	...	Member
30.	Shri V Sundararamaiah, Scientific Secretary, ISRO	...	Member-Sec.

HIGHLIGHTS OF THE PLAN PROPOSAL

Major thrust on large scale applications of space technology in the priority areas of National development and to undertake advanced space endeavors in the frontier areas of space research.

Major Goals of 11th Plan

Capabilities in Space Communications and Navigation

- Augmentation of INSAT/GSAT space segment to meet the demand of 500 transponders by end of the plan period.
- Development of high power Ka band satellites and ground systems for point-to-point connectivity.
- Building Navigational Satellite Systems & related services.
- Focus on R & D in Satellite Communications.
- Institutionalisation of Tele-medicine, Tele-education and VRCs
- Communications systems / support for Disaster Management.
- Progress towards self sustenance of INSAT/GSAT system.

Leadership in Earth Observations

- Improved imaging capability and continuity of data / services through three thematic series of EO systems – Land & Water resources, Cartography and Ocean /Atmosphere.
- Development of advanced microwave imaging capability.
- Strengthening Ground Systems and SNRMS.
- Establishment of National Natural Resource Data base.
- Undertake major applications projects in the area of Agriculture, land and water resource management, DMS, infrastructure and urban / rural development, etc,

Major thrust in Space Transportation System

- Operationalisation of GSLV Mk III with 4T launch capability.
- Perfect payload recovery and reentry technologies.
- Conduct Demonstration flights of Reusable Launch Vehicle.
- Critical technologies for Manned Mission.

Space Science Enterprise

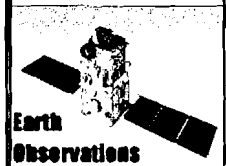
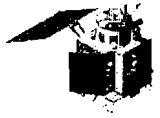
- Advanced space science endeavors – Chandrayaan, Multi-wavelength X-ray astronomy, Mission to Mars and Asteroid / Comet fly by missions.
- Establish Space Science Instrumentation Facility and Indian Space Science Data Centre.

Promoting Spinoffs

- Human Resource Development, Space science & technology education, Industry Interface, Academia interface and International cooperation.

TOTAL OUTLAY FOR 11TH PLAN: RS. 39, 750 CRORES

FIG 5.1: MISSION PROFILE 2005-15

		2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
 **Earth Observations**	*Land & Water*			TWSAT	Resourcesat-2	GEO-HR	TES-HyS	Resourcesat-3			HyS - Op
					RISAT-1			DMSAR-1	RISAT-3		
	Cartographic	Cartosat-1	Cartosat-2		11 Missions			Cartosat-3			Cartosat-4
	Ocean & Atmosphere			Oceansat-2	(Excluding Small Satellite Mission)				Oceansat-3		RISAT-4L
				INSAT-3D	Megha-Tropi	Altika-Argos				TES-Atm	M-T Cont.
Satellite Communications & Navigation 	*I-2K bus*		INSAT-4C	INSAT-4CR GSAT-4 GSAT-5	GSAT-9 GSAT-6		GSAT-12	GSAT-13			
	I-3K bus	INSAT-4A(P)	INSAT-4B(P)	GSAT-8 (P)	21 Missions						
	I-4K bus					ACTS-1(P) GSAT-10	ACTS-2(P) GSAT-11	GSAT-14 GSAT-15	ACTS-3 GSAT-16 (3E Repl)	GSAT-17 (Ka band)	GSAT-18 (MSS)
	IRNSS				IRNSS-1	IRNSS-3	IRNSS-5	IRNSS-7			
					IRNSS-2	IRNSS-4	IRNSS-6				
Space Science & Environment 	*Planetary Exploration*			Chandrayaan-1		Chandrayaan-2			Mars-O		
	Astronomy & Astrophysics			Astrosat-1	4 Missions			Aditya-1			Astrosat-2
	Space Weather				(Excluding Small Satellite Mission)			SENSE-P SENSE-E ITM-1			
	Climate & Weather					I-STAG					
Launch Vehicles 	*PSLV*	C6	C7	C8 - C10	C11-C15	C16-20	C21-22	C23-25			
	GSLV Mk II		F02	F03-05, D3	F06-07	F08	F9	F10			
	GSLV Mk III					D1	D2	F01-02			
	Technology Missions		SRE-1	DMRJ-FTD	SRE-2 DMRJ-FTD	DMRJ-FTD	RLV-TD	RLV-TD			

Abbreviations

ABP	Air brething Propulsion
ACTS	Advanced Communication Technology Satellite.
ALTM	Airborne Laster Terrain Mapper
AWS	Automatic Weather Station
DEM	Digital Elevation Models.
DM-SAR	Disaster Management - Syntheric Aperture Radar.
EO	Earth Observations
EOAM	Earth Observation Application Mission.
EWS	Early Warning System
FTD	Flight Test Demonstrator
GAGAN	GPS And Geo Augmented Naviation
IMM	Inner Magnetosphere Mission
IRNSS	Indian Regional Navigational Satellite System.
I-STAG	Indian Satellite for Aerosol and Gases.
LISS	Linear Imaging Self Scanner
MSS	Mobile Satellite Service
NARL	National Atmospheric Research Laboratory
NDEM	National Data base for Emergency Management
NNRMS	National Natural Resource Management System
NR	Natural Resource
NRDB	Natural Resource Data Base.
RISAT	Radar Imaging Satellite.
RLV	Reusable Launch Vehicle
SENSE	Small satellite for Earth's Near Space Environment
SNRMS	State Natural Resource Management System
SPL	Space Physics Laboratory.
SRE	Space capsule Recovery Experiment
TD	Technology Demonstrator
TES-HyS	Technology Experiment Satellite - Hyper spectral.
TSTO	Two Stage To Orbit
VPN	Virtual Private Network
VRC	Village Resource Centre
WiFS	Wide Field Sensor

1. OVERVIEW OF INDIAN SPACE PROGRAMME

1. Over the last four decades, India has achieved a notable progress in the design, development and operation of space systems, as well as, using them for vital services like telecommunication, television broadcasting, meteorology, disaster warning as well as natural resources survey and management. The space programme has become largely self-reliant with capability to design and build satellites for providing space services and to launch them using indigenously designed and developed launch vehicles.

The Objectives:

2. The Indian Space programme is characterized by a vision to use space technology for national development. The Programme is application driven with emphasis on the policy of self-reliance. The primary objective of the space programme is to establish operational space services in a self-reliant manner in the thrust areas of satellite communication, satellite based resource survey/management and satellite meteorological applications. The indigenous development of satellites, launch vehicles and associated ground segment for providing these services is integral to those objectives.

The Organisation

3. The Space Commission and Department of Space were set up in 1972 to formulate and implement space policies and programmes in the country. The Space programme is executed through the Indian Space Research Organisation and the four Grant-in-aid institutions viz., National Remote Sensing Agency (NRSA) , the Physical Research Laboratory (PRL), the National Atmospheric Research Laboratory (NARL) and the North-Eastern Space Applications Centre (NE-SAC). Besides these, the administrative control of Semiconductors Complex Limited (SCL) at Chandigarh has been transferred from Department of IT to Department of Space w.e.f 1st March 2005. SCL has now been registered as an R & D Society and redesignated as Semiconductors Laboratory (SCL) with the approval of the Cabinet. The establishment of space systems and their utilization are co-ordinated by national level committees namely the INSAT Co-ordination committee (ICC), Planning Committee of National Natural Resource Management System (PC-NNRMS) and Advisory committee on Space Sciences (ADCOS). Five Regional Remote Sensing Service Centrex (RRSSC) help in undertaking remote sensing applications projects relevant to the region.

Overview of Space Programme:

4. Over the years, India has established two operational space systems – the Indian National Satellite (INSAT) System providing services for telecommunications, TV broadcasting and meteorology including disaster warning support and the Indian Remote Sensing Satellite (IRS) System for natural resource monitoring and management. Two satellite launch vehicles, the Polar Satellite Launch Vehicle, PSLV, for launching remote sensing satellites into the required polar orbits and the Geosynchronous Satellite Launch Vehicle, GSLV, for launching communication and meteorological satellites into 36,000 km high Geosynchronous Transfer Orbit (GTO) have been operationalised. India is one among the six countries in the world to develop GTO launch capability.

5. The constellation of Indian Remote Sensing Satellites comprises of seven satellites including India's latest state-of-art Cartography Satellite Cartosat-1 launched on 5th May 2005 onboard India's PSLV and is the world's largest constellation of remote sensing satellites in operation today. They serve as main stay of the National Natural Resources Management System (NNRMS) besides providing data worldwide. Vital applications such as identifying zones which could yield ground water, suitable locations for recharging water, monitoring command areas, estimating crop areas and yields, assessing deforestation, mapping urban areas for planning purposes, delineating ocean areas with higher fish catch potential and monitoring of environment are being pursued actively by users with the space based data.

6. In the field of Space communications, the INSAT system, currently consisting of nine satellites, is one of the largest domestic communication satellite systems in the Asia Pacific region, with a capacity of about 175 transponders in C, Ext-C, Ku and S bands. INSAT contributes significantly to a variety of services in telecommunications and television broadcasting including meteorological observations, disaster communications, Tele-education, Tele-health services and Village Resource Centres.

7. The Department of Space has taken initiative to pilot a Satellite Communications Policy in 1997 paving the way for the use of INSAT capacity by private users. A comprehensive Remote Sensing Data Policy on acquisition and distribution of satellite remote sensing data from Indian and foreign satellites for

civilian users in India has been formulated and approved by the Government which ensures that users are not denied access to valuable satellite data for developmental purposes.

8. Front ranking scientific investigations are being carried out in the fields of astronomy, atmospheric sciences and long term climatic research using satellites, balloons, sounding rockets & ground instruments. India's first Lunar Mission Chandrayaan-1 and the multi-wavelength X-ray observatory satellite ASTROSAT are two important initiatives of the recent past in space science research.

9. The Indian Space programme has enabled a significant role for national industries in realisation of space systems. A strong bond with academic institutions exists through extensive research partnership. Unique organisational systems have been evolved in the national space programme for fulfilling diverse functions like development, operations and applications of complex space systems. The space programme has enabled significant technology growth in multiple disciplines as spin-off benefits.

10. Indian capabilities in space thus represent a wide spectrum of expertise ranging from the conceptual design to building and operating of a variety of space systems, which are matched only by a few nations in the world. In view of these multiple dimensions and capabilities, India is recognized as a leader in space applications that have a wide impact on society. The end-to-end capability in space for vital application in communications, broadcasting, meteorology and natural resource information, which are of direct relevance for national development, has secured India a unique place in the international community. The diverse roles of space technology/services in various fronts – social, commercial, economic and strategic – have made the space systems an important component of our national infrastructure.

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2. TENTH FIVE YEAR PLAN 2002-07 : TARGETS AND ACHIEVEMENTS

Programmatic Targets:

1. The overall thrust of the space programme during 2002-07, the tenth five year plan period, have been to continue and strengthen the space based services towards socio-economic development of the country. The focus of the programme has been the large scale application of space technology in priority areas of national development. The major programmatic targets of the plan period in the areas of Launch vehicle development, INSAT system, Earth Observations and Space science research are:

- **Launch Vehicle Programme**: Operationalise the GSLV Mk I & II and achieve substantial progress in development of advanced GSLV Mk III

- **INSAT System**: Augmenting the INSAT system capacity with fourth generation INSAT-4 series to meet the projected demand for transponders. Expansion of the Satellite based communication network for socially and nationally relevant services in the area of education and literacy, health-care, rural development and disaster management support.

- **Earth Observations (EO)**: Enhancing the imaging capability with all-weather active microwave Radar Imaging Satellite and ensuring continuity of EO data with a constellation of multi-spectral high resolution imaging sensors. The Natural Resources Census and hot spot identification, Natural Resource Data Base (NRDB), improved data for weather forecasting and Disaster management support are among the vital applications initiatives planned with EO data.

- **Space Science**: Advanced space science endeavours including planetary exploration. Missions planned include a dedicated multi-wavelength X-ray astronomy mission ASTROSAT, a joint Indo-French climatic research mission “Megha-Tropiques” and achieve substantial progress in the realisation of lunar mission Chandrayaan.

Accomplishments:

2. The first four years of the Tenth five year plan have witnessed significant progress in the Indian Space Capabilities. Operationalisation of GSLV, development and qualification of Indigenous cryogenic engine, establishment of the state-of-art Second launch pad facilities at Sriharikota, launch and operationalisation of KALPANA (Metsat-1), Resourcesat-1 and Cartosat-1 / HAMSAT by PSLV, augmentation of INSAT system with INSAT-3A, 3E, GSAT-2, EDUSAT and INSAT-4A satellites are some of the important achievements of the 10^{th} plan period. The work on Cartosat-2, SRE-1 and INSAT-4B satellites is also in advanced stages of completion, targeted for launch in the next two quarters to be followed by launch of GSLV D3 with indigenous cryo stage carrying GSAT-4 into orbit. With this, the total no. of Missions expected to be realised since the inception of the Indian Space Programme up to the end of 10^{th} plan (March 2007) would be 71 (48 satellite missions and 23 launch vehicle missions), out of which the contribution from the Missions expected to be realised during 10^{th} plan itself would be 22 (14 satellite missions and 8 launch vehicle missions).

3. GSLV Mk III has made good progress during 10^{th} plan towards establishment of S-200 facilities, SPROB expansion, liquid hydrogen plant, integration and testing facilities for C-25 and L-110, structural test facilities, manufacturing facilities and launch complex facilities and hardware realisation has begun. The initiatives related to RLV-TD and Air Breathing Propulsion have made significant progress. The payload realisation for the advanced meteorological satellite INSAT-3D is in progress. The work on INSAT-4 follow-on missions viz., INSAT-4D/GSAT-5 and INSAT-4E/GSAT-6 have also begun. Planetary mission Chandrayaan-1, X-ray astronomy mission ASTROSAT, Indo-French joint climatic mission Megha-Tropiques, microwave remote sensing mission RISAT and Oceanography mission OCEANSAT-2 are other important initiatives which have recorded significant progress during 10^{th} plan period. The Indian Regional Navigational Satellite System (IRNSS) and Resourcesat-2 have been approved recently, while the proposal for GSAT-8/INSAT-4G is under process for approval of the Government. The realisation of all these missions would essentially be carried over to the 11^{th} plan period.

4. Besides this, many application missions of national importance including National Drinking Water Mission on identification of potential sources of drinking

water based on satellite imagery, Bio-diversity Characterization of bio-rich areas of the country, Wasteland mapping/inventory for development of wasteland, Tele-medicine, Tele-education, developmental communications, training and Disaster Management support have been undertaken during the 10th plan. Under the satellite navigation GAGAN, the technology demonstration system has made considerable progress in establishing the reference ground stations and mission control centers. The 10th plan also saw the new initiative on setting up of Village Resource Centres to provide, through a single window system, integrated space enabled services to the rural community / backward regions of the country in association with NGOs.

5. Development of indigenous strategic capability in certain critical areas like ring rolling mill, Al. alloy, Titanium sponge, hi-rel electronic components and space materials has been an important achievement of 10th plan period. Bringing M/S Semiconductors Laboratory (SCL) under the folds of DOS has further strengthened our efforts towards indigenous realisation of special devices such as ASICs, FPGAs, high speed memory devices and advanced imaging sensors like CCDs, TDIs, etc., required for the Space programme.

6. The progress in commercial front too, through M/S ANTRIX has been noteworthy. The initiatives taken in the last decade in marketing of space capabilities have started yielding results. Besides substantial increase in the sales revenue, Antrix have also won contracts for two dedicated launches of PSLV. Recently, Antrix has also won two contracts for supply of a sophisticated communication satellite in consortium with a leading European manufacturer M/S EADS ASTRIUM. IRS data reception network has been expanded to more countries and INSAT system transponders are now being leased to many private users in the country on commercial terms.

7. Thus in all, the mosaic of achievements of 10th plan, in terms of programmatic output (missions), technological developments and preparatory efforts for future presents a satisfactory picture, though some of the missions, specifically RISAT, Oceansat-2, Astrosat, Megha-Tropiques and INSAT-3D, earlier planned for realisation in 10th plan, would spill over to the first half of 11th plan period.

8. The highlights of 10th plan achievements are summarized in Table 2.1, while a detailed appraisal of the 10th plan targets and achievements is presented in Appendix-A.

Financial Outlay:

9. The total expenditure of the Department during the 10th plan period would come to Rs. 13,242 crores approx. comprising of Plan component of Rs. 11,502 crores and Non-plan component of Rs. 1740 crores. In the first four years of the Plan period 2002-06, the Department has maintained budget utilisation of more than 99% of the final approved grant. (Budget utilisation has been in the range of 99.67% to 99.88% in the first four years). The indicative plan outlay for the Department for 10th plan is Rs. 13,250 crores. Hence, the final grant approved for the Department through Annual Plans has fallen short of the indicative outlay by Rs. 1748 crores. The observed shortfall of Rs. 1748 crores under Plan is essentially due to Phasing out of expenditure on PSLV/GSLV Continuation and EO followon missions based on programmatic schedules, savings in INSAT-4 costs, savings in Land/Civil works and Infrastructure operations cost and. However, final picture on financial status of 10th plan outlay would emerge during RE 2006-07, the last year of the 10th Five Year Plan.

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TABLE 2.1: HIGH LIGHTS OF TENTH PLAN (2002-07) ACHIEVEMENTS

- Operationalisation of GSLV with 2T capability – three successful flights.
- Successful qualification of Indigenous Cryo engine – Stage qualification in advanced stages.
- Enhanced payload capability of PSLV – from 1200 kgs to 1500 kgs through qualification of extended stapon PSOXL.
- Establishment of state-of-art Second Launch Pad at Sriharikota.
- Significant Progress in GSLV Mk III – establishment of test and fabrication facilities, subsystems development and testing and initiation of hardware realisation.
- Advanced Technology initiatives – SRE, Air breathing Propulsion and RLV-TD.
- INSAT system augmented with FIVE satellites (GSAT-2,3, INSAT-3A, 3E and 4A) – ~ 100 Transponders added to the INSAT system from these satellites. Current INSAT capacity : 175. INSAT 4B (24 Tx) in advanced stages.
- EDUSAT launch – an important achievement of 10^{th} plan for spreading education in the country.
- HAMSAT – India's contribution to international community of Amateur Radio operators – more than 1000 users from 50 countries.
- IRS system augmented with TWO state-of-art satellites viz., Resourcesat-1 and Cartosat-1. Cartosat-2 in advanced stages.
- Kalpana (METSAT-1) Operationalised. Currently, two Met satellites in service viz., Kalpana and INSAT-3A.
- Disaster Management Support – a key area of space applications developed in 10^{th} plan – Decision Support Centre, Virtual Private Network, Mapping Support, Emergency Communication Support and Data base support.
- Initiatives in large scale application of Space Technology – Tele-education, Tele-medicine and Village Resource Centres.
- Host of Natural Resource Management Applications developed and operationalised – National Drinking Water Mission, Waste Land Mapping, PFZ estimation, Land use / Land Cover mapping, Bio-diversity characterization and many more.
- Innovative Space Science initiatives – Chandrayaan, ASTROSAT, Megha-Tropiques, Life science experiments using balloon flights, aerosol measurement campaign and Middle atmospheric studies using Sounding rocket flights.

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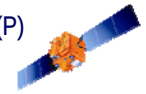
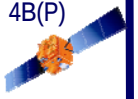
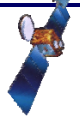
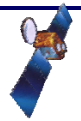
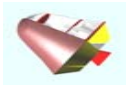
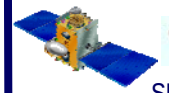
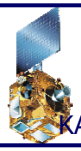
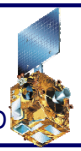
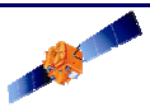
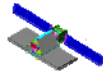
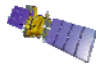
10th PLAN MISSIONS: TARGETS AND ACHIEVEMENTS

MISSIONS	10TH PLAN 2002-07					SPILLOVER TO 11TH PLAN
	2002-03	2003-04	2004-05	2005-06	2006-07	
INSAT	 3A(P)	3E(P) 		4A(P) 	4C  4B(P) 	
TECHNOLOGY/ EXPERIMENTAL		 GSAT-2	 GSAT-3	 HAMSAT	 SRE-1	 GSAT-4 SRE-2
METSAT	 KALPANA-1					 INSAT-3D
IRS		 RESOURCESAT-1		 CARTOSAT-1	 CARTOSAT-2	 OCEANSAT-2  RISAT-1
SPACE SCIENCE / ENVIRONMENT						 ASTROSAT  M..T.
PSLV	 C4	 C5		 C6	 C7	 C8 C 9 C10 C11
GSLV – MKI & II		 D2	 F1		 F2	D3  F3 

(P) - PROCURED LAUNCH

3. OVERALL VISION AND PROGRAMME DIRECTIONS

1. The guiding vision for the Indian Space Programme, from the very inception of the programme had been to be *'second to none'* in the development and applications of space technology to the solution of the real problems of society. India was among the first few countries to realize the importance of space technology to solve the real problems of man and society and took initiatives to develop the space technology for the benefit of the nation. 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. 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.

2. Space holds immense potential to accelerate the development process in the country and offers enormous opportunities to understand the universe. In the context of rapidly transforming India into an economically prosperous, socially secure and culturally rich nation, Space technology is an inevitable tool. The thrust of the space programme in future will have to be on large scale applications of space technology in the priority areas in the context of national development. The future directions for Space Programme have to take into account needs of the country in the context of emerging international environment and the potential that India holds for human development.

3. Space industry is inherently technology intensive and is dependent on long term R & D for its future viability. Space has vast potential for advancement in technology and applications. Revolutionary advances in space technology are expected to bring a quantum jump in application possibilities. Technology advancement, which is essential to maintain competitive relevance, will thus be an important thrust area for space endeavors of future.

4. The broad direction for the space programme for the next Decade and the 11^{th} five year plan will be driven by (a) development goals of the country in key social and economic sectors, (b) imminent need to achieve higher levels of self-reliance in critical areas of technology, (c) our desire to secure a unique place for

the country by embarking on missions of strategic importance and (d) our thirst for expanding knowledge about the universe, solar system and planet earth. It is well known that space technology is a powerful catalyst for social development in the areas of food security, rural development, education and literacy, health-care and environment. The changing world scenario characterized with rapid growth of technological innovation and its application, faster and cheaper communication, easy access to information, convergence of technologies and further opening up of global markets have thrown up a gamut of challenges and opportunities. The shift in the focus of delivery mechanisms from Communities to Individuals, arising from advances in information and communication technologies, is an emerging trend to be taken note of. It is important to take cognizance of the emerging global competitive environment for space services and adopt innovative strategies to enhance the cost-effectiveness of our space systems.

5. The overall thrust of the space programme will be to sustain and strengthen the already established space based services towards socio-economic development of the country. The programme profile will be based on the emerging requirements in the priority areas of national development and security requirements and will take cognizance of the policy framework and global trends.

6. The Programme Directions and the major thrust areas of the Space Programme during the next Decade 2010-20 are :

(a) Enhanced Capabilities for Space Communications.

- Competitive and state-of-art Space segment capacity augmentation in INSAT / GSAT system for national needs in the area of communications, broadcasting and information infrastructure.
- Establishment of Regional Satellite Navigational System and positioning services.
- Major thrust on societal applications including Tele-education, Tele-medicine and Village Resource Centres.
- Undertake major technology enhancement and applications development for space communications including Mobile Communications.
- Transitioning INSAT system towards self-sustenance and enabling private sector role in Indian Satellite Systems.

(b) Leadership in Earth Observations:

Position Earth Observation Infrastructure to meet national imaging demands and support National Natural Resource Management Systems, Disaster Management Support System, developmental activities, improved Weather and Ocean-state Forecast.

(c) Major thrust for Space Transportation:

Long term goal of realisation of a cost-effective state-of-art Two-Stage-To-Orbit (TSTO) Vehicle by 2025 and support the national launch needs till such time through expendable launch vehicles by upgrading the existing launch capabilities.

(d) Space Science Enterprise:

Undertake advanced space science endeavours including Planetary exploration.

(e) Enhanced Industry Participation

Increased role for Indian industries in realising the Space products and services.

(f) Promoting Spinoffs:

Human resources development, Strengthening the Academia interface and forging International partnerships.

7. Space is next frontier of human kind. With an impressive record of array of achievements in the space technology in the country, in terms of providing operational space services in a self- reliant manner, the next logical step to space research is to undertake manned mission, which hold enormous promise of bringing greater economic benefit to the nation. Material processing, building large space systems like space stations, servicing and refueling of satellites in space and the potential of space to augment our energy resources will be of increasing importance in the day's to come. Therefore, taking initiatives to

develop capability of manned mission is an important objective for the years ahead.

8. The forthcoming Decade 2010-20 unfolds with several challenges and opportunities in the space technology in the context of social, economic and strategic growth of the country. The Space programme, thus, will play a more critical role in the national development in the years to come.

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4.1 APPROACH AND PLAN FORMULATION PROCESS

1. The overall direction of the space programme, as it transits to 11th plan, is to consolidate the gains of developments in the 10th plan and to build upon its achievements

2. To generate inputs for long term planning, the Department has undertaken several studies & initiatives. The ISRO Policy and Programme Committee (IPPC), in its 8th meeting held on November 14, 2005 focused on Technology initiatives in the 11th plan period. The Launch Vehicle community has carried out a detailed exercise identifying the technology initiatives for future including Reusable Launch Vehicles. The Science panels constituted by ADCOS are working on the scientific problems and missions for the next 10-15 years covering the areas of Astronomy and Astrophysics, Space Weather, Planetary exploration and Weather and Climatic science. NNRMS standing committees and EOAM councils have deliberated on the emerging user requirements and trends in Earth Observations Systems. An expert committee headed by Dr R R Navalgund, Director, Space Applications Centre, has extensively deliberated and identified the thrust areas in Earth Observation Systems. The future trends in Satellite Communications have been deliberated in several forums. Also, the Centres/ Units of ISRO have carried out several studies on future directions in space science, technology and applications. The inputs generated through these initiatives provided a sound basis for the formulation of Programme Directions for the next Decade 2010-2020 and 11th five year plan .

3. The Centre/Units of ISRO/DOS generated the plans for implementing the programmes, missions/projects to be undertaken, upkeep and refurbishment of facilities and infrastructure, R & D / technology development requirements and human resources development requirements. The Programme groups set up at ISRO Headquarters in the areas of Satellite communications, Earth Observation Systems, Space sciences, Disaster Management support and Space Transportation System have generated programme directions taking into account the national requirements, international / commercial opportunities, technological trends and future growth.

4. A draft 11th plan proposal has been prepared by ISRO Hq programme office / Plan Formulation Group integrating the inputs of Programme sub-groups and Plan working groups of Centres/Units. The overall guidelines and directions

provided by Space Commission, Planning Commission and Finance Ministry from time to time have been adopted in the formulation process.

5. An Inter-ministerial Working Group on Space constituted by S & T Steering Committee has deliberated on the 11th five year plan proposal of the Department of Space during its meeting held on August 23, 2006. A brief summary of the discussions and recommendations of the working group are given in Appendix B.

6. The salient aspects of the Plan proposals in the areas of Satellite Communications and Navigation, Earth Observations systems, Launch Vehicle Development, Disaster Management Support, Space Science and Environment, Atmospheric Science, Master plan for North East, Development of Space materials and components, Industry Interface, International Co-operation, Commercialization and Human Resource / Organizational Development are highlighted in the subsequent sections.

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4.2 SATELLITE COMMUNICATIONS AND NAVIGATION PROGRAMMES

SATELLITE COMMUNICATIONS

1. INSAT system is the largest domestic satcom infrastructure in South East Asia, providing a wide variety of services in various sectors of the economy – TV and telecom, VSAT based business communications, rural / remote area communications, mobile communications, emergency communications and radio networking. Importantly, INSAT meets social needs of the country in the area of health (Tele-medicine), education (Tele-education) and rural development (Village Resource Centres). The spectrum of users of INSAT system includes Government, Private as well as NGOs / VOs.

Trends in Satellite Communications:

2. Globally, today there are more than 6000 Transponders in Space. The growth of Transponder requirement over next five years is predicted to be only moderate – about 8000. Multi-media and high definition TV are emerging as new application areas. The migration to Ka band for broadband services rather appear to be slow. The spacecraft bus is still hovering around 4T class, though there are few heavier class spacecraft in the range of 5 to 6 Tons.

3. In the next five years, two major developments are expected in the terrestrial communication area. The number of mobile phones with 3G and multimedia capability will increase considerably and Wi-Fi and Wi-Max systems with broadband multimedia delivery capability will be increasingly used for fixed communications. Large scale penetration of these two technologies in the Indian scenario will have two major implications on SATCOM services. The first, bandwidth in the 430 MHz, 800 MHz, 1800 MHz, 2.1 GHz, 2.3 GHz, 2.5 GHz and 3.4 GHz bands will be taken over substantially by these services and the second, the cost per Hertz for these terrestrial services will be much lower than the satellite bandwidth charges for similar capability. This will mean that the SATCOM bandwidth lease charges will have to be substantially reduced to remain in the competition. Use of advanced modulation techniques for increasing the throughput (bits / hertz) will become necessary to remain competitive. Use of satellites will be increasingly made for connectivity to remote and inaccessible places where no other medium is economical. The satellite systems are

increasingly being used for disaster recovery of telecom networks. Other emerging fields are digital multi-media broadcast, back hall link for WiFi-Wimax network and mobile communications.

INSAT / GSAT System in 10th plan:

4. There has been remarkable increase in the INSAT system capacity during the 10th plan period. The number of transponders grew from 100 in the beginning of the plan period to about 175 Transponders as of July 2006, which is expected to reach 199 by end of 10th plan with the launch of INSAT-4B during first quarter of 2007. The pattern of utilisation of INSAT system has also undergone a sea change in the past 5 years. INSAT services are increasingly being used to provide broadcast services including DTH, Satellite TV and remote area connectivity.

Thrust areas of 11th plan:

5. The major emphasis during formulation of 11th five year plan has been towards meeting the growing demand for transponders, ensuring continuity of quality services, protection of space systems, efficient spectrum management and continuous improvement in technology. The thrust areas of Satellite communications for 11th five year plan include:

(a) Build INSAT system capacity in C, Ext-C, Ku and BSS/MSS bands for Government, social sectors and private TV and telecom service providers and maintain continuity of services with adequate spare capacity.

(b) Development of high power Ka band satellites and ground systems for point-to-point connectivity.

(c) Development of cost-effective 4T-12KW bus with capacity of more than 50 transponders and flexible enough to accommodate wide range of payloads.

(d) 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.

(e) Communication support for space based disaster management system and address critical strategic requirements

(f) New communication services including multimedia broadcast, broadband services, high definition TV, Satellite based Tele-surgery and innovative communication media for education and training, and mobile communications.

(g) R & D in satellite communication technologies such as multiple spot beam communication payloads, multiple beam frequency reuse, reconfigurable beams, onboard data regeneration, etc.,

(h) Development of low cost indigenous ground systems including hand held communication system for voice and data communications for strategic users, low cost least maintenance Tele-medicine equipments and software, ground systems compatible for MEO SAR payloads.

(i) Progress towards financial self-sustenance of INSAT/GSAT system and corporatise the services with partial dependence on government funding.

(j) System level planning and management including efficient spectrum management and frequency interference management.

Transponder Requirements

6. The INSAT system currently has 175 Transponders. With the proposed launch of INSAT-4B in first quarter 2007, the total number of Transponders in INSAT system is expected to reach 199 as shown in the Table below. These transponders are providing essential services to a wide variety of users – BSNL, DD, AIR, IMD, strategic Govt. users, private VSAT and TV operators, public sector undertakings, Banking and financial institutions, international customers like INTELSAT and societal applications such as, tele-education, tele-medicine and VRC pilot projects.

Table: INSAT/GSAT Transponders

Bands	Existing Transponders (Equi. To 36MHz)	End of 10 FYP
Nor. C	90	102
Ext. C	47	47
Ku	34	46
BSS	2	2
MSS	2	2
TOTAL	**175**	**199**

7. Based on the interactions held with users and service providers in government and non-government sectors and deliberations at INSAT Co-ordination Committee, the additional Transponders projected for the 11th plan period stands at 260, out of which 192 Transponders (~75% of the demand) is from Government agencies and societal applications, as shown below.

Table: Additional Transponder Requirement for 11th plan for Government agencies and societal applications.

Agency	C-band	Ext-C band	Ku-band	S-band
BSNL	34	-	84	-
DD	10 (110 chls)	-	29 (227 chls)	-
AIR	1	1	-	2
NICNET	-	-	6	-
IMD	-	-	-	1
Societal applns	-	-	24	-
Total	**45**	**1**	**143**	**3**

Therefore, by end of 11th plan, it is estimated that India would need about 460 transponders in various frequency bands. (end of 10th plan: 200 + Additional demand for 11th plan : 260). Keeping in mind the growing demand and the need to maintain on-orbit spares, it would be prudent to create transponder capacity of about **500** by end of 11th plan period.

INSAT / GSAT Planning:

8. Besides the additional transponder requirements, out of the existing satellites, five satellites viz., INSAT-2E, GSAT-2, INSAT-3B, INSAT-3C and EDUSAT, which are together providing capacity of about 90 Transponders would reach the end of life during the course of 11th plan period and therefore would require replacement capacity. Hence, the total transponder capacity to be created during 11th plan period would be 350. (as against 150 in 10th plan period).

9. In order to meet the above demand, the satcom missions planned comprise of a mix of small, medium and large satellites compatible with GSLV Mk II, Mk III and procured launches. The small satellites are proposed to be launched by GSLV Mk II, the medium satellites by GSLV Mk III. The advanced communication technology satellites and large satellites carrying high capacity, high power DTH quality Ku-band transponders are planned to be launched by procured launchers. The planning takes into account the continuity of services for Search and Rescue as well as Data collection systems for meteorological services. Digital multimedia and data broadcast satellites with multiple beams in S-band have also been planned. Efforts will be made to realize hand-held terminals capable of receiving broadband services. With the INSAT and GSAT missions planned during 11th plan, the total capacity by end of plan period is expected to reach 500 transponders as shown in Table 4.2.1 in tune with the estimated demand. Table 4.2.2 gives an overview of the Satcom missions planned during 11th plan along with details of orbital slot and provisional payload complement for each mission.

10. The present transponders use of QPSK modulation on an average 1.2bits/hz. Keeping in view the changing trend for use of advanced modulation and coding techniques like 8-PSK,16-QAM, turbo codes, LDPC and higher compression techniques for transmission, new satellites will be designed to support these advanced transmission techniques which will help maximize the satellite throughput. Considering that at least 30% of the capacity will be utilized with higher modulation and higher FEC coding, INSAT/GSAT system would be able to support any unforeseen additional demand within the available capacity through optimisation of the band width usage.

Multi-media Services through INSAT-4E / GSAT-6

11. Government have approved INSAT-4E / GSAT-6 satellite being built to provide satellite based Multimedia service using high power transponders in S-band and regional beams covering India. This will cater to requirement of the multimedia service requirements of both fixed and mobile consumers including societal, educational and strategic needs via fixed, portable and mobile video/audio receivers for vehicles. The satellite has 5 spot beams in the CxS (BSS) band and a return link capability in SxC (MSS) band facilitating provision of interactive services and mobile communications. The satellite is being built around I-2K Bus. The life of the satellite will be 12 years. To protect, sustain and

expand the services for the long term, necessary back up capacity is being planned. Extensive use of the indigenously developed hardware is envisaged for the spacecraft realisation including the 5.5m unfurlable antenna.

Advanced Communication Technology Satellite

12. The Advanced Communication Technology Satellite is planned to be a multi-beam Ku-band satellite that uses 432 MHz bandwidth in Ku-band 4 times and 64 MHz spectrum twice -as national beam in both polarisation. Each beam will have a bandwidth of 108 MHz and will be powered with a 140W TWTA (shared between them) providing an EIRP of 60 dBW or equivalent. The national beams shall have 36/54MHz spectrum in either pols, use 140 W TWTAs with an EIRP of 52 dBW. The total payload power is expected to be about 4500W DC and the total bus power requirement about 5500W. The satellite will be built around the I-4K/I-3K bus and will be launched through a procured launch vehicle. This satellite is primarily meant for high bit rate multimedia connectivity to about 16,000 villages not covered by any other medium. A second satellite with similar configuration in Ku-band will also be planned for in-orbit redundancy and to take care of increased bit rate requirements in remote areas, health-sat, telemedicine and tele-education requirements.

Ka-band – Planning for future frequency bands

13. The ongoing GSAT-4 will be the first satellite in the 11th FYP to provide Ka-band capacity. With 8 beams, the total capacity available from GSAT-4 is 1.2 GHz. It is planned to have one more satellite in Ka-band with multiple spot beam for various services including ultra small aperture terminal (USAT).

Satcom Applications

14. The launch of EDUSAT and its application programme during the 10th five year plan has been an important milestone in the Satcom applications area. Currently, more than 8800 EDUSAT class rooms are operational in the country covering wide range of educational needs. INSAT based Tele-medicine has made its dent in the Health care system of the country. Village Resource Centre has been an innovative delivery mechanism, initiated in 10th plan, to take the benefits of Space technology to the gross roots. Tele-education and training, Tele-medicine and VRC have emerged as important satcom applications of 10th plan

and their expansion, institutionalization and sustenance is an important component of 11th plan.

15. With the planned expansion of these services, it is estimated that in the 11th plan period, these three core applications would require 24 transponders in Ku-band and 12 transponders in Ext-C band. Specific targets for 11th plan in these important applications areas are as given below:

Telemedicine

16. Telemedicine is one of the important applications of Space technology for societal development. The power of satellite communication has been very well adopted for the unique requirement of Healthcare in the form of providing digital connectivity between a Remote Rural District/Medical College/Mobile hospital on one side and the Speciality hospital located in a town or a city on the other side. The Telemedicine programme started by ISRO in the year 2001 has reached a stage of maturity from the initial proof of concept technology demonstration pilot projects to the gradual introduction of Telemedicine operational nodes in different parts of the country. Presently Telemedicine Network consists of 176 Hospitals – 142 Remote/Rural/District Hospitals/Health Centres connected to 34 Speciality Hospitals located in major cities

17. The focus of Tele-medicine programme in the 11th plan period would be:

(a) Establish tele-medicine facilities at the block level.

(b) State level networks will be operated from the respective state capitals

(c) Focus will be given for covering time critical services such as cardiac and trauma care.

(d) Adopt new cost effective diagnostic equipments into the tele-medicine network to cover specialized treatments.

(e) Adopt more Mobile Tele-medicine Facilities for rural diabetic screening, tele-ophthalmology, community medicine etc.

(f) Expansion of CME connectivity to cover all the hospitals.

(g) Satellite Communication infrastructure for providing about 225 concurrent tele-consultation sessions and about 10 CMEs.

(h) Efforts towards establishing self sustainable tele-medicine centers with Private-Public-Partnership (PPP) initiatives.

18. ISRO's role in the Telemedicine Programme is in terms of bringing awareness and introducing the technology of SatCom based tele-connectivity as a part of application of Space Technology for Healthcare and Medical Education in the form of pilot projects, so that an operational system for delivery of Speciality Healthcare to the remote and rural areas evolve progressively for implementation of the same by the Health Ministry and the respective State Governments and NGO agencies all over the country. Towards this objective, a National Task Force has been set up in October 2005 by the Ministry of Health & Family Welfare under the Chairmanship of Union Secretary, Health & Family Welfare, Govt. of India. The terms of reference of the Task Force is to work out the standards for Telemedicine, define national Telemedicine grid, identify players and projects for bringing Telemedicine connectivity from the speciality hospital to the primary health centre level, define medical institution network and finally work out a draft national policy on "Telemedicine and Tele-medical Education" and to prepare for a central scheme for 11th Five Year Plan. INSAT/GSAT system in 11th plan will meet the transponder requirement for country-wide expansion of Telemedicine.

Tele-education

19. At present Edusat implementation is in the semi-operational phase. Currently in the National beam, networks for the IGNOU, CEC/UGC, CIET/NCERT, AICTE, DST and Sidhi (MP) have been set up. In the Regional beam, networks for Kerala, Tamil Nadu, Gujarat, Karnataka, Rajasthan, J&K, Haryana and Karnataka (including VTU) are operational and are being extensively used. Today, there are more than 8800 EDUSAT class rooms operational in the country benefiting more than three lakh students from various parts of the country including remote / rural areas. Networks are being established in Punjab, Jharkhand, Madhya Pradesh, Tripura, Mizoram, Nagaland, Meghalaya and Arunachal Pradesh.

20. In order to effectively utilise the Edusat bandwidth, all services provided by ISRO to a state under TDCC, Gramsat, Tele-medicine and Edusat are integrated and delivered from Integrated hub established under Edusat programme. While selecting technologies for ground systems, efforts are made to

utilise advanced coding and compression technologies so that bandwidth is effectively utilised.

21. Considering the interest shown by the states and users of the network, it is expected that the utilisation of the Edusat is likely to expand during 11th Plan. Majority of the institutions have shown interest in utilising the network for on-line examination, on-line admissions, Intranet activities etc. In order to support multiple simultaneous teaching sessions and to support additional activities like on-line examinations for all participating institutions, it is proposed to plan for a replacement satellite with 12 transponders during 11th five year plan.

Village Resource Centres

22. Village Resource Centres (VRCs), a new initiative of 10th plan period, are intended to provide space based services such as Tele-medicine, Tele-education, agricultural advisories, weather advisories and natural resource data base services in an integrated manner at the door steps of rural mass. From the modest beginning of 3 VRCs and 1 Expert Centre in association with MS Swaminathan Research Foundation (MSSRF), Chennai in October, 2004; today 109 VRCs have been set up in the States of Andhra Pradesh, Gujarat, Karnataka, Kerala, Maharashtra, Orissa, Rajasthan, Tamil Nadu and Uttar Pradesh. Another 213 VRC nodes are currently being set-up in association with various agencies. By end of 10th plan, about 350 VRCs are expected to be operational in the country.

23. The feedback from the working VRCs has been highly encouraging. Even though it is difficult to isolate the impact created by VRCs alone since it is not a stand-alone system, VRC has clearly demonstrated the catalytic effect to other on-going activities. The programmes conducted cover a wide gamut, including agriculture, adult and computer literacy, alternate livelihood related vocational training, marketing of agro-products, micro-finance/ enterprises, livestock management, healthcare and disaster relief measures.

24. The plans and strategies for the 11th FYP include setting up of around 4000 VRCs covering rural/ semi-urban blocks/ taluks of the country and setting up of regional/ State wise HUBs/ servers to cater to these VRCs. These large number of VRCs also call for an exclusive satellite/ satellite transponder resource to enable adequate bandwidth for their smooth functioning.

25. Besides the above, the other satellite communication services planned during the 11th plan period includes mobile communications, multi-media broadcast supporting an exclusive science channel, search and rescue services, real time hydro meteorological data relay services, rural / remote area communications and emergency communications support for disaster management.

SATELLITE NAVIGATION

26. Satellite based Positioning, Navigation and Timing (PNT) service is of vital importance to economies and societies. It is emerging as an important space application area not only for civil aviation but in many other areas such as mobile telephones, surface transport, intelligent highway system, maritime transport, rail, oil and gas, precision agriculture, fisheries, survey and marine engineering, science, electricity networks and leisure.

27. Satellite based Communication, Navigation and Surveillance (CNS)/Air Traffic Management (ATM) system has been adopted by the International Civil Aviation Organisation (ICAO) for worldwide implementation. It will facilitate seamless navigation across geographical boundaries and would eventually replace different types of ground-based navigation systems providing services over different air spaces.

World Scenario in Satellite Navigation

28. There are two core constellations for satellite based navigation in the world today – the US Global Positioning System (GPS) and the Russian Global Navigation Satellite System (GLONASS). The US Defence planned GPS in the early 1970s. The GPS constellation consists of 29 satellites at present in the 20,000 km circular orbit. The GPS is being modernised through the addition of an L5 signal, modifications in the satellite and control segment to offer better accuracies and ruggedness. The global GPS receiver market is estimated to be about US $ 18 billion in 2005 and is likely to grow 20% annually. The Russian core constellation called GLONASS was fully operational with 24 satellites in 1995. Then onwards, the number of satellites in the constellation steadily declined to 14 now. The Russian Government has decided to revamp the GLONASS constellation and make it operational with 21 satellites by 2008-09. A

third core constellation (Galileo) with 30 satellites in 24000 kms orbit has been planned by the European Union Member States at a cost of Euro 3.2 billion (about Rs.17600 crores). Besides civil aviation, the Galileo system is aimed at providing service to various modes of transport, communications network, intelligent highway systems, personal mobility and vehicle tracking. Galileo system proposes to offer a host of services: an open service aimed at mass-market applications leading to low cost receivers.

29. The position accuracies provided by these global constellations are not adequate to meet the requirements of integrity, availability, continuity and enhanced accuracy for civil aviation during the precision approach and landing of aircraft. Augmentation systems to GPS have been planned by US, Europe, Japan and India for seamless global navigation.

Approach to 11th plan

30. The programmatic directions for 11th plan for India in respect of Satellite Navigation include the following

(a) Implement the Indian Satellite Based Augmentation System, GAGAN for civil aviation over the Indian Airspace, develop a Global Navigation Satellite System receiver and promote position, navigation and timing services in a variety of application areas in India.

(b) Implement the Indian Regional Navigation Satellite System (IRNSS) for critical National applications, develop critical technologies on ground and in space, establish an atomic time standard in India.

(c) Development and demonstration of positioning services including associated hardware and software development.

(d) Co-operation and Participation in Global navigational systems.

(e) Apply satellite navigation technology for accurate weather predictions

Augmentation System (GAGAN)

31. The GPS and Geo Augmented Navigation (GAGAN) is a Space Based Augmentation System (SBAS) for the US Global Positioning System (GPS) being implemented by the Indian Space Research Organisation (ISRO) jointly with the

Airports Authority of India (AAI). The augmentation system delivers increased position accuracies required for precision approach and landing of civilian aircraft with integrity, availability and continuity.

32. The GAGAN TDS ground segment commissioning has been completed and the preliminary system acceptance test was conducted in the last fortnight of May 2006. The Final System Acceptance Test (FSAT) is to be completed after the availability of the Geostationary satellite with L1 and L5 downlinks. The TDS and the development of the iono tropo models (Phase-1B) will be completed in the 1st year of the 11th FYP. This will be followed by Final Operations Phase, fully funded by Airports Authority of India.

IRNSS

33. Access to the Global SATNAV constellations such as, GPS, GLONASS and Galileo is not guaranteed in hostile situations. An indigenously built system capable of providing equivalent stand-alone position accuracies is required. Government has approved a regional system called Indian Regional Navigation Satellite System (IRNSS) comprising of 7 satellites – 3 in the Geo-stationary orbit and 4 in a non-GSO orbit inclined at 29 deg. to the equator. The service area is taken as primarily the Indian Land mass and an area about 1500 Km from the Indian land mass. The total cost of the system is estimated to be Rs. 1420 crores (Rs. 1100 crores in FE). Table 4.2.3 summarizes the IRNSS missions planned during 11th plan.

34. Some of the critical technologies will include establishment of Indian Atomic time standard, space qualified atomic clocks, safety and verification software development, Navigation software development, precision orbit development, regional iono tropo model development, timing and synchronization technology.

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35. Indigenous capability in the development of a Global Navigation Satellite System (GNSS) receiver is of vital importance. A GNSS receiver capable of operating with all core constellations and augmentation satellites provides the much needed redundancy and reliability to derivation of PNT services to a variety of applications in civilian and security needs of the country. There is also large

scope for industrial tie-ups related to the space, control and ground segment of the satellite navigation programme.

Participation in International Systems:

36. Participation in international programmes such as, GLONASS and Galileo will further enhance the Indian technological edge in this critical technology area.

SATNAV Markets

37. About 400 million phones are expected to be added to the current population of 100 million phones in the country. If even 1% of these new phones has a capability to offer position, navigation and timing service and if the annual rental + fixed charges for such a facility is estimated to be $ 40 per annum, the SATNAV market is expected to be about $ 160 million or Rs. 750 crores annually by the end of the Five Year Plan.

38. The challenges in technology thrown up by the satellite navigation programme will help in improving ISRO's expertise in making satellites, launching and controlling them and harnessing the infrastructure developed in ushering in modern technology and services for critical National applications.

39. In brief, precision orbits, ionospheric modeling for enhanced position accuracy, designing safety of life hardware and software, controlling sophisticated navigation satellites and synchronizing the signals to accurate atomic time standards are all quantum jumps in technology towards which the space programme must move. It also establishes an infrastructure for modernizing the Indian Airspace and introduction of advanced communication, navigation, surveillance and Air traffic management which is an engine for growth in developing economies such as India.

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11TH FIVE YEAR PLAN
TABLE 4.2.2: SATELLITE COMMUNICATION MISSIONS
(Excluding User funded missions)

Sl. No.	Satellite Name / Mission / Weight	Orbital slot (deg.E)	Approx. Launch date	No. of Transponders	Coverage
1	**INSAT-4CR** Replacement to 4C	**74.0**	**Q2 2007 GSLV Mk-II**	**Ku-Band : 12**	India coverage
2	**GSAT-4 /** I-2K	**82.0**	**Q3 2007 GSLV MkII**	**Ka- Band : 8 x 150 MHz** GAGAN: L1 L5	8 spot beams for India coverage
3	**GSAT-8 / Reliance** (DTH / 3300Kg)	**55.0**	**Q4 2007** Procured Launch	**Ku-Band : 18** **GAGAN2 P/L: 1**	Indian Main Land in D/L & U/L
4	**GSAT-5/ INSAT-4D** (Nor.C, Ext.C In-Orbit Spare,first indgn. cryo-stage / 2250Kg)	**82.0**	**Q1 2008 GSLV-Mk-II**	**Normal C : 12** **Lower Ext.C: 6**	Wider Coverage in U/L and D/L to cover Asia, Africa & Eastern Europe / Zonal Coverage Switchable Polarization
5	**GSAT-9** (Stand –By, Spare/ 2500Kg)	Initially 83.0 Then to be shifted to 48 after GSAT-10 Launch	**Q2 2008 GSLV-Mk-II**	**Ku-Band : 18** **Antarctic P/L: 1** **Gagan 3 P/L: 1**	Indian Main Land in D/L & U/L Switchable Polarization
6	**GSAT-6/INSAT-4E (**S-DMB, dedicated S-band)/ 2132Kg)	**83.0**	**Q3 ,2008 GSLV-Mk-II**	**BSS : 5 spot (CXS)** **MSS SxC : 5 spot**	C-band feed link: India Cover S-band: through five spot beams over India
7	**Advanced Com. Tech. Satellite (ACTS-1)**	**74**	**Q2, 2009 Procured Launch**	**Ku-band: 52**	India coverage with multiple spot beams & frequency reuse and national beams
8	**GSAT-10** (Replacement to 2E & 3B/ I-4K)	**83**	**Q4 2009** 4000KG, **GSLV Mk-III,** 1st flight	**Ku Band : 12** **Normal C : 12** **Upper Cx : 12** **Lower Cx : 06**	Characteristics similar to INSAT-4A

Sl. No.	Satellite Name / Mission / Weight	Orbital slot (deg.E)	Approx. Launch date	No. of Transponders	Coverage
9	**GSAT-11** (Replace. To 3C & Edusat/ I-4K)	**74.0**	**Q2, 2010 GSLV Mk-III**, 2nd flight	**Normal C : 24 Upper Ext.C :12 Ku-Band :12**	Characteristics similar to INSAT-4A for DTH application.
10	**GSAT-12** Replace. To INSAT-3E/ 2500 Kg	**55.0**	**Q3, 2010 GSLV Mk-II** or 3	**Normal C : 24 Ext.C : 12 BSS : 02**	Characteristics similar to INSAT-4A
11	**ACTS-2** Second ACTS with National beam Healthsat requirements	**74.0**	**Q4, 2010** Procured launch	**Ku-band: 52 (Planned band)**	India coverage with multiple spot beams & National beam
12	**GSAT-13** (Replacement to INSAT-3A/ 2500 – 2700 Kg)	**93.5**	**Q2, 2011 GSLV Mk-II/III**	**Ku-Band : 6 Normal C :12 Upper Ext.C : 6**	Characteristics similar to INSAT-4A
13	**GSAT-14**	**55.0 or any other INSAT slot**	**Q2, 2011 GSLV Mk-III F01 flt**	**Ka-band : 8 x 500 MHz Regenerative Payload**	Multiple beam India coverage
14	**GSAT-15** (I-4K)	**TBD**	**Q1, 2012 GSLV Mk-III**, **F 02 flt.**	**Normal C : 12 Ku-Band :36**	Characteristics similar to INSAT-4A for DTH application.

SATELLITE NAVIGATION

TABLE 4.2.3: IRNSS MISSIONS PLANNED DURING 11TH PLAN

Satellite Name/Bus	Orbital slot (deg.)	Approx. Launch date	No. of Trans-ponders	BW available/Transp. (MHz)	Tx EIRP (EOC) dBW and Coverage
IRNSS - 1 1300Kg	34.0	Q3, 2008 PSLV	Navigation P/L L5-Band : 1 S-Band : 1	 24 16.5	 31 32	Regional coverage over India & adjoining areas.
IRNSS - 2 1300Kg	82.0	Q1,2009 PSLV	Navigation P/L L5-Band : 1 S-Band : 1	 24 16.5	 31 32	Regional coverage over India & adjoining areas.
IRNSS - 3 1300Kg	132.0	Q3,2009 PSLV	Navigation P/L L5-Band : 1 S-Band : 1	 24 16.5	 31 32	Regional coverage over India & adjoining areas.
IRNSS - 4 1300Kg	Non-GSO Equat.Long.Crs. : 55.0	Q1,2010 PSLV	Navigation P/L L5-Band : 1 S-Band : 1	 24 16.5	 31 32	Regional coverage over India & adjoining areas.
IRNSS - 5 1300Kg	Non-GSO Equat.Long Crs.:111.0	Q3,2010 PSLV	Navigation P/L L5-Band : 1 S-Band : 1	 24 16.5	 31 32	Regional coverage over India & adjoining areas.
IRNSS - 6 1300Kg	Non-GSO Equat.Long.Crs. : 55.0	Q1,2011 PSLV	Navigation P/L L5-Band : 1 S-Band : 1	 24 16.5	 31 32	Regional coverage over India & adjoining areas.
IRNSS - 7 1300Kg	Non-GSO Equat.Long.Crs.:111.0	Q3,2011 PSLV	Navigation P/L L5-Band : 1 S-Band : 1	 24 16.5	 31 32	Regional coverage over India & adjoining areas.

4.3 EARTH OBSERVATION SYSTEMS

1. Earth Observation (EO) Systems from satellites and aeriel platforms has emerged as an important and powerful tool for natural resources management as well as environmental assessment at global, regional and local levels. It has opened up a new dimension of spatial data gathering due to its unique capabilities like synoptic view, multi-resolution & multi-temporal data coverage. EO systems provide data in support of wide range of information needs on Earth parameters for a broad range of user communities including national, regional, and local decision makers, business, industry and service sectors.

2. The Indian Earth Observations Programme is one of the most vibrant programmes in the world with a unique institutional framework. The Indian Remote Sensing (IRS) satellite system has the world's largest constellation of remote sensing satellites in operation today with seven remote sensing satellites in operation – CARTOSAT-1, Resourcesat-1, IRS-1C, IRS-1D, Oceansat-1, IRS-P3, and Technology Experiment Satellite, (TES). Both the remote sensing payloads and the INSAT meteorological payloads together provide an immense imaging capability to the national and global community

3. Current day EO applications are widespread and cover research, operational and commercial activities. EO satellites help to monitor the global scale activities, the vast expanses of oceans, sparsely populated deserts, mountains, forests and polar regions; the mid and upper troposphere and stratosphere; measure the solar output, Earth's radiation budget, vegetation cover, ocean biomass productivity, atmospheric ozone, stratospheric water vapour and aerosols, green house gas distributions, sea level and ocean interior, ocean surface conditions and winds, and tropical precipitation and many more.

Global Trends in Earth Observations

4. Globally, there have been many developments in the recent times in the Earth Observation scenario in both the public good and commercial domain. Most of the space faring nations and their space agencies like NASA, NOAA, CSA, ESA, CNES, DLR, JAXA, China are addressing on small satellite constellations, formation flights, autonomous missions, intelligent networking,

event driven observations, sensor web, data mining/fusion, on-board processing, quantitative remote sensing etc. NASA has planned multiple constellations of satellites that will fly in orbital formation (Cloudsat, Aqua, Aura, Calipso and Parasol) to gather data needed to evaluate and improve the understanding of the clouds in the global models. One of the well known constellation of satellites is by the Surrey Satellite Technology Ltd., UK, whick consists of five micro satellites weighing less than 100 kg each providing 32 m resolution and covering the globe daily for monitoring and mitigation of natural and manmade disasters as well as dynamic Earth observation. The COSMO-SkyMed is a four spacecraft constellation of ASI, Italy, each satellite equipped with a X-band SAR instrument. NASA and Taiwan are also building a satellite constellation (Rocsat-3/Cosmic) of six micro satellites for atmospheric science research. It can thus be seen the global EO scenario is widely varied with the trend shifting towards smaller satellites with advanced payloads onboard and also there is trend to go in for the constellation of satellites. There have been many global initiatives to share the data sources to have an optimum mix of payloads and to improve the global observational capability towards meeting specific societal goals.

Indian Earth Observation Programme: Long term directions

5. The relevance of Earth observations from space has become more pertinent in the recent years in view of the growing concern on global well being. The EO systems hold immense potential to provide challenging opportunities for the research community to expand the frontiers of knowledge about the earth systems and its processes, which needs to be encouraged and exploited. The Indian EO programme has gained a position of pre-eminence amongst space faring nations and maintaining this leadership by positioning state-of-art operational EO infrastructure is an imperative need, which would ensure continuity of data with improved services. The EO ground segment will receive thrust in the coming years and development of user specific products and technological innovations in product generation will be a priority. New opportunities unfolded by the information age of the 21st century will diversify the applications further. The digital revolution of the recent times has also enhanced the demands on the EO systems for delivering the services in faster, cheaper and better ways. Therefore, development of efficient delivery mechanisms will be an important thrust area in EO applications. The diversity of uses of EO demands working together with the knowledge partners in the

Government, industry and academia. There will be a shift in the overall application strategy with emphasis towards working with the community (from working for the community) through applications such as Village Resource Centres. Thus, the EO services in the years to come will strive to become a part of ***everybody's every day life***.

Formulation of 11th Plan

6. The Indian EO 11th FYP takes cognizance of the achievements made over the years, the priorities and the gap areas identified by the user agencies, and tries to align the advances made in the technologies and to facilitate the infusion of advanced products and services meeting the user demands. The inputs from various NNRMS Standing Committees and the Planning Committee of NNRMS (PC-NNRMS) have been synthesized and appropriately taken note of while preparing the plan. It also has kept in mind the overall outline provided in the EO 2025 Strategic Plan and the EO Decadal Plan. Specifically, for preparing the Indian EO 11th FYP, an Interagency Committee was constituted by Chairman, ISRO/Secretary, DOS under the Chairmanship of Dr. RR Navalgund, Director, Space Applications Centre (SAC), Ahmedabad, and the Committee comprising of many user agencies has recommended specific EO sensors and missions for the 11th FYP after taking note of the international scenario in regard to complementary and supplementary missions. This plan is the outcome of all such efforts and identifies specific EO satellite missions, products and services for realizing the EO 11th FYP.

Accomplishment of 10th Plan

7. The EO programme transitioned from the earlier general purpose application missions to specific theme oriented satellite missions in the 10th FYP to meet the user specific needs The EO missions of 10th FYP include the successfully launched Metsat-1/Kalpana in September 2002; INSAT-3A (carrying VHRR & CCD) in April 2003; Resourcesat-1 in October 2003; Cartosat-1 in May 2005 and Cartosat-2 to be launched during the current financial year

8. The NNRMS activities have been restructured in the recent times to reflect the changing technological and applications dimensions in the country and elsewhere. Accordingly, a 3-tier strategy is being considered with (a) user funded projects meeting the objectives /goals of the user departments/agencies both at

the national and regional/local scale; (ii) organising the spatial databases with GIS capabilities and working towards a Natural Resources Repository with a front-end NNRMS Portal for data and value added services; and (iii) taking cognizance of the convergent technologies, integrating satellite communications and remote sensing applications for disaster management and Village Resource Centres with the concept of reaching the community directly.

9. Even as user projects for different thematic application areas have been taken up over the years, as stated in the above 3-tiered approach, NNRMS has launched many applications towards systematically generating national level databases by conducting (i) periodic Natural Resources Census at 1:250,000 and 1:50,000 scales (ii) Large Scale Mapping applications at 1:10000 scale (iii) Disaster Management System Support integrating remote sensing, GIS and GPS along with Satellite Communication, (iv) enhanced Meteorology & Oceanographic Applications through improved weather and climate models/forecasting using densification of EO observation network both onboard and on the ground, and (v) encouraging EO Science applications.

Driving Considerations and Strategy for formulation of 11th plan

10. Based on the goals set and the achievements made during the 10th FYP, and the feedback received from various users through the NNRMS Standing Committees as well as through the interactions, many newer areas of interests have been identified commensurate with the overall developmental plans envisaged by the concerned Ministries / agencies both in the State and in the Central Governments. Some of the broad conclusions arrived at based on these inputs are listed below towards setting up the priorities for the major projects in the 11th FYP.

(a) Consolidation of natural resources inventory and mapping efforts in diverse areas (land cover, wasteland, forest cover etc.) and by providing appropriate repositories in the regions for affordable access to the user community.

(b) Continuity of major resource management applications for meeting the user defined requirements in the areas such as:

- Food security (FASAL, cropping systems analysis, horticulture, PFZ, irrigated & rain-fed area management, agricultural drought, etc).
- Water security (ground & surface water management, snow & glaciers..)
- Environmental security (coastal, marine and terrestrial)
- Inputs for international protocols and conventions
- Inputs to disaster management support covering all the phases of disasters (National Database for Emergency Management (NDEM), Hazard zonation and risk assessment etc)
- Improved weather forecasting and climate modeling.
- Infrastructure development – physical and social (urban, rural development)
- Ocean related applications (physical, biological)
- Convergent applications (VRC, DMS, Geospatial services etc.)
- Scientific studies on hyperspectral, polarization, process studies on cryosphere, land surface, etc.)

11. It is recognised that there are still many gap areas in the EO observational capability, which need to be programmatically addressed during the coming years. These include:

(a) Need for EO system with high spatial & high-multispectral data with larger swath to provide higher temporal coverage for monitoring multiple crops.

(b) Need for ensuring atmospheric correction, particularly for large swath and multi-angular observations.

(c) Need for improving the payload-mix for ocean related applications in the thermal IR domain. It could be useful for land applications as well.

(d) Need for hyperspectral data for many applications in the land and water resources domain; crop stress detection; mineralogy.

(e) Need for very high spatial resolution data with maximum swath in an agile platform for large scale mapping of better than 1:5000 scale.

(f) Need for improving the repetitivity / revisit capabilities by a constellation of satellites with both optical and microwave sensors for meeting the needs of disaster management.

(g) Need for multi-frequency, multi-polarisation passive and active microwave payloads for many land, ocean and atmospheric applications.

These gap areas have been addressed while defining the missions planned for 11th five year plan.

Targets and Programmes for 11th Plan:

12. The major emphasis of the 11th FYP will be to consolidate the theme-specific satellites, in order to fill the gaps in observation including those of disaster monitoring and mitigation, and also to develop a synergy with international missions for complementing and supplementing Indian missions. Strengthening ground segment to meet the need for having easily accessible user-specific products for the community of users is also important. The major thrust areas of 11th plan are:

a. Ensure continuity & enhanced services through operational work-horse missions

b. Newer missions, adapting & assimilating advances in technologies meeting user needs

c. Understanding the total Earth system and the impacts of natural resources and human-induced changes on the global environment

d. Innovative technology development both for on-board & ground systems for futuristic missions

e. Develop 'actionable' EO products & services and address issues on access, affordability, timely delivery, user-friendly format & style

f. Develop strategy for HR development and capacity building in user agencies and decision making bodies

g. Encourage Government - Industry - Academia Triad to enable core indigenous competence in critical areas

h. Position appropriate policies and institutional mechanisms.

EO Missions:

13. The Indian EO programme has transitioned over the years from the earlier general-purpose application missions to thematic series of satellites in the 10th

FYP. Accordingly, the EO series of satellites both in IRS and INSAT series addresses broadly the thematic applications in 3 streams, viz.,

(i) Resourcesat series of satellites for integrated land and water resources development (including the microwave RISAT mission).

Missons Planned (11th plan & spillover to 12th plan): Resourcesat-2 & 3, RISAT-1 & 3, DMSAR-1, GEO-HR Imager, TES-HyS & HyS-Op

(ii) Cartosat series of satellites for addressing large scale mapping applications;

Missons Planned (11th plan & spillover to 12th plan): Cartosat-3& 4

(iii) Atmosphere/ocean series of satellites, both in INSAT and IRS systems, addressing land, atmosphere, ocean interactions and meteorology applications.

Missons Planned (11th plan & spillover to 12th plan): Oceansat-2 & 3, Altika-Argos, INSAT-3D, Megha-Tropiques, TES-Atm, INSAT-3D followon & RISAT-4L

14. Periodic inventory of natural resources, generation and updation of large scale maps, disaster monitoring and mitigation, improved weather forecasting at better spatial and temporal scales, ocean state forecasting, facilitating infrastructure development, providing information services at the community level for better management of land and water resources continue to be thrust areas of applications.

Table – 4.3.1 shows the EO missions of 11th Plan and 12th plan (initiation in 11th plan).

Land and Water Resources series:

15. **Resourcesat**: The Resourcesat-1, launched on 17th October 2003, is currently providing the operational services. It will be followed by an identical

Resourcesat-2 (already approved) scheduled for launch in 2008 and these two missions would provide service with identical LISS-III, AWiFS and LISS-IV for more than a decade. In future missions, LISS-III, which is currently the workhorse for all resource mapping would be modified to Advanced LISS-III-WS (Wide-swath), having a swath and revisit capability similar to AWiFS, thus overcoming any spatial resolution limitation of AWiFS. Resourcesat 3 satellite with LISS-III-WS sensor will be launched during 2011-12. LISS-III-WS would have additional channels and an Atmospheric Correction Sensor (ACS) on the same satellite for quantitative interpretation and geophysical parameter retrieval.

16. **Microwave**: Imaging RADAR applications will be serviced through RISAT series of satellites. RISAT-1 is already approved and the development work is in progress with a target launch in 2008. In order to develop a large user community and service continuity, it is planned that a follow-on mission RISAT-3 should have features similar to RISAT-1 (C-band, multi-polarization) with multi-resolution capabilities while with appropriate technology mastering the next satellite of SAR series, RISAT-4, would have L-band capability for supporting applications like biomass, soil moisture and crop and forest type discrimination by 2014. In addition, it is desirable to design, develop and launch agile SAR mission (DMSAR C/X) to meet needs of monitoring disaster situations.

17. **Geostationary** orbit provides constant surveillance, and 1 km-imaging capability in VIS-NIR exists on INSAT 3A and additional channels will be available on INSAT-3D. Beyond Resourcesat-2, high repetivity sensor would be continued on geostationary platform as Geo-HR-Imager. This will provide multiple/day acquisition capability and overcome all limitations posed on AWiFS availability. Since geostationary satellites have longer life, with 2010 launch, this will assure 60m coverage over India every half an hour or so for a decade.

18. **Technology Experimental Satellite**: Hyperspectral land sensor has been planned as an EO Technology/Experimental satellite. This will have a swath of 30 km and upto 64 narrow channels. The same satellite could also support a multispectral high-resolution sensor (2.5m XS + 1m PAN) for continuity and enhancement of analysis carried out by LISS-IV. In addition, aerial sensors in microwave region are proposed for disaster application, namely an Airborne SAR in C band (ASAR-C) in 2006 and ASAR in X/Ku band by 2010.

Cartographic series:

19. **Cartosat:** Cartosat 1 & Cartosat 2 aim at terrain and large-scale mapping applications. It is planned that this series be continued with launch of a very high resolution Cartosat-3 (0.30 m) that will be suitable for cadastre and infrastructure mapping and analysis. Cartosat-2 and Cartosat-3 would also enhance monitoring disasters and damage assessment.

Ocean and Atmosphere series:

20 **Oceansat**: As continuity of Oceansat-1, Oceansat-2 carrying Ocean Colour Monitor (OCM) with 2 modified channels and a Ku band Scatterometer is planned for launch in 2nd quarter of 2007. Oceansat-3, which is planned for launch in 2012, will include thermal IR (TIR) sensor to go along with OCM and Scatterometer. TIR and OCM combination will support joint analysis for operational Potential Fishing Zone (PFZ) advisories. **Altika-Argos** planned for launch in 2009 will have altimeter and Data Collection Platform (DCP).

21. Technology development towards flying L-band radiometer and polarimetric radiometer are also planned to be taken up during 11th Plan period.

22. **INSAT-3D** scheduled for launch in 2007 would carry 6-channel imager and 19 channel sounder and provide profiles of atmospheric water vapour and temperature, in addition to cloud vapour winds, Sea Surface Temperature (SST) etc. The multispectral imager would also have land applications and useful in characterizing land surface for mesoscale modeling.

23. **Megha-Tropiques**, a collaborative endeavor with French Space Agency (CNES) with three sensors for rainfall, atmospheric and cloud water vapour and radiation balance is planned for launch in 2009. With low-inclination orbit, it will provide data in multiple passes per day, needed for assimilation in climate models.

24. **Technology Experimental Satellite**: During 11th FYP, technology development activity would be initiated for Hyperspectral Sounder, Rain Radar and Millimeter Wave Sounder for atmospheric profiles and constituents with the launch of an experimental satellite.

EO Advanced Technology Development

25. Development of cricital technologies to realize state-of-art spacecraft is of utmost importance. The main challenges for technology development towards enabling these missions shall be large optics, focal plane arrays, high-speed mixed signal and digital electronics, miniaturization, mm-wave components and systems, L-band active antenna and radar onboard signal processing. Some of the critical technology areas in the field of electro optical sensors and microwave sensors would be Multi-segment mirrors, Active pixel detectors, Application Specific Integrated Circuits (ASIC), Adaptive optical elements, High speed data acquisition and processing, Onboard corrections and processing, Data compression techniques, Mechanisms for positioning opto-electronic components, Sub-meter (0.5 meter and 0.25 meter) resolution Sytheric Aperture Radar (SAR) Images, Higher radiometric resolutions, Transmit-Receive (TR) Modules in L & X-bands, High Power TWTA in C, X & Ku Band, Milli-Meter (MM) wave Reflector Antenna, Digital signal processor (60-100 FLOPS), Mixed signal technology, Onboard payload data processing technology, Ultra-High Resolution (Sub-meter) SAR Processing algorithms.

Strengthening Ground Segment

26. In order to realize the above missions and derive maximum benefit from their use, a number of areas, especially related to ground segment need to be addressed simultaneously. The emphasis would be given for (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. The realization of strengthening of ground segment would be:

(a) In case of each new proposed mission, a system study needs to be undertaken to define optimal parameters based on user needs.

(b) While standard products only are normally defined, it is necessary to clearly define and set a path to realize operational geophysical products, as applicable for each mission.

(c) The products need to be generated in near-real time basis and distributed to users in an easily accessible format. i.e., web based service format.

(d) Given the large number of missions and data product generation requirement, it is essential to think in terms of multi-mission acquisition and processing facility, a departure from past practice.

(e) A simultaneous targeted effort for capacity building and outreach should be organized for each mission to educate and prepare various segment of users.

(f) As a service to users, necessary freeware tools of data access and processing should be made available.

(g) The emphasis should be on products and services from RS missions, thus for most efficient utilization of global EO capability, each mission should address the synergy with international missions.

Aerial Survey and Utilisation Plan:

27. Aerial Surveys will continue to be yet another source for specific type of images and data. In the 11th Plan, Digital Elevation Model from Aircraft Laser Terrain Modeling (ALTM) instruments, aerial sensors in microwave region for disaster application, namely an Airborne Synthetic Aperture Radar (ASAR-C) in C band and ASAR in X/Ku band has been planned.

NNRMS & SNRMS:

28. The Indian Earth Observation (EO) Programme continues to serve as the mainstay of NNRMS, with planned missions both in IRS and INSAT series of satellites. Furthering the goals of NNRMS and supporting information needs of the nation by establishing a reliable observation/ imaging infrastructure is the key driver for the Indian EO programme. A suite of instruments have been planned onboard these satellites to provide necessary data for NNRMS and also to cater to the global needs.

29. The thrust applications areas identified during 11th FYP can be summarized under following categories.

(a) Natural Resources Inventory & Databases (NRC, CRD, NRDB)

(b) Food security (FASAL, Cropping System, PFZ, Fish stock)

(c) Water security (snow and glaciers, ground water exploration and recharge, surface water inventory, water quality, water harvesting)

(d) Natural and human-induced disasters (early warning, pre-cursors, hazard zonation, vulnerability assessment, preparedness monitoring and damage assessment) – Support DSC for DMS, NDEM

(e) Infrastructure Development, Urban & rural planning, LSM, NUIS, ...

(f) Weather forecasting (now casting, medium range & long range forecast with RS assimilation), mesoscale modeling

(g) Ocean State Forecasting (Open oceans and coastal)

(h) Protection of ecosystem & biodiversity (coastal, marine, terrestrial, forest, wildlife)

(i) Services to society through synergy of EO, communication and navigation (e.g., VRC)

(j) Climate Variability and Change (GBP, biogeochemical cycle aerosol transport, energy and water balance)

(k) Earth Science (lithology, geomorphology, mineral (oil exploration tectonics, terrain & subsidence...)

(l) Planetary geology (Chandrayaan mission)

Major Application Projects:

30. In the 11th FYP, many of the ongoing major applications such as the Natural Resources Census; Agriculture crop forecasting (CAPE / FASAL); forest cover/type mapping; coastal studies; snow & glacier studies; groundwater prospect zone mapping; wasteland mapping; Disaster Management Support; Natural Resources Repository related activities; Village Resource Centres; weather and climate related studies etc. will be continued with additional inputs coming from the newer missions and sensors. Further, it is also envisaged take up new initiatives in the application areas based on the demand from user agencies and national requirements.

31. The EO applications encompass research, operation and the commercial domains. In the context of the future developments and expectations, apart from the pure mapping applications hitherto carried out, there could be more quantitative remote sensing and meteorological applications in the coming years. These could include improved observations of land, atmosphere and ocean, and their coupled interactions. Some of the typical challenges for the EO and NNRMS community in the coming years could be as hereunder:

Land and Water Resources Management

32. With increasing population and the extra pressure built through events like global warming, there have been growing concerns on the sustainable developmental practices. Agriculture forms the prime area of concern with decreasing productivity. Many applications covering a broad range of information in all scales on parameters such as land cover / land use and vegetation state; crop acreage and yield; land degradation; desertification, soil characterisation such as fertility and moisture levels; water resources management including surface and ground water; irrigated area management to avoid soil salinity and alkalinity; rain fed agricultural management through watershed development have been carried out under NNRMS over the years.

33. The coming years will see the emergence of requirements such as *the* cropping system analysis; precision farming; coping with the pests and locusts; cropping system insurance etc. The planned EO missions with hyper spectral capability, higher resolution and microwave sensors could provide the wherewithal for enhancing the scope and capabilities in the land and water resources management.

Infrastructure Development

34. Infrastructure development, both social and physical, is the essential requirement for a developing country like India. During the 10th FYP, NNRMS took up many projects addressing the infrastructural needs at different levels. Road / rail alignments, planning of national highways, urban infrastructure planning including the utility services etc., were some of the projects earned out for physical infrastructure development, whereas the project like Rajiv Gandhi National Drinking

Water Mission was a typical example of the efforts made in the social infrastructure area. With the availability of high-resolution satellite data as well as aerial photography and ALTM, there have been increasing demands for inputs for infrastructure development and other related engineering applications. The coming years will see more and more demand for data for applications such as setting up of hydro thermal power stations, interlinking of rivers, rural road connectivity and various other engineering applications. The EO missions of the future should address these requirements along with advanced image processing / image analysis / data fusion techniques.

Environmental Applications

35. While there have been many applications carried out addressing the bio-resources and environment in the past, including many environment impact analyses, there have been increasing demands for monitoring atmospheric aerosol transport, their sources and composition analysis for use in climate modeling; atmospheric trace gases measurement; carbon-di-oxide flux measurements from vegetative surfaces and many other related areas. While these call for densification of in-situ measurements like development and augmentation of Agromet towers and flux tower networks, the feasibility of developing specific sensors and a small satellite platform has been under consideration by the science community for quite long. It is expected that some of these requirements could be integrated as part of the planned EO missions in the coming years.

Ocean Applications

36. There have been increasing demands from the ocean community for enhanced applications in biological, physical and geological oceanographic areas. The potential fishery zone mapping applications operationally carried out under NNRMS demand species specific forecasting as well as for long term forecast along with the marine weather information. The physical oceanographers look for enhanced data for use in the areas such as understanding cyclogenesis and ocean state forecasting. The geological oceanographers look for improved information on magnetic and gravity parameters. Various other applications for studying aspects related to coastal vulnerability zoning, bathymetry etc.

Weather and Climate

37. Though globally a system of operational meteorological satellites provides valuable information for Numerical Weather Prediction models, there are still science questions related to understanding the tropical weather. EO, in addition to providing high-resolution cloud images, their motion, information on temperature and humidity profiles, sea-surface temperature, precipitation and liquid water, sea-surface winds, land surface processes, snow-cover etc. The gaps are in the monitoring of soil moisture, reliable land surface temperature, surface pressure, wind profiles, ocean salinity etc. The coming years will see newer developments such as L-band synthetic aperture radiometer for soil moisture and ocean salinity, Global Precipitation Mission (GPM) which includes Megha Tropiques, NPOESS etc.

EO systems for Disaster Management Support

38. In the area of disaster management, the future challenges are in providing more accurate early warning services. Improved spatial and temporal resolution of the future EO sensors should provide more accurate detection and tracking of storms and providing improved landfall predictions. For the extreme events prediction, there is a need for understanding the complex weather related parameters, and there is a need to have a unified approach to densify the EO observation and in-situ measurements as well as necessary improvements in the forecast models themselves. Early warning of agricultural drought is another expectation, which calls for integrating various parameters from meteorological, hydrological and specific cropping systems. Operational forest fire warning. Vulnerability assessment for tsunami/storm surge etc. Early warning and predictions of earthquake is yet another area of research, which is expected to get more focused in the coming years with the availability of advanced EO sensors such as SAR interferometry, ionospheric current measurements, electromagnetic radiations, thermal anomalies, dense GPS networks, etc.

39. With the above broad outline of the expectations and challenges in applications, as well as the specific suggestions/recommendations made by the NNRMS Standing Committees in the recent times, the EOS/NNRMS has worked out following possible applications projects for the 11th FYP given in **Table 4.3.2**

HRD & Plan For Empowerment:

40. In the 11th Plan, major emphasis will be placed on HRD and training

programmes - covering school-level, university and professionals. Leveraging entry of EO and Geographical Information System (GIS) at school-level will make it a well- known subject and will make students "image and info savvy". Close tie-ups with national and state school systems will be required for this. Similarly, it is essential that EO and GIS form a part of University education also and towards this, UGC/AICTE will be involved. Focus on professional-level training will continue with emphasis on long-term Training Strategies with other user agencies.

(a) Support (financial and technical) in conduct of specific training programme in different application themes.

(b) Long-term collaborative training programme to generate trained manpower in any specific application areas by entering MOU with concerned organisations.

(c) Support (financial and technical) to Universities/ academic institutes to enable them to set up centralized remote sensing & GIS infrastructure for conducting educational programmes.

(d) Development low-cost application tools (customisation & stand alone).

Policies:

41. Positioning the right policies and guidelines for the EO and NNRMS programme will be key for the EO-2025 Strategy and this will be continued in the 11th Plan. Some of the national policy initiatives have already been placed – specially the Remote Sensing Data Policy (RSDP) - which defines the procedures and methods for licensing EO satellites, acquisition/distribution of EO data in India and also licensing Indian EO capabilities worldwide; Map Policy – defining the procedures and methods for the access of Survey of India (SOI) toposheets and sharing digital SOI data with users; Natural Resource Data Base (NRDB) establishment and operations in the country, Aerial survey policy etc. Remote Sensing Data Policy (RSDP) has safeguards for ensuring that images of sensitive areas are screened out so as to protect our national security interests.

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TABLE 4.3.1: EARTH OBSERVATION SYSTEMS MISSIONS

11TH FIVE YEAR PLAN 2007-12 & PLANNED SPILL OVER TO 12TH PLAN

No	Target Launch	EO Mission	Broad Specs	Remarks
Land and Water Resources series				
1.	**2008-09**	**RESOURCESAT-2** (Approved and Ongoing)	AWiFS – <55m resolution, 4 bands, >700 km swath; LISS-3 – 23 m resolution, 4 bands, >140 km swath; LISS-4 – 5.8m resolution, 3 bands, 23 km swath (electronically steerable within 70 km or 70 km PAN (red)	Mainly for crop applications, vegetation dynamics and natural resources census applications. Useful for 1:50k thematic mapping with improved accuracy.
2.	**2011-12**	**RESOURCESAT-3** ~ 500kg (Copassanger with Cartosat-3 onboard PSLV)	Wide Scan LISS-III – 23.5m (3 bands in VNIR) and 10m (SWIR); ~700 km swath; ATCOR instrument	As work-horse mission for crops and vegetation dynamics, natural resources census, DMS and large scale mapping of themes.
3.	**2008-09**	**RISAT-1** (Approved and Ongoing) (PSLV dedicated launch)	SAR – 3-50 m resolution, C-band, multi-polarisation and multi-mode operation	Mainly for crops, terrain and flood inundation and damage assessment applications – specially during cloud season.
4.	**2011-12**	**DM SAR 1** ~ 500 kgs	C/X-SAR, +/- 45^0 Tilt, 65-125 km swath	For disaster management purpose, mainly to overcome the problems of cloud during observation. Most useful for the flood and cyclone.
5.	**2012-13** 12TH FYP	**RISAT-3**	SAR – 3-50 m resolution, C-band, multi-polarisation and multi-mode operation	Mainly for crops, terrain and flood inundation and damage assessment applications – specially during cloud season.

No	Target Launch	EO Mission	Broad Specs	Remarks
6.	**2009-2010**	**GEO-HR IMAGER** ~1200 kg (launch by PSLV XL)	AWIFS - 60m resolution (V, NIR, SWIR), >700 km swath, constant view-angle and provision for multi-angle observations, assure 60m coverage over India every half an hour	High repetivity sensor on geo-stationary platform as HR-CCD. This will provide multiple/day acquisition capability and overcome all limitations posed on AWiFS availability. Crop inventory, vegetation dynamics, drought assessment; Resource Inventory at regional level; Global datasets and products.
7.	**2010-11**	**TES-HYS** (PSLV dedicated launch)	15m resolution, 200 Channel of 5 nanometer width, 30 km swath; 2.5m Stereo; 5m MX; 1m capability	Continuity of LISS IV and Cartosat-1 stereo, useful for applications in forestry, agriculture, coastal zone & inland waters, soil, Mineral/ rock mapping.
8.	**2014-2015** 12TH FYP	**HyS-Op** (PSLV dedicated launch)	VNIR – SWIR, continuous from 420-2450 nm in selected absorption bands, 10 nm spectral, 30 m spatial with swath >30 km	Hyperspectral satellite for agriculture monitoring and mineral studies.
Cartographic series				
9.	**2011-12**	**CARTOSAT-3** ~ 600 kgs (Co-passenger with Resourcesat-3)	PAN 0.3 m resolution, 6 km swath	Suitable for cadastral and infrastructure mapping and analysis
10.	**2014-15** 12TH FYP	**CARTOSAT-4** ~ 600 kgs	PAN 0.3 m resolution, with stereo capability; 1m MX; TIR	Suitable very large scale mapping for cadastral and infrastructure mapping and analysis.
Ocean and Atmosphere series				
11.	**2007-08**	**OCEANSAT-2** (Approved and Ongoing) (PSLV dedicated launch)	OCM – ~360 m resolution, 8 bands, 1400 km swath ScanSCAT – Ku-band, ~1400 km swath	Mainly for ocean biology and sea state applications. Establishment of global databases and contribution to IGOS.

No	Target Launch	EO Mission	Broad Specs	Remarks
12.	**2009-10**	**ALTIKA-ARGOS** ~ 400 kgs	Ka-band Altimeter, DCP	It will have Altimeter and DCP for ocean studies.
13.	**2008-09**	**MEGHA-TROPIQUES** (Approved and Ongoing) (PSLV dedicated launch)	MADRAS – 6 channel radiometer SCARAB – 4 channels Saphire	Global capability for climate and weather applications in tropical region. Contribution to IGOS.
14.	**2007-08**	**INSAT-3D** (Approved and Ongoing) (GSLV launch)	VHRR – 6 bands; 1 km (visible and SWIR), 4 km (MIR, Split-TIR), 8 km (WV); SOUNDER – 18 channels	Cloud motion vector, improved SST, vertical profile of temperature and humidity etc.
15.	**2012-13** 12TH FYP	**OCEANSAT-3** (PSLV dedicated launch)	12 Channel OCM, Scatterometer and Altimeter, Thermal IR Sensor and Passive Microwave Radiometer (PMR)	TIR and OCM combination will support joint analysis for operational PFZ. Mainly for ocean biology and sea state applications including SWH, Geoid etc., establishment of global databases. Also useful for meteorological applications.
16.	**2013-14** 12TH FYP	**TES-Atm**	Hyperspectral Sounder, Rain Radar and millimeter wave sounder	This will be an experimental satellite for technology development for atmospheric profiles and constituents.
17.	**2015-16** 12TH FYP	**INSAT-3D** (follow-on)	VHRR – 6 bands; <0.5km (visible and SWIR), 2km (MIR, Split-TIR), 4 km (WV) SOUNDER – 18 channels	This will be continuity of INSAT 3D mission with enhanced features.
18.	**2014-15** 12TH FYP	**RISAT-4L** L-Synthetic Aperture Radiometer	L band Aperture Synthetic radiometer	Studies related to soil moisture and ocean salinity

EARTH OBSERVATION SYSTEMS

TABLE 4.3.2: Thrust application projects identified for 11th FYP

No.	Projects
	Food Security
1.	National level Crop Acreage and Production Estimation (CAPE) (MoA)
2.	Watershed Development Monitoring (MoA)
3.	Command Area Monitoring/Irrigation Infrastructure Mapping (MoWR)
4.	Land Degradation Mapping (MoA)
5.	Wasteland Development (MRD)
6.	PFZ Mapping (DoD)
7.	Monitoring of Accelerated Irrigation Benefit Programme - AIBP (MoWR)
8.	Agricultural Resource Information System (MoA)
9.	Agriculture Development Planning towards Food Security (MoA)
10.	National Soil Moisture Mapping (MoA)
	Creating Natural Resources Assets
11.	Natural Resources Repository (NRC, LSM, CRD, Database for VRCs)
12.	Biennial Forest Mapping (FSI)
13.	Snow & Glacier Mapping; Wetland Inventory (MoEnF)
14.	Waterlogging/Salinity Mapping & Reservoir Sedimentation (MoWR)
15.	Drinking Water Mission (MoRD)
16.	Creation of Spectral Library for Rocks & Minerals (GSI)
17.	Monitoring of MRD's Programmes: IWDP,DADP, DDP (MoWR)
18.	National Water Resources Information System (MoWR)
19.	Inter-linking of Rivers (MoWR)
20.	Ocean Salinity Sensing (DoD)
21.	Coastal/coral/mangrove studies
	Weather Forecasting
22.	Ocean State Forecasting (DoD)
23.	AWS, DWR, PRWONAM, RCM... (IMD)
24.	Storm – surge
25.	Monitoring of Extreme Events
26.	Intensity & Track Prediction
	Disaster Management Support
27.	Monitoring & Impact Assessment (DoS)
28.	Flood, Drought, Cyclone, Landslide, Tsunami (MHA/CWC/Relief Com.)
29.	Hazard Zonation & Emergency Communication (GSI/MHA)
30.	Coastal Zone Mapping/ Vulnerability Zoning (MoEnF)
31.	Urban Disaster Mapping & Monitoring
	Infrastructure Building
32.	National Urban Information System (MoUD)
33.	Topographic maps (1:25,000 & 1: 10,000) (SOI)
34.	National GIS for G2G (PMO & PC)
35.	Modeling of sustainable urban development
36.	Rural Road Connectivity (MoRD)

4.4 DISASTER MANAGEMENT SUPPORT (DMS)

Background:

1. India, characterized by the unique geodynamics, typical monsoon behavior, flood prone river basins coexisting with semi-arid & arid regions and long coastlines, is amongst the nations most vulnerable to natural disasters. While the country has administrative response mechanisms in terms of a three-tier hierarchical organizational set-up connecting centre, state and district level functionaries, there are also networks of knowledge institutions mandated to provide the operational scientific and technological solutions towards disaster management.

2. Towards strengthening the national response mechanisms further, Department of Space (DOS) in the 10th Five Year Plan launched a Disaster Management Support (DMS) programme. Using synergistically space (mainly INSAT and IRS satellites) and airborne systems in conjunction with the conventional technologies, the programme has been providing space-enabled products and services on a reliable and timely basis to strengthen the resolves of disaster management in the country.

3. DMS programme of DOS is developed as a mission oriented and project based endeavor providing the critical technological and institutional support towards disaster management in the country. As an integral component of national systems, DMS would enhance considerably the national capacity for disaster reduction by integrating fully space enabled products and services. During the 10^{th} plan period, DOS has created a single window delivery system – Decision Support Centre (DSC) to disseminate all space enabled products and services to the end users. The Disaster Management Support (DMS) programme office at ISRO hq develops the institutional interface with policy makers, international organizations and user agencies besides providing the overall programme directions.

Global Scenario:

4. Space agencies worldwide have attached considerable focus on disaster management activities. China is developing small satellite constellation in support of disaster management. At global scale, the collective initiatives of all

space agencies on Global Earth Observing System of Systems (GEOSS) is already on towards putting in place a global system for improved coordination of observations (space & in-situ), essentially aimed at reducing loss of life and property from natural and human-induced disasters. Constellations of smaller, faster and cheaper satellite missions are emerging as promising tools to capture the natural disasters in real time and also to monitor them regularly. Further, international cooperation has been recognized as one of the important strategies.

New Paradigms for 11th FYP:

5. Early warning systems is a key area of development in Disaster Management. The forecasting challenge in providing early warnings spans a continuum from less than one hour for tornadoes and flash floods to seasonal and inter-annual time scales for drought. To enable the warnings for these hazards, there are three pillars for building Early Warning System (EWS) – modeling (statistical, simulation and process based), Earth Observation (EO Satellite based products - imaging and non-imaging) and networks (automated and manual). In the 11th FYP of DMS, it is envisaged to work on strengthening all the three pillars for improving substantially the quality and outreach of early warning systems in the country. Improvements in EO technologies as well as products followed by densification of the observational networks like Automatic Weather Station (AWS); deployment of Doppler Radar etc would go a long way to realize these new paradigms of DMS programme.

Institutional linkages.

6. DMS programme has already developed an active interface with user agencies, especially with Prime Minister's Office (PMO), Crisis Management Group (CMG), Ministry of Home Affairs (MHA) for all disasters except drought for which Ministry of Agriculture is the nodal agency. In fact, requirements of nodal agencies drive the overall programmatic activities of DMS. For example, the GIS database creation activities and hazard zonation mapping under the DMS programme are being harmonized taking into account the operational requirements of the National Data base for Emergency management (NDEM) activities of MHA. Similarly, establishing the secure satellite based Virtual Private Network (VPN) is being configured as per MHA requirements and providing technological and institutional support to Department of Ocean Development (DOD) for development of Indian Ocean Tsunami Warning System (IOTWS).

Further, the DMS activities are also to be harmonized with some of the related activities of the other agencies like IMD, CWC, DOD, etc.

11th Five Year Plan – Thrust Area:

7. The major thrust areas / priority areas for Disaster Management Support during 11th Five Year Plan include:

(a) Realisation of National Database for Emergency Management (NDEM) in the country through creation of Digital, Thematic and Cartographic Database for Hazard Zonation and Risk Assessment.

(b) Impact Mapping and Monitoring Support for Disaster management – with improved turn around time and better quality of EO products and services.

(c) Communication Support to Disaster Management – Networking of Central, State and Some of the selected District Emergency Control Rooms; strategies for quick deployment of emergency communication equipments in the multi-hazard prone areas.

(d) Strengthening Early Warning Systems (EWS) – enabling the operationalization through key development supports and R&D for Indian Ocean Tsunami Warning System (IOTWS), EWS for Cyclone, floods, drought, landslides and forest fires.

(e) Augmenting Satellite and Hydro-meteorological Networks by large-scale operationalization of Automatic Weather Stations (AWS), Doppler Weather Radar etc.

(f) Development of Tools and Techniques for Decision Support – taking into account the operational requirements of National, State and District Emergency Operations Centres

(g) Realization of Aircraft Version of Disaster Management SAR (DM-ASAR)

(h) Pursuing the key areas for R&D – precursor study of Earthquake, extreme rainfall events, flood forecasting models, drought study, vulnerability indexing for desertification/land degradation and forest fire study.

(i) Developing a dedicated constellation of EO satellites for disaster management and tasking of Village Resources Cenre (VRC) by virtue of having the community access to all kinds of emergency resources, warning messages etc so that the efforts could lead to work like community based disaster management in the multi-hazard prone areas in the long run.

The programme directions and specific targets for 11th plan in these thrust areas is detailed below:

National Database for Emergency Management (NDEM):

8. Accurate maps, thematic as well administrative, are prerequisite in disaster management at District, State and Central levels. NDEM is intended to enable expert decision making for rescue, relief and rehabilitation and responding to disaster situations more efficiently. The database consisting of various thematic layers such as land use/ cover, topography, geomorphology, infrastructure details, etc., is to be created for risk assessment and networked for data exchange amongst the implementing agencies. NDEM is envisioned to include:

- National GIS data on 1: 50,000 scale covering the themes – road, rail, drainage/surface water bodies, DEM, settlements, demography, livestock, administrative boundaries, land use/land cover, litho logy, geomorphology and soils. All these will from the core data.
- For 169 multi-hazard prone districts, additional and specialized data sets, apart from the above, need to work out in consultation with multi-disciplinary domain experts.
- For important settlements having population more than one lakh, spatial data required on 1:10,000 scale, while for mega cities (5), the requirements is for 1:2000 scale to cover urban utilities like road networks, sewerage water distribution lines, telephones, power lines, hospitals, educational institutions, cultural centers, industry locations, residential, commercial, entertainment places etc.

9. Development of geospatial database for emergency management with a mirror database at MHA and design and realize appropriate communication network for data exchange and query for decision support system, is envisaged during the 11th plan period.

Impact Mapping and Monitoring Support

10. It is envisaged providing more efficient and user's friendly 'actionable' space data, including aerial photographs, essential for disaster management, in an operational manner. An aircraft system with necessary instrumentation such as Digital Camera and Synthetic Aperture Radar will be used strategically to fill the data gaps and for mapping at detailed scales. A Disaster Watch Group with experts is already in place to continuously monitor the disaster events (floods, cyclone, drought, etc.) and assess the risk profiles for taking necessary pro-active measures.

11. Near real-time damage assessment (both spatial extent and quantification) will be carried out using the complement of satellite and aerial data in conjunction with the NDEM repository. Focus will be placed on assessment of damage to standing crops, infrastructure and buildings using high-resolution satellite and aerial data, employing suitable techniques and models.

Communication Support for Disaster Management

12. Development and deployment of fail-safe emergency communication equipment is an important component of the DMS System. The equipment proposed to be developed / utilized are:

(a) Integrated WLL-VSAT system: Vehicle mounted VSAT will be suitably integrated with small WLL hub to provide local communications, and through the VSAT gateway to the external communication lines.

(b) Hybrid DSDB reporting technology: Already developed technologies of Digital Data Broadcast and one-way reporting system will be integrated to disseminate warnings.

(c) Improved DCP: By integrating GPS with GCPs, it is proposed to use time syncronised transmission of data to satellite, and increase the satellite capacity, so as to meet the large number of DCP deployments planned over land and ocean.

(d) Communication link to airborne survey system: Suitable system will be developed to transmit high volume data from aircraft for real-time processing.

(e) Cyclone Warning Dissemination System: In coordination with IMD, it is planned to deploy the newly developed digital system with acknowledgemet facility.

Early warning systems (EWS)

13. EWS are considered to be the most important element in the overall disaster management system. Space inputs are critical for the dynamic and real time observation of the disaster related phenomena, their modeling and networking for information dissemination.

14. Tropical cyclones occur in the pre and post monsoon seasons with a frequency of 2-3 annually. Current accuracy of predictions is about ±140 kms for 24 hrs prediction and ±250 kms for 48 hours prediction. This translates into warning of very large areas. There is an imperative need to improve the accuracy significantly. Globally, using multi-ensemble models and mesoscale models, accuracy has been achieved in the range of ± 60-80 kms for 24 hrs predict. The current predictions are based on interpretation of INSAT/ METSAT imagery (for assessing intensity and position of cyclone), and limited run of Quasi-Langrangian Model for dynamic prediction of track. This needs to be improved by using state-of-the-art multi-layer mesoscale models with real-time inputs of data from satellites and ground radar systems. DOS will enable operationally the: (i) use of Scatterometer winds to study cyclone intensity and movement, and (ii) track prediction using techniques such as chaos technique, upper troposphere temperature patterns, lower lever wind shear, etc.

15. Towards the Indian Ocean Tsunami Warning System (IOTWS), being set up by DOD at the lead, ISRO/ DOS has taken up the responsibilities for: (i) networking of seismic stations, tide gauges and data buoys of Deep sea Assessment & Reporting Terminals (DART); (ii) development of Pressure Sensor for DART; and (iii) generation of spatial database for vulnerable coastal areas for inundation and storm surge modeling.

Satellite based Hydro-meteorological Networks on Land and in the Ocean:

16. Towards monitoring the extreme weather based disasters, such as cyclone, floods, drought, etc., real time observation of the associated parameters

with appropriate network density holds the key. To strengthen the capability, following efforts have been envisaged:

(a) Densifying satellite enabled Automatic Weather Stations (AWS) networks providing real-time data from remote and inaccessible locations by (i) maximizing the usages of Data Relay Transponders (DRT) on board INSAT/ KALPANA and (ii) through value addition to AWS by integrating GPS and Cyclone Warning and Dissemination System (CWDS).

(b) Supporting Department of Ocean Development (DOD) through technology development in setting up ocean data buoys in the Indian oceanic regions for the study of oceanic processes, ocean-atmosphere interactions and role of ocean in the Indian monsoon.

Tools and Techniques for Decision Support at State level

17. Towards augmenting Decision Support Centre (DSC), efforts have been envisaged to provide decision support mechanism through automated query based systems and thus facilitate different users to get the services through on-line querying. Along with query shells, the data and information will be made available in a user- friendly format to the end-users. The querry-shell will be organised so as to integrate spatial and non-spatial data and with capability to select area of interest, view selected layers, overlay one layer over another, simple and complex querying, multi-thematic query, tiled displays, display options with zoom/ pan, statistical evaluation, morphometric analysis, etc. Thus, the query system will assist the users and administrators in decision-making and impact assessment.

Operationalisation of Aircraft Version of Disaster Management SAR (DM-ASAR):

18. The aircraft version of Disaster Management SAR (DMSAR) and the digital camera as well as the Airborne Laser Terrain Mapper (ALTM) will be made fully operational to support the disaster management programme. An airborne SAR (DMSAR) is already planned to feed into this aspect and is undergoing developmental model integration to be followed subsequently by its test and experimental flights. Presently the system is planned to fly on Beechcraft 200,

which flies at 8 km. altitude with a nominal velocity of 432 km/hr. However, it is being pursued to have a jet for this purpose, which can fly at an altitude of more than 12 kms with nominal velocity of around 720 km/hr.

Key Areas for Research & Development (R&D):

19. Carrying out R&D activities in related areas is one of the key factors for continuous improvement of services. While R&D in the areas of Early Warning covers cyclone, floods, drought, extreme weather events, landslide and forest fire, long-term efforts will be on forecast improvement, simulation models, study on earthquake precursors, etc. DOS has identified clearly the focused areas for research and development in association with concerned laboratories and academia.

Creating the 'niche' for DMS Programme:

20. DMS programme, in 11th FYP, envisages creating ' niche' areas by virtue of developing innovative technological solutions and by reaching out to the community directly for disaster related services. Two areas have been envisaged – (i) constellation of Earth Observation (EO) satellites for disaster management, showcasing the innovative technological solutions, and (ii) space enabled village resource centre focused on community based disaster management services and emergency resources. Pursuing these two activities is expected to have far reaching impact on developing newer technologies in terms of realizing state-of-the-art EO missions and taking the advances down the line to the vulnerable communities.

21. Currently, the Indian satellites have repetitivity not enough to capture the disaster events on real time basis. Efforts are therefore initiated to develop intelligent and autonomous missions, in form of the dedicated constellation of cost effective and small EO satellites comprising a network of optical and radar satellites to capture the real-time subtle features associated with natural disasters. Such a constellation, with appropriate sensors, platforms and other unique mission characteristics, would help towards improving further the repetitivity and coverage to the extent of a day or better. Such efforts of integrating high-end technological solutions to down the line problems would go a long way to build the disaster resilient society.

International Dimensions

22. The association of DMS programme to the international missions relevant to disaster management like International Charter on Space and Major Disasters has helped in integrating DMS programme to the global system. While the commitment to International Charter will continue, closer association with 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) are being developed. Such cooperation is needed for developing our policies related to sharing of data in real time with international agencies. The association of DOS to UN agencies – Economic and Social Commission for Asia and the Pacific (ESCAP), Office of Outer Space Agency (OOSA), Food and Agriculture Organisation (FAO) etc has been developed to share our experiences, exchange the information and best practices.

Thus DMS programme cuts across several boundaries to harness the increasing potential of space technology. On the one hand, there are linkages of DMS programme to national systems and down the line community based organizations like NGOs, Trusts etc – on the other hand partnership with global initiatives are aimed to ensure that global knowledge and practices could flow in to enrich India's institutional capacities on disaster management.

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4.5 SPACE TRANSPORTATION SYSTEM

Introduction

1. Development of launch vehicles has been an integral part of achieving end-to-end self-reliance in Space technology. Starting from SLV-3, India has developed four generations of launch vehicles increasing the capability to launch payloads to low earth orbits by a factor of more than 100 from 1980 to 2006. With an impressive success record and good heritage, PSLV has emerged as a cost-effective and reliable operational launch vehicle for launching 1500 kg remote sensing satellites into polar sun-synchronous orbit. GSLV, capable of launching 2T class INSAT satellites into GTO, has been declared operational with the first operational flight GSLV F01 launching EDUSAT satellite in 2004. Thus, by the end of 10^{th} plan, GSLV and PSLV have emerged as the two work horse launch vehicles meeting the launching requirements of INSAT and IRS type of satellites. The development of next generation launch vehicle GSLV Mk III capable of launching 4T satellites into GTO has also made significant progress towards realising the first launch in 2008-09.

Launch Vehicle Development – International Scenario :

2. All leading countries in space are pursuing many promising options for cost reduction and higher speed to cut journey time. Today's expendable launchers have effectively reached a technology plateau. Novel solutions are required to reduce the cost of access to space. Reusability appears a key area of focus. Development of newer materials like composites, smart materials, structures and propulsion systems such as nuclear, laser, microwave, antimatter, plasma, electric and the magnetic rail launching system are in the anvil. The air breathing propulsion option is being pursued by most of the advanced nations to achieve higher aviation speed.

3. The goals of all major players in space transportation systems are alike when we look at their decade profile and beyond 2020. USA is planning retirement of its fleet of shuttle and change over to Crew Recoverable Vehicle (CRV) concept. With the above proposals journey to International Space Station (ISS), Moon, Mars and beyond becomes simple. European Space Agency (ESA), French Space Agency (CNES) and Japanese Space Agency (JAXA) have a methodology wherein technology demonstration of newer materials, propulsion system, guidance system will be carried out in the next five to eight years to

ultimately end up in the development of Reusable launch vehicle which can be ferried with cargo as well as with human being. Technology build up process has been initiated among the space majors and it is found that the developments are running in parallel. The application of re-usability will be initially to the ISS and then on to the Moon, Mars and Beyond. The journey beyond Moon will call for better propulsion system, materials, structures and the relevant Navigation Control System (NGC) system. It can be forecast that around 2015, the re-usability of space vehicles will be amply demonstrated and made operational. Around 2020 and beyond interplanetary missions will take shape and the presence of all major players in the solar system exploration arena will be prominent.

Launch Vehicle requirements – Indian Scenario :

4. In terms of launch capability, the current version of PSLV can meet the launch requirements of earth observation and space science satellites. However, there is an imperative need to realise 4T launch capability in GTO for launching heavier class INSAT satellites, which is crucial for reducing the cost of transponders. Therefore, an important target for the 11th plan period would be to operationalise the GSLV- Mk III vehicle. The number of satellite missions envisaged for 11^{th} plan in the areas of earth observations, satellite communications and navigation and space science research call for six PSLV / GSLV launches per year on an average. (as against 2 PSLV/GSLV per year in 10^{th} plan). Strategies for increasing the production of current version of PSLV and GSLV, with enhanced participation of Indian Industries is of immense importance during 11^{th} plan period. Also, to meet the launch requirements for lower satellite mass, the newly configured 3 stage variant of PSLV would play a major role in providing cost competitive launches.

5. With the development of GSLV Mk III, the launch vehicle fleet of ISRO would comprise of three types of vehicles viz., PSLV, GSLV and GSLV Mk III, involving a number of propulsion modules specific to each vehicle. In order to reduce the number of propulsion modules for different types of vehicles, studies have been undertaken to evolve a standard core vehicle configuration and strap-on boosters with different propellant loading to meet the varying payload requirement, leading to the concept of "Unified launch vehicle". To arrive at the standard core configuration, the most optimum solution would be to use the semi cryogenic stage as the first stage and the heavier cryogenic stage as the upper

stage. This configuration would meet the payload requirements in all mass ranges for the future.

6. In the coming years, the driving factor in launch vehicle development would be reduction of cost of access to space. Based on the current assessment of technologies available and that would be achieved in the next one or 1½ decades, it appears that Re-usable launch vehicle technology will have to be developed with appropriate flight demonstration tests. Air breathing propulsion system related technologies being developed will feed into RLV program. With the above, an intermediate Two-Stage-To-Orbit (TSTO) vehicle may be the path for realisation by about 2025 which could take us towards a Single-Stage-To-Orbit (SSTO) vehicle beyond this period. Parallely advanced interplanetary missions studies will be initiated. 'Chandrayaan-1' the first lunar mission of ISRO is considered as the beginning. Manned mission initiatives will be carried forward and development of related technologies will be given thrust.

Programme Directions 2010-2020:

7. The long term vision for Space transportation System for the next 25 years is realisation of a cost effective state-of-art Two-stage-To-Orbit (TSTO) vehicle while supporting the national needs through expendable launch vehicle till such time.

8. The major thrust areas of development in the coming Decade 2010-2020 in the area of Space Transportation system will be to:

- Derive a unified modular launch vehicle to cater to LEO, SSO, MEO and GTO missions. This approach would bring down the number of hardware requirements and cost.
- Realise Semi cryogenic stage to cater to Modular Launch vehicle, RLV and manned mission requirements.
- Initiate design and development of TSTO based on RLV, ABPP and semi-cryo developments being done.
- Develope and realise Manned Mission simulation and test facilities.
- Manned mission technology initiative.

- Development of advanced propulsion systems to facilitate interplanetary missions.

9. The key areas of focus would be Advanced R&D programs, Development of critical materials and technologies, realisation of Infrastructural facilities, strengthening of interface with R&D and academic institutions and development of centers of excellence.

Programmatic targets for Eleventh plan :

10. Based on the launch vehicle requirements scenario for the eleventh plan and keeping in view the long term vision of the space transportation system, the programmatic targets for the Eleventh plan in the launch vehicle development area would be as below

(a) PSLV and GSLV to remain as work horse launch vehicles with enhanced capabilities.

(b) Ability for Enhanced level of production of launch vehicle modules with vigorous industry participation. Attain a ready to launch condition

(c) Capability to launch 4 T class into GTO or up to 10 T LEO by GSLV MKIII

(d) Increased launch frequency to meet national needs and customer requirements.

(e) Missions to perfect payload recovery and re-entry technologies.

(f) Technologies towards realisation of an air-breathing demonstrator and recovery experiments by middle of the plan

(g) Experience in conducting Indian micro-gravity experiments on-board space station

(h) Completion of various phases of Reusable Launch vehicle technology demonstration missions through RLV-TD flights

(i) Develop technologies for Manned Space Mission

Next Generation Launcher - GSLV MKIII :

11. While the GSLV Mark-I and II will lead towards payload capability of 2.5 T in GTO, there is a need for improving the capability to 4.0T before the end of the decade. GSLV Mk III is configured as a cost effective vehicle with two and half stages. The first stage will use two-engine cluster of Vikas engine as core stage with two solid motors of 200 t propellants loading. The second stage will be a cryogenic engine of 25 T loading strapped to core vehicle. Some of the key factors of the GSLV-Mark III are improved payload fractions, minimisation of systems, maximum utilisation of existing technologies and minimum cost for development and unit cost. The project has made considerable progress so far. The establishment of facilities, hardware production and testing of subsystems have already began. Most of the S200 processing facilities are in the advanced stages of realisation. L110 flight duration engine test was successfully carried out. C25 sub-system level tests for turbo-pumps and gas generator were completed successfully. Testing of subsystem, establishment of facilities and production of hardware has begun. The first launch is scheduled in 2008 -09.

Development of Advanced Technologies and Future Launchers :

12. The goals set by ISRO are well defined and in order to achieve those, a number of technological developments have to be undertaken both in the launch vehicle area as well as in spacecraft domain. The current level of technologies have to be upgraded to a higher magnitude and novel concepts have to be introduced to achieve a much better and reliable space transportation system. New Technologies acquired will be the driving force for futuristic space missions. Development of advanced propulsion technologies such as nuclear propulsion for planetary missions will have to be initiated. A number of research and development programs in all areas of aerospace discipline have been initiated and these have to take shape and maturity before actually getting inducted in the missions. Once the technology gets proven at laboratory level, it has to be demonstrated at a sub-scale level and then on using a complete version of the system before inducting in operational missions. Based on the technologies available with ISRO and the same to be acquired in the next decade, a modular launch vehicle capable of carrying payloads from 500 kg to 6000 Kg on the expendable side and a totally reusable launch vehicle in another half a decade seems a reality. The development of semi-cryogenic and a higher capacity cryogenic engines has been initiated to realise a modular vehicle. On the reusable vehicle side, a number of demonstrator flights are planned. The

developments in Air breathing Propulsion technology and the space capsule recovery experiment are supposed to provide valuable inputs towards the reusable launch vehicle development.

Indian Manned Mission Initiative

13. India has made significant progress during the last four decades in the development of space technology and their applications to common man in the areas of communications, natural resource management, weather forecasting and disaster management. With the undertaking of Chandrayaan-1, deep space and planetary exploration to enhance our understanding of moon and its potential to augment our energy resources have been initiated in the recent years. 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.

14. 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 after mission duration of few orbits to 2 days extendable up to 7 days, rendezvous and docking capability with space station / orbital platform, emergency mission abort and crew rescue provision during any phase of the mission from lift off to landing and provision for extra vehicular activity. Man rating of the launch by improving safety and reliability, life support systems, rescue and recovery, robotic manipulator, mission management and control and crew training are some of the technology elements to be developed for the Manned mission. An inter-centre study committee is currently addressing some of these aspects. The development of a manned mission would take about 10 to 12 years and it is planned to focus on developing critical technologies required during 11th plan period and achieve substantial progress towards realising a manned mission during 12th plan period.

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4.6 SPACE SCIENCE & ENVIRONMENT

Introduction

1. The exploration of space has the key to find possible answers to the basic question of our own existence in the universe. Investigation of space science and related subjects provides knowledge towards understanding the mysteries of the universe. Through space science investigations we seek to understand the processes governing solar radiation, evolution of planetary system, the formation of galaxies, evolution of stellar systems and the universe. Space science research activities often contribute as a driver for cutting edge and future technology development having applications in related fields.

2. The Indian space science research activities were initiated with the launching of sounding rockets from the Thumba Equatorial Rocket Launching Station (TERLS) in 1963 to measure the equatorial electrojet parameters. Since then large number of rocket and balloon borne experiments have provided new data on upper atmospheric phenomena, cosmic rays and energetic x-ray and gamma rays. With the advent of satellite era, scientific experimental payloads have been launched onboard Indian satellites - Aryabhata, Bhaskara, IRS-P3, SROSS C2 and GSAT-2.

Global Scenario

3. From a global perspective, the space science research across the countries is focused on four major areas viz.,(a) Galactic, stellar and planetary phenomena, (b) Robotic/human exploration/utilisation of resources of moon and planets of solar system, (c) Interactive processes between the Sun, Heliosphere and Earth and (d) The Origin and Distribution of Life in the universe.

4. There is a resurgence of Planetary Exploration Program with a large number of space missions announced in the coming decade by NASA, Europe, Japan, China and Russia for understanding the planetary evolution, their present and past environments and presence of extinct or extant life. Return to lunar exploration is driven by possible exploitation of minerals and using it as a robotic or human base station for planetary voyages.

5. In astronomy research, space borne observations in the high energy X-ray/gamma ray region of spectra would continue to be pursued with more sophisticated detector technology development such as high temperature super conducting bolo meter, microcalorimetry, x-ray polarimetry, mm wave detectors etc.

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 different earth system processes, including the demonstration of new observation techniques in missions such as the Earth Clouds Aerosols and Radiation Explorer (EarthCare); a core ESA mission to provide basic data for numerical modeling and global studies of divergence of radiative energy, aerosol-cloud-radiation interaction, vertical distribution of water and ice and their transport by clouds, and the vertical cloud field overlap and cloud-precipitation interactions, the Water Vapour and Lidar Experiment in Space (WALES) will measure the distribution of water vapour and aerosols relevant to climate change studies, the Soil Moisture and Ocean Salinity Experiment (SMOS) is a mission of opportunity scheduled for 2007, to provide global observations of soil moisture and ocean salinity.

Decadal Profile (2010-2020) and XI Five Year (2007-2012) Plan:

7. The 10^{th} five year plan has been very significant for space science research with the initiation of satellites dedicated for space science. Planetary mission Chandrayaan-1, Multi-wavelength X-ray astronomy satellite ASTROSAT and climatic research satellite Megha-Tropiques, all of which are currently under development, have provided impetus to space science research activities in the country and created special awareness and enthusiasm amongst the younger generation. The microgravity experiments planned in Space Capsule Recovery Experiment is yet another important initiative of 10^{th} plan. A major target for 11^{th} plan, therefore, is to completed these ongoing missions and further undertake newer missions to sustain and promote the wherewithal created for space science research. Akin to this, a major challenge lies in creating the human resource based in the country for analyser the enormous amount of scientific data that would be available from these missions.

8. In order to formulate the proposals for Decade profile 2010-20 and 11th five year plan 2007-12, the Advisory Committee for Space Science, Chaired by Prof. U R Rao, has formulated four science panels in the areas of

(a) Planetary Exploration/Science

(b) Astronomy and Astrophysics

(c) Space Weather

(d) Weather and Climate Science

9. These science panels organised discussions amongst interested Indian experts / scientists from different research institutions and universities and come out with plan proposals on undertaking space science and related missions during the next decade and what specific programmes could be undertaken or projected for the XI plan period. While formulating the proposals, the panels took into account the present status of space science research activities, global trends, gap areas of scientific interest, observational and instrumentation requirements, issues related to data archival and dissemination and human resource development. ADCOS deliberated on the panel reports to arrive at final recommendations, as highlighted in the following paragraphs, on space science research proposals to be pursued for next 15 years.

Planetary exploration/science

10. In the area of Planetary exploration, the Chandrayaan-1, the India's first planetary mission, is already in progress and the launch is expected to take place in the first year of 11th plan period. The primary focus of planetary exploration programme is towards *"Understanding the Origin and Evolution of Solar System Objects".* It is recognised that exploration of resources on Moon and Mars could also bring economic benefits to the mankind.

11. In terms of technological capability, exploration of the INNER SOLARSYSTEM is feasible in the near future with existing ISRO capabilities (launch vehicle, spacecraft, communication and navigation). However, development of specific technologies such as Lander, robotics and rover, auto-navigation and thermal managements are needed for scientifically fruitful exploration of the inner solar system objects. Exploration of the OUTER SOLARSYSTEM will need significant technological development, in the area of

spacecraft resources (power, communication, navigation). Therefore, initiatives on development of critical technologies required for exploration of outer planets have to be put in place in 11th plan period so that possibility of exploration of outer solar system may be considered after 2015.

12. Taking note of the ongoing and proposed future planetary exploration programmes of NASA (USA),ESA (Europe), JAXA (Japan), China and Russia, four specific missions and planetary targets are proposed within the 2020 time scale. These are :

a. Follow on Mission to Moon and a possible Lunar Observatory.

b. Mars Orbiter

c. Asteroid Orbiter & Comet Fly by

d. Technology demonstrator fly by to outer solar system.

13. The follow on Mission to Moon, Chandrayaan-2, is proposed for implementation within the XI plan period. Missions to Mars and Asteroid/Comet are planned to be initiated during 11th plan period, but the realisation of the missions could be XII plan period. The proposed technology Mission to outer solar system is planned for realization within the 2015-2020 time frame. It is also planned to initiate work in 11th plan towards establishment of a lunar observatory for realisation in 12th plan period.

14. The scientific objective of Chandrayaan-2 (2007-2012) is to further investigate the 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 and studies of lunar radiation environment including solar wind-magnetotail interactions. In-situ analysis of lunar samples with alpha/neutron/X-ray Florescence spectroscopy, studies of lunar regolith properties (remote & direct analysis) using Robotics/Rover are also planned. It is also planned to initiate during 11th plan development of critical technologies required towards possible establishment of a Lunar Observatory in 12th plan.

15. Towards understanding Martian atmospheric processes and weather/dust storms, Martian ionosphere, effect of solar wind, surface magnetic fields, search for paleo-water and surface resources, Mars Orbiter has been planned during the

time frame 2009-2015. The mission envisages placing a spacecraft in low latitude (<100 km) orbit around Mars and to monitor radiation, electric and magnetic fields (tens of nano tesla) and energetic particles in Martian space.

16. The Asteroid Orbiter &Comet Flyby (2009-2017) is intended to study evolution of asteroids and comets, early solar system processes, meteorite-asteroid connection, physical and chemical properties of asteroid and cometary material. Primary Target is 4 Vesta though near-earth asteroid may also be considered as an option. Studies of energetic particles, radiation and fields in interplanetary space is an integral part of this long duration mission. The important technology goals of this mission would include: (i) Orbiter around small (low gravity) objects (ii) Achieving high impulse (>6 km/s) needed for reaching main belt asteroid (iii) Command, communication, navigation, control and orbit capture (iv) Miniaturization (mass, size) of remote sensing instrument

17. A Technology Demonstration Mission /Flyby to Outer Solar System(2012-2019) is proposed to develop and demonstrate one or more of advanced technology such as Ion Propulsion; Radioisotope Thermoelectric Generator (RTG), Lander/Penetrator (asteroid/planetary target); Robotics and Rover for in-situ analysis of surface materials using XRF, APS, Imaging, UV-VIS-NIR Spectroscopy; Sample Return (from specific lunar sites: polar/far side) etc.

Astronomy and Astrophysics

18. The major science program in Astronomy and Astrophysics during the next five-year plan is the launch of ASTROSAT in 2008 and its scientific data analysis/utilisation. Two main themes of interest to be pursued during 11th plan are Solar Astronomy and X-ray Astronomy.

19. Since solar physics is currently one of the exciting areas in astronomy, the time is ripe to rejuvenate this branch of astronomy. The establishment of a 1 m class solar telescope at Udaipur will give the necessary impetus. It is proposed to fly a space borne solar coronagraph “Aditya” in visible and near IR bands with polarimeter and spectrograph on one of ISRO’s small satellite mission. Coordinated observations with such a coronagraph and ground-based optical telescopes, as well as radio telescopes such as the GMRT, ORT and the low frequency telescope at Gauribidanur, are likely to be rewarding in the study of coronal mass ejections and the consequent space weather. A space coronagraph equipped with suitable polarimetric and spectroscopic capabilities will provide the

most accurate and unique data about the crucial physical parameter for space weather, viz. the coronal magnetic field structures. Along with coronal magnetic field measurements, the telescope will also provide completely new information on the velocity fields and their variability in the inner corona that will clearly highlight the role of waves in the important and hitherto unsolved problem of coronal heating. Aditya is proposed for launch by 2012 during the solar maximum year.

20. Several new initiatives / payloads have been considered in the area of X-ray and Gamma ray multi-wavelength astronomy in the next astronomy satellite ASTROSAT-2. These include:

(a) Soft X-ray, high-resolution spectroscopy with focusing optics and bolometer (Time-scale: 5-10 years).

(b) X-ray polarimeter (4-8 years).

(c) A sensitive X-ray sky monitor (~5years).

(d) A black hole monitor (~4-6 years).

(e) High sensitivity hard X-ray experiment (6-8 years)

21. The combination of payloads for ASTROSAT-2 will have to be decided in due course of time taking into account the development status of the instruments. Provisionally, it is planned to initiate the ASTROSAT-2 development during 11^{th} plan period, though the realisation could be only in 12^{th} plan.

Space Weather

22. 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. Any scientific program on 'Space weather' would call for quantitative evaluation of the physical changes in the near Earth space environment, in response to the variations in the solar radiation, solar plasma ejection and the electromagnetic status of the inter-planetary medium. Space weather processes have significant effects on space-based systems, Navigation/ Communication systems and Power Systems, highlighting the need for a comprehensive understanding of the complex processes, so as to reach the level of predictive capability.

23. The main areas of investigations covered under Space Weather are:

(a) The Sun including solar radiation, energetic particles and the solar wind

(b) The magnetosphere including solar wind–magnetosphere interactions, magnetospheric waves, particles fluxes and fields, ring current dynamics, geomagnetic storms and sub storms.

(c) The ionosphere/thermosphere system including electric fields, and current systems, ionospheric irregularities, ionospheric disturbances and the neutral atmospheric structure and energetics.

24. Broadly, the programme envisaged under Space weather development of piggyback payloads such as radio beacon and radio occultation of GPS satellites, ground based LIDAR and other facilities, rocket borne payloads for measurement of electric/magnetic fields and optical experiments in UV, visible and IR. The satellite missions envisaged includes three small satellites, one for aerosol studies and 2 for electrodynamics of near space environment under different geophysical conditions during 2008-10. Two of the small satellites are planned to be part of a twin system having near equatorial and near polar orbits. In addition, a major mission for investigations of the phenomena of earth's inner magnetosphere is also planned.

25. Small Satellites for Earth's Near-Space Environment (SENSE) (2008-10) is 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. With in-situ particle, field and visible/EUV remote sensing measurements it would be possible to resolve the question- What 'basic' state large-scale processes drive during quiet geomagnetic conditions is an unresolved issue that can be addressed quite effectively by the twin-satellite mission.

26. A major mission for study of Inner Magnetosphere Mission (2010-12) is proposed to explore the inner Magnetosphere, Ring current zones, Plasmasphere, Plasmapause regions etc.. A small satellite (co-passenger) along with the geo-stationary satellite launch is a good possibility. Small satellites left in the transfer orbit would enable investigation of these not so easily accessible regions. Magnetospheric charged particle fluxes, DC & AC electric fields, magnetic fields, Optical and X-ray sensors etc. have to be developed as part of payload instrumentation. The magnetosphere including solar wind-magnetosphere

interactions, magnetospheric waves, particle fluxes and fields, ring current dynamics, geomagnetic storms and sub storms will be studied. This could be followed later by a satellite orbiting around the moon, and further extended with a Lander on the Moon and/or a spacecraft at the L1 Lagrangian point. Of course the time lines would, in that case, extend to 2016.

Climate and Weather Science

27. In order to maintain a lead amongst the global players in the field of space-based monitoring of weather and climate parameters, it is important for India not only to further develop the meteorological monitoring capabilities of future geostationary INSAT satellites, but to launch a constellation of satellites in a low-altitude tropical orbit for observation of critical climate-related parameters as well. Development of techniques for assimilation of direct radiance measurements made by Indian satellites into numerical weather prediction models may be taken up on high priority.

28. Keeping in view the long term research interest, two satellite missions viz., Indian Satellite for Aerosol and Gases (I-STAG) and Tropical Weather and Climate Satellite have planned during the 11th plan period.

29. I-STAG is a small satellite mission carrying the following payloads.

a. MAPI :a nadir-viewing multi-angle polarisation imager and multi-spectral sensor in the wave-length bands 0.4-1.2 μ, 2- 4 μ and 10.5 – 12.5 μ

b. MAVELI : measurement of vertical distribution and extinction properties of aerosols in the stratosphere and troposphere by viewing along earth's limb.

c. MAGIS : Measurement of Atmospheric Gases by IR Spectrometer in the 2 – 5 μ range using a Cassegrain telescope and a linear 256 pixel In-Sb detector array.

30. The main scientific objective of I-STAG mission is to delineate the changes that take place in atmospheric aerosol and trace gases globally with an emphasis on the South and South East Asian regions and to estimate their impact on atmospheric radiation budget, chemistry and climate system.

31. A comprehensive mission for Tropical Weather and climate studies is envisaged in 11th plan, carrying the following payloads.

(a) Either a scanning radiometer operating at 10.6 (VH), 18 (V/H), 23, 37 (V/H), 89 (V/H) and 150 (V/H) GHz, similar to MIMR or preferably a polarimeter-radiometer operating at 6.6, 10.6, 16, 23, 37, 89 and 150 GHz with a combination of VV, VH, HV and HH polarisations. These are specially tailored to measure vector winds, atmospheric water vapour, liquid water and rain.

(b) Synthetic Aperture Radiometer operating at 1.4 GHz for measuring global moisture with a spatial resolution of about 20 km.

(c) Precipitation radar in ku/ka band for measurement of rain and rain rate.

32. As a long term plan, development of above payloads will also lead to the design of a single combined passive microwave imager and sounder operating at 10.6, 18,23,37, 52-58, 89, 150, 183 GHz (both V&H), combining the functions of scanning radiometer, temperature sounder and humidity measurer, which will be the instrument of the future. The launch may be taken up as a follow up indigenous mission of Megha-Tropiques and realised by 2012-14.

Space Science Instrumentation Facility (SSIF)

33. SSIF is a newly constituted unit of ISRO Satellite Centre (ISAC) working under the direct supervision of the Space Astronomy Instrumentation Division of ISAC. The facility is primarily meant to assist in developing experiments to be conducted from space by various institutional groups in the country. Main thrust would be developing various sensor/detector systems required for space borne measurements. SSIF would eventually become the hub for space science research with space-based instruments in the country. Establishment and commissioning of SSIF as a national facility for space science payloads is a major target for the 11th plan.

Indian Space Science Data Centre

34. Indian Space Science Data Centre (ISSDC) is a new facility being established as a backbone data centre to manage the science data archive for the space science missions of ISRO. This will be the primary data centre for all the future space science missions of ISRO. As national facility this will provide a

single point of access to the space science data. ISSDC has the responsibility for the full life cycle of the data starting from the reception of data to dissemination of the data to the users. Reception of raw data, ingest, on line archive support, processing of data for the generation of the higher levels of data, data management/dissemination through network will be managed from this centre. It is targeted to set up the data centre facility at Bangalore well before the launch of Chandrayaan-1 in 11 plan. .

Initiatives at PRL, NARL and SPL

35. In addition to the above missions, at PRL, NARL and SPL, apart from strengthening the existing programmes, new programmes will be initiated. A decadal (1996-2005) of the PRL covering all the major research areas was conducted by international panels of experts during early 2006, which provided valuable inputs for planning the 11th plan programmes. Some of the new programmes planned at PRL includes observations in the 3-13 micron window from Mt. Abu Observatory, acquisition of a fibre-optic Echelle Spectrograph, installation and operation of the Multi-Application Solar Telescope (MAST) at Udaipur Observatory, ground, balloon and aircraft based studies of erosols, trace gases and cloud condensation nuclei, radio probing of the ionosphere, studies of new astro-materials,(cometary dust / asteroid samples), acquisition of a Multi-Collector Inductively couples plasma mass spectrometer for studies of very early crustal components and fossil records of early biogenic activity and high resolution studies of palaeo-climate and palaeo-envirnoment since last glacial maximu. The thrust in the theoretic physics area at PRL will be to understand new data that will soon be available from high energy collider, branching into the area of nuclear astrophysics and probing new dimensions in the field of non-linear dynamics, quantum optics and quantum information.

36. The focus at NARL during 11th plan will be to reach out wider area of observations around the globe and the related technologies required to carry out front line research in the area of atmospheric science. Some of the major programmes envisaged at NARL include GPS Occultation techniques for atmospheric studies, development of a dual polarisation dual wavelength cloud and aerosol lidar, development of sodium lidar for temperature profiling, development of X band and MF radar and UV-Raman lidar for profiling of lower atmospheric water vapour.

37. At SPL, space borne experiments with rockets and satellites for atmospheric and upper atmospheric studies will be a priority area. SPL will also initiate ground based microwave radiometric studies to fully utilise the data from missions such as Megha-Tropiques.

Geosphere Biosphere Programme (GBP)

38. Realizing the importance of temporal and spatial scales in Geosphere and Biospheric exchange processes, the GBP of ISRO during the 11th FYP focused its objectives mainly addressing large-scale issues, which contribute to the overall understanding of parameters responsible for our climate change.

39. The Specific Atmospheric Assessment Projects (SAAP) include 1) Aerosol Radiative Forcing over India – on a periodic basis is contemplated through the established MWR network in the country for possible uses in the assimilation of our numerical weather forecasting. 2) Atmospheric Trace Gases and Transport over India –envisages to apportion the sources and sinks of the trace gases and their residence time of transporting to other regions and to identify ecological hotpots. 3) Atmospheric Dust Composition and Transport – through establishment of observatory network the transport of atmospheric dust from the continental and extra continental regions provide insights on the intra-annual variability of our atmosphere and the possible role of dust in regulating radiative forcing. 4) Atmospheric Boundary Layer Characterization – through establishment of boundary layer towers is envisaged. 5) Energy, Water and Mass Exchanges in Vegetative Systems – a project planned to understand the exchanges of energy and water use during the growing season of our major agricultural systems to possibly assimilate into the crop production and protection models.

40. The Integrated Land Ecosystem and Atmospheric Projects (ILEAP) include 1) Land Use Land Cover Dynamics and Impact of Human Dimensions in the Indian River Basis over the last 30 years is proposed to analyze the issues causing concerns on our dwindling hydrological regime. 2) The Multiproxy Quantitative Palaeomonsoon Reconstruction for past 21,000 years BP and Regional Climate Modeling efforts are integral part of the past and future predictions of our changing Indian climate on a scientific basis.

41. As far as atmospheric CO_2 and its flux is concerned there are no primary databases or reliable observations available for use in the carbon dynamics

studies. Towards this GBP is planning for Intense Observational Projects (IOP**)** related to 1) Vegetation Carbon Pool Assessment and 2) Soil Carbon Pool Assessment.

42. In summary, the 11th FYP of GBP projects identified are to provide enhanced understanding of the India's regional climate and its atmospheric composition for improved weather prediction models.

Megha-Tropiques Science and Utilisation Plan

43. The Megha-Tropiques (MT) satellite mission is aimed to study the convective systems and their influence on tropical weather and climate. The monsoon and the tropical cyclones over Indian Ocean region are the prime concerns for detailed investigation using this data. The specific characteristics of these events are large intra-seasonal, inter-seasonal and inter-annual variations and may lead to catastrophic manifestations like floods and cyclones. The studies contemplated using the MT mission may be considered as a sequel to TRMM mission, which was launched in 1997 and was mainly aimed for estimation of tropical rainfall. The Megha-Tropiques mission has been accordingly planned for a specific geographical coverage in the tropical region ($\pm$ 20° in the north-south direction) and a large temporal revisit frequency. The basic plan of the mission sensors has been arranged in a way that it will complement the existing /or to be available observations from geo-stationary and other polar orbiting satellites from national and international agencies.

44. The MT satellite payloads are highly advanced sensors viz. Microwave Analysis and Detection of Rain and Atmospheric Structures (MADRAS), a millimeter wave humidity profiler, SAPHIR, and an optical-IR radiometer for radiation budget (ScaRAB). These sensors will be integrated with IRS platform and are primarily developed under ISRO-CNES joint collaboration. The launch is scheduled for late 2008 by ISRO-PSLV.

45. In determining the applications potential of MT, a deliberate emphasis has been laid on the complimentary role of other data sources available during and after the actual mission period. This synergy of data is expected to provide a much-focused scope for data applications strategy. In general, the major challenge of the project is the retrieval of geophysical parameters from MT sensors. The project also includes synthesis of applications of data from INSAT-

3D, OCEANSAT-II from Indian space efforts and ENVISAT, METOP, EOS (Aqua, Terra etc.) and GPM from international side.

46. The MT-Utilization programme is planned to execute in two phases, Viz: pre-launch and post-launch. During pre-launch phase developmental studies with respect to parameter retrievals and definition of application models are envisaged while in the post-launch phase application of actual data along with supporting data from other satellites has been emphasized. Since, major emphasis of MT observations is on providing all season capability having high-resolution data fields using MW sensors, the major themes of the applications plan includes:

1. Geo-physical retrievals and calibration-validation,
2. Synergy of data from different sources and value addition
3. Science studies
    i. Study of convective/ precipitating systems
    ii. Cloud radiation interaction studies
    iii. Study of severe convective systems like tropical cyclones
    iv. Assimilation of the data in numerical models (atmosphere and ocean)
    v. Study of air-sea exchanges
4. Applications in weather, ocean, land and environment
    i. Synoptic analysis of weather and forecast on operational scale for short range
    ii. Applications in near real time data usage for medium range forecast
    iii. Fine structure analysis and short range forecast for marine weather & estimate of ocean state

47. The prime activity of the mission is centered on development and implementation of algorithms for geo-physical parameter retrievals (level 2 products). The CAL-VAL (Calibration and Validation) activity is basically required to provide feed back on the sensors performance, software performance and provisions for improvements. The data synergy and value addition is also an important activity for effective utilization of MT data in its core scientific and application themes.

Other Initiatives / Programmes

48 The programmes on Microgravity research will be conducted under the framework of National Microgravity Research Programme. Space science Instrumentation Facility (SSIF), to facilitate developing experiments from space platforms by various institutional groups and Indian Space Science Data Centre, as a national facility to provide single point access to space science data in the country will be established during 11th plan period.

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4.7 ATMOSPHERIC SCIENCE PROGRAMME (ASP)

Background

1. Understanding of the atmospheric and land surface processes that are complex and non-linear is essential for the prediction of earth atmospheric system and optimal management of natural resources and environment. Meteorology and Atmospheric Sciences, covering upper air and boundary layer parameters, cloud dynamics, rainfall estimation, ocean atmosphere interactions, weather modeling etc have been of keen interest to ISRO since inception of space programme in early 70s. Analysis of satellite data from optical, thermal and microwave regions, developing unique algorithms for parameter retrievals and their applications in monsoon meteorology, seasonal prediction and upper atmosphere research have been the core areas of research in atmospheric science. The ISRO groups have also been proactively interacting with national agencies such as IMD, NCMRWF, IITM etc. in these studies with operational satellite data.

2. Over the past two decades, ISRO/DOS has established state-of-the-art space infrastructure by launching series of INSAT, IRS and Oceansat and developed a host of associated technologies such as Doppler Weather Radar, Automatic Weather Station etc. The data from these satellites are providing spatial and time series data on earth-atmosphere system. Further, efforts have been initiated using suitable atmospheric models to improve the prediction skills through assimilation of space and collateral data. The future advanced missions such as INSAT 3D, Oceansat 2, RISAT and Megha Tropiques will further enhance the space capabilities to provide critical data required by the modelers.

3. Considering the need to provide an impetus on studies and research in this critical area of atmospheric research, an **Atmospheric Science Programme** (**ASP**) has been initiated with special emphasis on use of satellite and advanced observation tools, techniques of modeling and a mechanism for interactions with scientific departments and academia for initiating suitable projects, leading to operational end user products in different domains.

Primary Goals of the Programme

4. The primary goals of the Atmospheric Science Programme will be to pursue high quality research and development work in Meteorology, Atmospheric processes, Atmospheric dynamics with emphasis on use of satellite inputs. The thrust area of work encompasses retrieval of geophysical parameters from satellite data, validation and their use in various application themes. While the primary objective of the programme is on satellite applications to meteorology and atmospheric science, the availability of core groups in associated technology field with in ISRO will enable taking up of development of appropriate observation tools and initiation of fundamental studies in atmospheric processes and interactions with land surface and oceans. Some of the key application areas envisaged are tropical cyclone intensity and track prediction, monsoon dynamics, weather prediction at seasonal and short range, etc. As a spin off, better atmospheric correction models will become available for retrieval of ocean color, aerosols etc.

Perspectives for the 11th FYP

5. The 11th five year plan in atmospheric sciences would also focus on assimilation of space observations in ocean-atmosphere models to enhance forecasting capabilities of weather across temporal and spatial scales and development of appropriate indigenous technology for observation tools such as Automatic Weather station, Doppler Weather Radar, wind profiler, Ground and space based LIDAR, GPS Sonde etc. The objective also will be to transfer technology and methods to the user communities for operational use in several key areas. Improved observing tools, enhanced use of space data, techniques for data reduction and analysis, better scientific understanding of processes and integration of same in models will be some of the priority areas. The deliverables will include operational techniques for improved predictions and monitoring systems for weather, monsoon rainfall, cyclone track and intensity, ocean state forecast, mesoscale modeling for tailored applications etc. The plan will also simultaneously work on enhancing the observation network through use of indigenously developed systems. The end goal is to meet some of the critical user needs in terms of weather monitoring and accurate prediction of severe weather events. The Atmospheric Science Programme envisages close interaction with ongoing ISRO/DOS programmes such as Earth Observation System, Disaster Management Support and Village Resource Center.

Thrust areas of ASP

6. The scientific approach will be to integrate land-ocean-atmosphere data, improved modeling and process parameterisation leading to enhanced prediction capabilities in different time and spatial scales. Technology development taken up in-house has led to realization of state-of-the-art systems such as Automatic Weather Station, Doppler Weather Radar and GPS Sonde. It is proposed to continue these efforts to develop indigenously Wind Profiler, Agromet Tower, Lidar etc., to enhance network of observations to supplement and complement satellite data for specific tailored operational programmes. Further, advanced satellite sensors such as soil moisture, aerosol, atmospheric constituents, cloud parameters, rainfall etc. will be developed for future missions. Multi agency projects in the themes of weather modeling, INSAT satellite parameter retrieval, monsoon research, cyclone forecasting, data assimilation techniques etc. are also envisaged. Recently, the project PRWONAM (Prediction of Regional Weather through Observation Network And Modeling) has been initiated with active participation from national agencies, for improving weather prediction over SHAR for launch support. Under the project a meso network of observations is being set up for providing adequate data for mesoscale models, which could be extended to other parts of the country. The road map for the Atmospheric Science Programme encompasses integration of atmospheric data with geospatial information for a holistic view of the earth system and lead to several applications such as land surface processes, hydrology, energy generation, developmental planning etc. and other strategic applications. The key areas of activities identified are -

i. Contributing to the observation infrastructure through indigenous development of observation systems such as AWS Mk2, Agromet tower, GPS Sonde, Tower based observations, Wind profiles, Ground and Space based LIDAR, Cloud radar, rocket payloads etc., to supplement and complement space based observations.

ii. Satellite applications for atmospheric and ocean studies

iii. Satellite products retrieval and assimilation in models for improved weather prediction for varied applications

iv. Multi-agency Application Projects in thrust areas [Improved forecast of severe weather events Atmospheric correction models, Ground based

atmospheric simulator, GPS retrieval of atmospheric parameters, Special studies of island weather, Ocean-land-atmosphere interactions]

v. Integration of geospatial and atmospheric data and applications

vi. Advanced sensors for future missions [soil moisture, aerosol, ocean salinity, atmospheric water vapour etc.]

vii. Integration of geospatial and atmospheric data

viii. Developing a Center for Atmospheric Data Management and Modeling Studies

ix. Support research in academia in key areas and Training

7. The 11th plan activities for atmospheric science programme has been worked out based on the past expertise, satellite missions that are currently available and planned in future, potential areas for operationalisation, user requirements and interest. It broadly covers retrieval of important geophysical parameters, their applications, prediction modeling, etc. The projects will be carried out involving the relevant users, so as to be able to develop core expertise in their organizations and subsequently technology transfer for operational use.

8. Several direct and indirect benefits are expected from the Atmospheric Science Programme. The direct benefits will be improved understanding of atmospheric processes leading to better forecast of cyclones, severe weather and monsoon, enhanced observation network, indigenous technology for systems such radar, weather stations, upper atmospheric observations etc, advanced sensors for future satellite missions and spin off in terms of industry participation. The indirect benefits especially by integration of geospatial and atmospheric data are manifold such as hydrology, energy potential exploitation, development planning besides better perspective of the earth atmosphere system.

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4.8 MASTER PLAN FOR UTILISATION OF SPACE TECHNOLOGY IN NORTH EASTERN REGION

1. Recognizing the unique capabilities of space technology, the North Eastern Space Applications Centre (NESAC) was established as a joint initiative of the Department of Space (DOS) and the North Eastern Council (NEC) with the main objective of providing space technology inputs for the development of the NER. The broad spectrum of space technologies of relevance to development of North Eastern Region include Satellite (INSAT/GSAT) based communications including developmental communications, Remote Sensing Satellite (IRS) data for Natural resource management applications and Disaster Management Support.

2. The Department, has taken up several projects (through NE-SAC and other programmes) towards application of space technology for the development of the NE region and demonstrated the potential of the space technology. Some of the salient projects completed and / or in progress are:

(a) Establishment of Natural Resource Information System (NRIS) for North Eastern Region.

(b) Technology Mission for Integrated development of Horticulture in the NE States including Sikkim.

(c) Waste land map updation for the States of Meghalaya and Nagaland.

(d) Remote Sensing Based Agricultural Statistical System for the State of Meghalaya.

(e) Rapid assessment survey of Hydro-electric Project sites in Arunachal Pradesh and Assam.

(f) Satellite based survey of water bodies for development of inland fisheries in Ri Bhoi District, Meghalaya.

(g) Remote Sensing and GIS based forest working plan inputs for Eastern Assam Forest Circle.

(h) Development of an Early Warning System for the Japanese Encephalitis.

(i) Disaster Management Support in terms of digital data base creation for flood prone districts, emergency communication support and mapping support for NE States.

(j) Establishment of satellite based Tele-medicine connectivity in 21 hospitals.

(k) Satellite based education infrastructure in five NER States viz., Mizoram, Nagaland, Tripura, Arunachal Pradesh and Meghalaya.

3. In order to give further thrust to the pace of development in the NER and to optimally harness the space technology in that direction, a High Power Committee (HPC) was constituted to address the specific planning needs of each of the eight States in the region and suggest ways and means to utilize the space technology. The HPC met twice and drafted a Master Plan for utilization of space technology in the NER during 11^{th} plan period. This plan is based on the review of the developmental needs of the region, resource potentials in the region, present and future satellites/sensors, suggestions made during interaction meetings with the senior officers of State governments, written inputs received from States in the NER, and deliberations of the HPC, inputs received from various centres of Indian Space Research Organization (ISRO) and DOS.

4. The Master Plan envisages implementation of a number of state level projects and a set of regional projects that have been prioritized through consultations, with the State governments, and written inputs received from States in the region and the suggestions made by the North Eastern Council. It is envisaged that these projects would help in building productive and sustainable livelihoods based on natural resources of the region, provide necessary communication infrastructure and contribute to the socio-economic growth of the region.

5. It is estimated that implementation of this Master Plan would require an amount of Rs 108 crores spread over a period of five years ending by the year 2012. The Mater Plan of action would require pooling of human resources from the user agencies. They need to be provided on-the-job and orientation training. A few resource persons have to be recruited as project staff and research associates at the State-level Remote Sensing Applications Centres in the NER. The Master Plan of Action requires strengthening of the North Eastern Space Applications Centre and cooperation and collaboration of many organizations/institutions in the country and especially those located in the NER.

6. A summary of the plan of action of the Master Plan is given below:

Sl No.	Application areas	Tasks planned	Imple-mentation time-frame
1.	**Disaster Management support**	♦ Creation of database. ♦ Creation of Digital Elevation Models (DEM) for critical districts. ♦ Geomorphological mapping of NE region. ♦ Facility for processing of Air borne Synthetic Aperture Radar (SAR) data ♦ Mapping of Flood affected areas. ♦ Sand deposited area map ♦ Landslide hazard mapping ♦ Augmentation of Communication support facilities at NESAC	**2006-2012**
2.	**Natural Resources Census**	♦ Land Use land cover mapping (level 3) on 1:50,000 scale ♦ Land Degradation Assessment	**2006-2010**
3.	**NRIS**	♦ Establishment of Natural Resource Data base at district level for all the 8 States.	**2006-2008**
4.	**Inputs for preparation Forest Working Plans**	♦ Forest crown density mapping ♦ Forest type maps ♦ Digital infrastructure layer ♦ Area statistics ♦ Identification of regions prone to degradation. ♦ Sampling design for pre and final ground inventory of growing stock. ♦ Generation of growing stock details. ♦ Wild life habitat mapping. ♦ Identification of corridors for movement of wild animals	**2006-2009**

Sl No.	Application areas	Tasks planned	Imple-mentation time-frame
5.	**Horticulture Mission & Agriculture Development**	♦ State-wise mapping of jhum, areas ♦ Identification of suitable areas for settled agriculture & horticulture. ♦ Development of satellite based crop area reporting system ♦ Action plans for 20 watersheds per year	**2006-2012**
6.	**Bamboo Technology Mission**	♦ Survey of bamboo breaks ♦ Identification of suitable sites	**2006-2009**
7.	**Soil and land capability map on 1:25,000 scale for agricultural district**	♦ Soil mapping of 40 plus agricultural districts in the region at 1:25,000 scale. ♦ Land capability / suitability assessment at the cadastral level for the above districts. ♦ Identification of blocks / districts for intensive agriculture.	**2006-2009**
8.	**VRC**	♦ Setting up VRCs at block level in all the 8 States.	**2006-2010**
9.	**Infrastructure Planning Inputs**	♦ Inputs for identifying locations for infrastructure planning such as Agro processing industries, schools, hospitals, etc., based on remote sensing data depending on requirements of States.	**2006-2012**
10.	**Human settlement analysis**	♦ Urban sprawl mapping at least three cities every year & NUIS Database creatuion. ♦ Urban land use plan and sites for industrial growth ♦ Mapping of existing transport network ♦ Rural connectivity assessment.	**2006-2012**

Sl No.	Application areas	Tasks planned	Imple-mentation time-frame
11.	**Water resource development & conservation**	♦ Ground water potential zones mapping ♦ Floride and arsenic contamination in ground water ♦ River migration & land form change ♦ Reservoir sedimentation ♦ Glacial and snow cover change & run off ♦ Wetland mapping ♦ Suitable sites for micro hydel power projects & inputs for environmental clearance.	**2006-2012**
12.	**Inland fisheries development**	♦ Mapping natural water bodies & identification of breeding grounds ♦ Identification of links.	**2006-2008**
13.	**Telemedicine**	♦ Providing Tele-medicine connectivity to all the districts of North East Region including the State Headquarters. (72 nodes).	**2006-2008**
14.	**Development Communication / EDUSAT utilization**	♦ Establishment of developmental communication network for broadcasting, interactive training programme and VRC services. ♦ Networking of universities with colleges, SCERTS with training centres for providing quality education in the NE States.	**2006-2009**
15.	**State-wise Priority Projects**	♦ State wise priority projects as identified by each State for application of space technology in the area of natural resource management, health-care and education.	**2006-2012**

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4.9 DEVELOPMENT OF SPACE MATERIALS AND COMPONENTS, INDUSTRY INTERFACE, ACADEMIA INTERFACE COMMERCIALISATION AND INTERNATIONAL CO-OPERATION.

Development of Space Materials and Components:

1. It has been the endeavor of ISRO to maximize the use of electronic components and space materials made in the country and towards this, ISRO has taken a pro-active role by promoting the Indian Industries to develop the components and materials to the specification requirement of Space Programme. More than 160 types of electronic components and 115 types of space grade materials have been developed and qualified for use in spacecraft, launch vehicles and ground systems. During 11^{th} plan, special thrust will be given to development of strategic items, electronic components, space materials and high-end technology devices.

2. The focus of the efforts in space materials will be towards development of various metallic and nonmetallic materials, semi-cryo materials, Hafnium and Niobium plants, Al-Li alloys, Al-Be alloys, Polymer and chemicals and other materials. The development of radiation hardened devices, special sensors such as CCD based TDI devices, MEMS / MMICs, TWTAs, thermal control materials, nano materials, cables and connectors and other passive and active electronic components will be a thrust area during 11^{th} plan.

3. Semiconductor Laboratory (SCL), Chandigarh, is a premier laboratory of the country for development of semi-conductor devices and has been a major partner in indigenous development of semiconductor devices required for space programme. SCL has been brought under the administrative control of DOS from March 2005. The VLSI facility at SCL is an integrated facility comprising Design, Wafer Fabrication, Testing, Packaging, Quality Assurance and System/Board level assembly. The Wafer Fabrication facility is the only facility of its kind in India's IC fabrication. SCL developed the 0.8µ technology in the year 2001 based on indigenous efforts but has not been able to initiate any activity on the next generation technologies such as 0.65, 0.35, 0.25 and 0.18µ technologies, primarily due to the limitations of the performance capability of the existing equipment and non-availability of certain additional process equipment. Due to this the company could not maintain its competitive edge and provide the highly needed technology up-gradation in the vital area of microelectronics.

Considering the programmatic need of indigenously developing critical devices such as Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGA), Charge Couple Devices, etc., it is necessary to upgrade the facilities at SCL. Hence, it is proposed to upgrade the existing 6" facility from 1.2/0.8µ to 8" facility of 0.35µ technological capability or better at a total estimated cost of Rs. 500 crores. The up gradation is proposed to be completed before 2008-09.

Industry Interface

4. In accordance with ISRO's policy of maximally utilizing industrial capability, the Indian industries took active part in realising hardware and software services for space segment as well as ground segments. Concerted efforts were made during the 10th plan period to (i) increase the role of industries from being a component supplier to systems level integrator; (ii) transfer all production and operations management tasks to industries for manufacturing sub-systems and components, on a self sustaining basis.

5. In the launch vehicles area, the magnitude of industry contribution has grown apace with needs of operational flights of both PSLV and GSLV and the new developments undertaken in the context of GSLV-Mark III. Various initiatives in coordination with industries have resulted in establishment of production centers for assembly and integration of liquid rocket stages (L-40) to supply complete L-40 stages, PS4 main engine and pneumatic modules, thruster valves, propellant tanks, engine hardware, structure, transducers, propellants etc. Apart from this, the completion of the second launch pad is an exemplary effort by a consortium of industries, pooling their resources to execute a complex multidisciplinary project.

6. In the spacecraft segment, the 10th Plan period has witnessed strategic partnerships with industries to achieve cost effective and reliable spacecraft subsystems. Some of the major elements that are now being produced by industry include power systems (solar panel and batteries), sophisticated systems such as heat pipes used in spacecraft thermal control, radiation cooler for meteorological imaging instruments and other crucial spacecraft hardware such as optical solar reflectors, spacecraft mechanism elements. In the area of satellite payloads, vendor development activities have been pursued vigorously, with more than 60% of fabrication for mechanical and electronic assemblies now

being carried out through vendors. This approach has released the internal resources for carrying out core developmental and R&D activities towards meeting future challenges.

7. During the 11th plan, emphasis will be on capacity building in industries to meet the throughput requirements for proven satellite and launch vehicle subsystems and ground segment. Given that the number of spacecraft (IRS, GSAT & INSATs) and launch vehicles (PSLV, GSLV and Mk III) required to be realised in 11th plan period are almost three times the quantity witnessed in 10th plan, strategies in the 11th plan would be on Standardisation of subsystems and form out to Industries with bulk ordering approach. Vendor development, vendor qualification, documentation and quality control are the key factors in achieving productionisation through Industries.

8. It is also planned to place systematic efforts to develop Industries to undertake in a progressive manner spacecraft assembly and integration tasks with necessary technical assistance / know-how and training support from ISRO. The role of Industries will be further enhanced with more responsibilities placed on industries right from design to systems engineering, integration and testing of complete rocket stages in terms of launch vehicles and complete satellite subsystems in case of spacecraft. For technologically complex sub-systems a participative approach, right from the design stage may be adopted, resulting in reduced development cycles. Greater thrust would be accorded to reducing cost and improving quality and reliability of products. New sources for manufacturing is planned to be identified and developed to avoid single point dependency as well as reducing the cost by increasing the overall competitiveness.

Academia Interface

9. The professional relationships established by ISRO with academic institutions, national technological institutions/laboratories and universities through Sponsored Research programme RESPOND has been an important component of Space programme over the last 30 years. One of the objectives sought in the programme is capacity creation in universities in terms of expertise and infrastructure in the area of space science, technology and applications. A note worthy development in 10th plan in this direction is the initiative of Anna

University to undertake the development of micro satellite ANUSAT with technical assistance from ISRO.

10. It is planned to further strengthen the RESPOND programme during 11th plan period and expand the network of universities/institutions participating in the programme. There are several advanced R & D and technology development initiatives planned in 11th plan in the area of space transportation system, satellite navigation, planetary missions, atmospheric science and Meteorology which require greater interaction and inputs from Academia. The existing programmes in terms of research projects and space technology cells will be further expanded to enable larger participation of the academia in the space programme.

Commercialisation

11. The tenth five year plan has been very special and significant for Antrix, who have recently bagged two prestigious contracts against stiff competition – one from the European Telecommunication Satellite (EUTELSAT) to build a communication satellite W2M and the other to build Highly Adoptable Satellite HYLAS for Aventi Screen Media. M/S Antrix has achieved steady growth during 10th plan in providing various space services including leasing of transponders to private customers. The Sales turnover of Antrix has recorded an impressive increase of more than four-fold during 10th plan period. The performance of Antrix in 10th plan has provided a strong foundation to take the commercialisation activities during 11th plan to greater heights.

12. The eleventh five year plan will be executed during the rapidly expanding field of globalization where many competitive players would be in the arena for providing infotainment-communication services. The main demand for satellite communication in the 11th FYP period is envisaged from DTH, Broadband users, TV distribution and broadcasting, VSAT, satellite navigation, digital mobile broadcasting, telemedicine & tele-education applications, emergency communication services, etc. In the Indian scenario, DTH is an imminent service, that could lead to an overall channel growth and more demand for transponders.

13. In the manufacturing segment, during the year 2005, out of 19 new commercial telecommunication satellites contracted for manufacture globally, six of them belonged to spacecrafts weighing less than 2.5 tons, which is of I-2K / I

3K class. In the Indian scenario, with DTH being an emerging market, private sector participation could be encouraged to build, own and operate satellite systems for commercial service. Considering the above, it is estimated that there is a global demand of 5 -6 satellites of the < 4Kw power range. Presently, Antrix in partnership with EADS Astrium is executing two such satellite contracts for Europe. Considering the present market trends, Antrix alliance with EADS Astrium is expected to lead to at least one satellite contract per year on a conservative basis.

14. In the remote sensing data business, while the current spacecrafts, viz., IRS-1C & 1D would be phased out, business on Resourcesat and Cartosat-1 would grow further. Business prospects are expected to be enhanced with the planned launches of high resolution Cartosat -2 and RISAT during 2007-2008 time frame. RISAT is expected to contribute towards commercial provision of new data sets. To gain a stronger foothold into the remote sensing data services market, plans are afoot towards creating adequate market infrastructure and another high latitude facility for down linking recorded data, probably, near the polar region.

15. In the launch vehicle segment, operationalisation of PSLV and GSLV (MK-II) with increased launch frequencies is expected to open up new commercial opportunities. The current major orders for full fledged launches on PSLV would be executed by 2006-07. Global market demand during the 11th Plan period, is expected to be around 15 for GTO launch and around 3-6 opportunities for LEO. In addition to the national requirement, two launches (PSLV and GSLV each) are assumed each year, supplemented by the launch of a microsat every year.

International Cooperation

16. India's entry into the space programme rather started with International Co-operation with the establishment of Thumba Equatorial Rocket Launching Station as a co-operative effort and dedicated to UN. Since then, ISRO has come a long way from the phase where international cooperation was looked upon as an opportunity to obtain exposure to advanced technology and training opportunities from developed countries, to a place where ISRO can work together even with the most advanced countries as partners. For ISRO the goal behind cooperation is to promote exchange of scientific knowledge relevant for global welfare, to derive synergies of co-operative endeavours in terms of shared

costs and benefits / experience and to ensure Indian presence in space related matters in international fora.

17. The tenth five year plan witnessed remarkable initiatives and programmes on international co-operation. An Indo-French joint mission "Megha-Tropiques" has been undertaken for study of tropical climate. Indian Lunar Mission Chandrayaan-1 is carrying scientific instruments from USA, Europe and Bulgaria as payloads of opportunity. GSAT-4 and Oceansat-2 satellites are carrying UV Telescope from Israel(TAUVEX) and Atmospheric temperature and humidity profiler (ROSA) from Italy respectively. Canadian space agency is providing assistance in development and testing of UV detectors for Indian Astrosat satellite. An Indo-US conference on Space Science, Applications and Commerce was organised in June 2004 to strengthen and expand the co-operation with USA. The Centre for Space Science and Technology Education for Asia and the Pacific (CSSTE-AP) established under the initiative of the UN has successfully completed 10 years by December 2005 and has emerged as one of the best performing Centres. With these and many other co-operative initiatives with other countries, the International Co-operation of India in Space has become far more stronger and important than before.

18. The thrust of International co-operation during 11^{th} plan will be to continue and further strengthen the ongoing relations with various space agencies. Co-operative programmes in Space science, environment, meteorology, earth science, space education & training and humanitarian services will be pursued with International Agencies. The support for UN sponsored CSSTE-AP will be continued. Joint initiatives on participation in Satellite Navigation programme GLONASS of Russia, joint development of ALTIKA / ARGOS satellite for Oceanography studies with CNES of France and development of Small satellite Youthsat by universities of India and Russia, which are currently in various stages of processing, will be pursued further.

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4.10 ORGANISATION DEVELOPMENT & HUMAN RESOURCES

1. Since its inception, ISRO has been very careful in spotting and recruiting the very best quality manpower from the best of the minds to take up its challenging tasks in hi-tech area. Their innate talent and technical competence together with the challenging complexities of space programme and organizational culture has been bringing out their best in demystifying SPACE. The organization has achieved very high degree of success in the space programme during the last three decades and this could be attributed to the dedicated efforts of scientific and technical staff who enjoyed the excellent support from administrative and auxiliary staff. At present, the organization is supported by nearly 16000 staff working in various projects in different parts of the country, which involves substantial research and developmental efforts. The organization is also well supported by Indian industries in realization of very critical space worthy hardware and software. The students and academicians of innumerable educational institutions of the country have partnered the research efforts in participating in many research projects involving extensive theoretical and experimental efforts.

2. ISRO has also drawn its plans during the 11^{th} plan to provide continuity in space based services and also provide newer services apart from adding value to many of its present services. All these efforts involve development of a host of new technologies resulting in increase in its activities by many folds calling for improvement of its resources both qualitatively and quantitatively. Many of the new initiatives envisages use of newer technologies and also high end design and developmental efforts which will have to be carried out exclusively inhouse. All these efforts requires dedicated team of scientists/engineers conversant with the state of the art technologies and highly skilled technicians to support the design and development efforts. The Department has been successfully containing the manpower growth in spite of the ever-increasing technical activities through partnering with Indian industries where in some of the production, fabrication, testing and software development activities have been outsourced. Few of the routine production jobs, which requires capital intense infrastructure as well as few strategic and security reasons, will have to be taken up inhouse by creating few production islands. In the present assessment of the activities vis-à-vis the existing stock of human resources, it is essential to strengthen the development teams with addition of 700 scientists/engineers.

3. During the 10th plan period, a high level work study group took a holistic review of manpower requirements, while considering the quality, quantity and levels of manpower, required for the targeted objectives. The group also took stock of current manpower stock in terms of their optimum utilization, their attrition pattern, replacement strategy etc. and identified the optimum level of human resources required during the plan period. The exercise resulted in redeployment of more than 500 posts under technical category from areas where the workload decreased considerably due to the successfully outsourcing. In short, the savings achieved in outsourcing of the activities have been carefully redeployed for more critical needs. Similar exercise will be continued during the 11th plan also but little scope exists for re-deployment and there is an imperative need for strengthening the team with quality engineers and technicians for taking extensive research and development and high end design efforts which will have to be initiated internally.

4. Like in previous plan periods, during the 11th plan period, nearly 800 senior scientists will be leaving the organization on superannuation leaving behind a very high standard legacy. The Department has drawn elaborate and properly tuned succession plan for various key positions by identifying highly competent second level personnel at each and every functional entities of all Centres/Units. They are groomed for a smooth changeover from technical assignments to techno-managerial assignments through a series of training and development programmes organized in the professional institutions. However, at the working level, attracting the young talent in the coming years will be a major challenge especially due to the abundance of lucrative jobs in private sectors. Extensive efforts will have to be put by the organization in spotting and recruiting the large number of scientists/engineers in the coming years. ISRO has been contemplating to start its own top class educational and training institute, which will generate high quality engineers and scientists suiting the professional requirements of the organization during the plan period. The curriculum for the professional courses will be fine tuned to suit the state of the art technology to be pursued in the organization.

5. Concerted efforts will be directed towards transforming the organization towards more effective one with best composition of stabilized staff, well in tune with the long term vision, immediate mission requirements and also in synchronization with the stated policies of the government. The working group on Space has suggested to consider the need to setting up separate Centre /

Units for initiates related to Satellite Navigation, Life Support Systems for Manned Mission and EDUSAT ground segment management, which will be pursued during 11th plan. Thrust on continuous improvement in human resources is in focus of the organization vision. Continuous training for middle and senior level management personnel on management, leadership and HR skills apart from professional updates along with re-education programme through sponsorship in reputed management and technical institutes will be the main thrust area. Specialised training on new vistas of technologies and science will be provided to the young engineers/scientists so as to keep them updated in their areas for a better performance in their assignments. Similar training programmes will be planned for administrative and auxiliary services for providing necessary impetus for making administrative and auxiliary services more dynamic and effective in the era of e-governance.

6. Towards improving the Organisation and Methods, development and implementation of Computerised Working in Administrative areas (COWAA) has been an important achievement in 10th plan. COWAA has been implemented in all the Centres and units and has gained acceptance in the system. The work on improved version of COWAA is already in progress. During the 11th plan, the emphasis will be towards process re-engineering and evolving Digital Work Flow system taking best advantage of IT and move towards near-paperless office. Improvements in work methods and simplification of administrative procedures in all the functional areas will be a continuous process.

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5. MISSION PROFILE AND PLAN OUTLAY

1. Based on the projected national requirements for Space technology development and services, the overall Mission Profile envisaged for the time frame 2005-15 encompassing the 11th five year plan and part of 12th five year plan is summarized in Figure 5.1 (excluding User funded / commercial missions).

2. The budgetary resource requirements for the missions planned for 11th plan as well as the advance investments required for the missions planned for the beginning years of 12th plan period, works out to Rs. **39,750 crores**. (at 2006-07 prices) including Rs 5000 crores towards Manned Mission Initiatives. Out of this, the Plan outlay requirements for 11th plan would be Rs. 36,750 crores while the non-plan budgetary support is expected to be Rs. 3000 crores approx. Table 5.1 and 5.2 provides the summary and detailed breakup of the budgetary estimates for 11th plan.

3. Broadly, the outlay projected for 11th plan has six major components viz.,

	Outlay	*%ge wrt Total Outlay*
1. COMPLETION OF MISSIONS INITIATED IN 10 TH PLAN PERIOD (GSLV Mk III, GSLV/PSLV Operational, INSAT-3/4, RISAT, ASTROSAT, Chandrayaan, Megha-Tropiiques, Oceansat-2, Resourcesat-2 and IRNSS)	Rs 6,986 Cr	***18%***
2. NEW MISSIONS TO BE INITIATED AND COMPLETED IN 11th PLAN (GSAT 9-15, ACTS, Resourcesat-3, Cartosat-3, DMSAR-1, GEO-HR, TES-HyS, Altika-Argoes, Chandrayaan-2, Aditya-1, SENSE, I-STAG, IMM & Application missions)	Rs 11,040 Cr	***28%***
3. NEW MISSIONS TO BE INITIATED IN 11TH PLAN FOR REALISATION IN 12TH PLAN AND BEYOND. (RISAT-3, Cartosat-4, Oceansat-3, HyS-Op, TES-Atm, ACTS-3, GSAT 16-18, Astrosat-2, Mars-O, RLV. Semi-cryo development, etc.,)	Rs. 4,804 Cr	***12%***

	Outlay	*%ge wrt Total Outlay*
4. MANNED MISSION INITIATIVES	Rs. 5,000 Cr	***12%***
5. TDPs / R & D / FACILITY REPLACMENT / AUG. / PRODUCTIONISATION / INDIGENISATION / ETC.,	Rs 4,760 cr	***12%***
6. ORGANISATION AND INFRASTRUCTURE MAINTENANCE, GRANT-IN-AID & OTHERS	Rs. 7,160 cr	***18%***
TOTAL	Rs.39,750 cr	***100%***

4. Space is inherently a technology intensive endeavor and long term technology development / R & D is crucial for its long term viability. Accordingly, it can be seen from the above that about 36% of the total outlay proposed for 11th plan (Sl No. 3, 4 & 5) has been towards "Preparing for Future", which includes advance investments for missions planned for realisation in first half of 12th plan, initiatives on technology development / R & D / capacity buildup, advanced propulsion systems development for next generation launch vehicles and Manned Mission initiatives.

5. The tentative annual phasing of expenditure and the plan component therein are as under:

TABLE: PHASING OF EXPENDITURE DURING 11TH PLAN

(*Rupees in Crores*)

YEAR	TOTAL BUDGET	*Plan Component*
2007-08	5,200	4,770
2008-09	6,500	5,920
2009-10	7,900	7,280
2010-11	9,400	8,740
2011-12	10,750	10,040
TOTAL	**39.750**	**36,750**

6. The major thrust 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. With a view to assess the cost-effectiveness of Indian space systems and to determine the benefits derived from Indian Space Programme, an external study carriedout by Madras School of Economics has examined the investments made in space, undertook a detailed economic costing exercise to derive the unit costs of products and different services provided by ISRO, estimated the tangible benefits and identified the intangible benefits. 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. A comparative cost analysis of remote sensing satellites and launch vehicles is rather difficult due to the nexus between civil and military projects, subsidies and secrecy, differences in capabilities and non-availability of reliable estimates. Despite this limitation, the data available on the development costs of Ariane launcher of European Space Agency indicates that the development costs of Indian launch vehicles is almost one-third the development costs observed in foreign launchers like Ariane. The reported costs of LANDSAT (US) and SPOT(French) remote sensing satellites are several factors higher than the cost of Indian IRS-1D which has comparable capability. These estimates amply demonstrate cost-effectiveness of Indian satellites and launch vehicle programmes.

8. Space Programme generates many benefits, some of them are tangible while many others are intangible and are important to achieve the goals of national development. The output basket of the space program contains a mix of private goods, public goods, social goods and strategic/incommensurable goods. While a comprehensive detailing of all the benefits is outside the scope of this note, some of the important benefits of space programme are highlighted in the following paragraphs.

9. The major benefits of the INSAT system to Doordarshan are expansion in area coverage from 13.7 percent in 1983 to 77.5 percent , population coverage from 25.7 percent in 1983 to 89.6 percent , increases in the number of channels from 2 to 32, remote area coverage, Satellite News Gathering (SNG), dissemination of weather and cyclone warning, use of TV as a media for social development programmes, agricultural advisory services, education and training. The growth of satellite TV has also aided in the emergence of new economic activities. The advent of satellite TV contributed to the growth of several industries like the manufacturing of TV sets, cables, receiving antenna and other equipment and program production. There are about 100,000 cable TV operators and about 35 million cable TV households in the country. The gross earnings of cable TV operators is nearing Rs. 10 billion. Studies show that the satellite is the only cost-effective way of achieving 100% (by population) TV coverage for the country.

10. In telecommunications, the niche areas for satellite technology are remote area communication, Village Public Telephone (VPTs), back-up facility, portable terminals for disaster management, prospecting and expeditions, Search & Rescue (SAR) services and satellite navigation. All these services yield many social benefits such as connectivity to urban markets/government offices, social and community services and removing the sense of isolation. In remote area communication alone, there is considerable cost saving due to use of satellite technology compared with optical fiber cable (OFC) network. The study found that the cost of connecting 393 remote areas (currently served by INSAT) by OFC to the main network is estimated at Rs.2358 crore. It may be noted that about 30,400 villages in mountain, forest, and desert areas can be connected to the rest of India only by using satellite technology in a cost effective manner.

11. Satellites have made significant contributions to the generation of meteorological information by extending observation to oceans and remote areas on land, enabling generation of new types of observations, facilitating new concepts of data assimilation into models, reducing costs of a few types of observations and enhancing the reliability of certain types of data. The contribution of satellites for detection of cyclones is very high. A comparative study of 1977 (before INSAT) and 1990 (after INSAT) cyclones which hit Andhra Pradesh, shows that even though the two cyclones are similar, due to the

successful tracking of the cyclone in 1990 with the INSAT imaging instrument (VHRR) and the success of preparatory steps taken by the government, the loss of lives in 1990 was only 817 compared with 10,000 in 1977. This is an important incommensurable benefit of satellite technology.

12. 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, hydrogeomorphological 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.

13. The spin-offs 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 and given the control regimes and the import restrictions operative in the area of space, it is difficult to attach a value for the technologies realized in-house.

14. 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.

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TABLE 5.1: BUDGETARY OUTLAY- 11TH PLAN 2007-2012

SUMMARY

(PLAN + NONPLAN)

(RS. IN CRORES)

A	**TECHNOLOGY DEV. & PROJECTS**			
1	**OPERATIONAL MISSIONS**			
	* SATELLITE MISSIONS			
	(a) Satcom missions	4700.00		
	(a) Navigation missions	2420.00		
	(a) EO missions	2730.00		
	* LAUNCH VEHICLES	4468.00	**14318.00**	***36%***
2	**ADVANCED TECHNOLOGY MISSIONS**			
	* GSLV MK III	1000.00		
	* RLV & ABP RELATED	534.00		
	* MANNED MISSION INITIATIVES	5000.00		
	* SEMI-CRYO DEVELOPMENT	1800.00		
	* 600KN CRYO DEVELOPMENT	700.00		
	* SRE & OTHER MISSIONS	120.00	**9154.00**	***23%***
3	**R & D / TDP / INDIGENISATION /**		**4821.00**	***12%***
	INFRASTRUCUTRE / CAPACITY BUILDUP			
	TOTAL - TECHNOLOGY & PRJOECTS		**28293.00**	***71%***
B	**SPACE SCIENCE / ATMOSPHERIC**			
	SCIENCE PROGRAMME.			
	* PLANETARY EXPLORATION	1050.00		
	* ASTRONOMY & ASTROPHYSICS	325.00		
	* SPACE WEATHER	300.00		
	* CLIMATE & METEOROLOGY	125.00		
	* ATMOSPHERIC SCIENCE RELATED	358.00		
	* AUXILIARY SPACE SC. ACTIVITIES	387.00	**2545.00**	***6%***
C	**SPACE APPLICATIONS**		**1752.00**	***4%***
	(DMS, VRC, Tele-education, Tele-medicine			
	NR Management, etc.,)			
D	**ORGANISATION & MAINTENANCE**		**7160.00**	***18%***
	GRAND TOTAL		**39750.00**	***100%***

DEPARTMENT OF SPACE

ELEVENTH FIVE YEAR PLAN 2007-12

TABLE 5.2: BUDGETARY PROJECTIONS

(PLAN + NONPLAN)

11THPLAN BUDGET REQUIREMENT / 26.7.06 *(RUPESS IN CRORES)*

10TH PLAN OUTLAY APPROVED	10TH PLAN OUTLAY ACTUALS	PROGRAMME	*Total Cost (Projects)*	*11th plan Cashflow*
		1. SATELLITE COMMUNICATIONS		
		Ongoing carried forward from 10th plan		
		1.1 INSAT-3D	200	70
		1.2 INSAT-3D Launch Services	10	10
		1.3 GSAT-4	99	20
		1.4 GSAT-5 / INSAT - 4D	124	50
		1.5 GSAT-6 / INSAT - 4E	269	200
		1.6 GSAT-8 / INSAT - 4G & Launch Services	610	500
		1.7 INSAT-4CR	95	50
		Subtotal	**1407**	**900**
		New Initiatives of 11th plan		
		1.8 GSAT-9, 12 & 13 (2 T bus)	600	600
		1.9 GSAT-10, 11, 14 & 15 (4T bus-MkIII launch)	1200	1200
		1.10 ACTS 1 & 2 (procured launch)	1600	1600
		1.11 Short term leasing of Tx	100	100
		1.12 Pre-investment for followon satellites	900	300
		Subtotal	**4400**	**3800**
2965	**2496**	**SUBTOTAL - 1**	**5807**	**4700**
		2. SATELLITE NAVIGATION		
	100	2.1 IRNSS	1420	1370
		2.2 Participation in global systems	1000	1000
40	60	2.3 GAGAN	50	50
40	**160**	**SUBTOTAL - 2**	**2470**	**2420**
		3. SATCOM/SATNAV APPLICATIONS		
165	190	3.1 Tele-education	150	150
10	35	3.2 Tele-medicine	150	150
	6	3.3 Science Channel	50	50
		3.3 Satellite Navigation applications	50	50
20	85	3.4 New / Other Satcom applications	200	200
195	**316**	**SUBTOTAL - 3**	**600**	**600**

(RUPESS IN CRORES)

10TH PLAN OUTLAY APPROVED	10TH PLAN OUTLAY ACTUALS	PROGRAMME	*Total Cost (Projects)*	*11th plan Cashflow*
		4. EOS MISSIONS		
		Ongoing carried forward from 10th plan		
		4.1 RISAT-1	378	100
		4.2 RESOURCESAT-2	139	120
		4.3 OCEANSAT-2	129	60
		4.4 MEGHA-TROPIQUES	82	55
		Subtotal	**728**	**335**
		New Initiatives of 11th plan		
		4.5 GEO-HR Imager	275	275
		4.6 ALTIKA & ARGOS	100	100
		4.7 TES-HyS	300	300
		4.8 RESOURCESAT-3	150	150
		4.9 CARTOSAT-3	300	300
		4.10 DM-SAR - 1	300	300
		4.11 OCEANSAT-3	300	300
		4.12 TES-Atm	150	100
		4.13 RISAT-3	375	300
		4.14 RISAT-4L	375	120
		4.15 INSAT-3D Followon	100	50
		4.16 Preinvestment - Followon missions	100	100
		Subtotal	**2825**	**2395**
1215	**685**	**SUBTOTAL - 4**	**3553**	**2730**
		5. EO APPLICATIONS		
10	8	5.1 Pre-investment application Programs	25	25
30	33	5.2 EOAM	50	50
		5.3 Aerial survey and utilisation	30	30
		5.4 NRSA applications projects	50	50
		5.5 North-East region specific applns	25	25
		5.6 SAC application projects	50	50
		5.7 RRSSC application projects	10	10
75	**63**	**SUBTOTAL - 5**	**240**	**240**
		6. NNRMS & SNRMS		
120	83	6.1 NR Census	80	80
100	60	6.2 NRDB	40	40
30	24	6.3 Large Scale Mapping Programme	50	50
		6.4 High resolution DEM from Cartosat	50	50
		6.5 National soil moisture mapping	10	10
		6.6 Cadastral level resource mapping	50	50
		6.7 Rural infrastrucutre assessment	20	20

(RUPESS IN CRORES)

10TH PLAN OUTLAY APPROVED	10TH PLAN OUTLAY ACTUALS	PROGRAMME	*Total Cost (Projects)*	*11th plan Cashflow*
		6.8 Geological / mineral exploration	20	20
25	15	6.9 NNRMS - Grants and Training	20	20
10	10	6.10 SNRMS Support	20	20
		6.11 Support to States	30	30
	1	6.12 IRS Promotional efforts	5	5
	4	6.13 NNRMS Secretariate	5	5
5				
290	**197**	**SUBTOTAL - 6**	**400**	400
		7. INTEGRATED SPACE TECHNOLOGY		
		SERVICES		
70	151	7.1 DISASTER MANAGEMENT SUPPORT	212	212
	30	7.2 VILLAGE RESOURCE CENTRES	300	300
70	**181**	**SUBTOTAL - 7**	**512**	**512**
		8. SPACE SCIENCE, ATMOSPHERIC SCIENCE		
		& ENVIRONMENT RESEARCH		
		Missions carried forward from 10th plan		
145	112	8.1 ASTROSAT-1	178	100
240	248	8.2 CHANDRAYAAN-1	386	250
		Subtotal	**564**	**350**
		New Missoins Initiatives of 11th plan		
		8.3 CHANDRAYAAN 2 & LUNAR OBSERVATORY	500	300
		8.4 Mars Orbitor	525	300
		8.5 Asteroid orbitor and Comet fly by	525	150
		8.6 Flyby to Outer Solar System	525	50
		8.7 ASTROSAT-2	280	100
		8.8 ADITYA	125	125
		8.9 SENSE - E & P	100	100
		8.10 IMM	200	200
		8.11 ISTAG	125	125
		Subtotal	**2905**	**1450**
		Other Ongoing Programmes		
		8.12 SPACE SCIENCE INSTRUMENTATION	200	200
30	2	8.13 MICROGRAVITY RESEARCH	50	50
15	8	8.14 SOUNDING ROCKETS	200	55
158	200	8.15 PRL PLAN COMPONENT	54	54
		8.16 PLANETARY SCIENCE	50	40
		8.17 SPACE SCIENCE PROMOTION	25	25
		8.18 NARL PLAN PROGRAMMES	80	80

(RUPESS IN CRORES)

10TH PLAN OUTLAY APPROVED	10TH PLAN OUTLAY ACTUALS	PROGRAMME	*Total Cost (Projects)*	*11th plan Cashflow*
		8.19 SPL PROGRMMES	5	5
15	32	8.20 GEOSPHERE BIOSPHERE STUDIES	74	74
		8.21 MEGHA-TROPIQUES DATA UTILISATION	20	20
		8.22 ATMOSPHERIC SCIENCE PROGRAMME	142	142
705	**673**	**SUBTOTAL - 8**	**4369**	**2545**
		9. LAUNCH VEHCILE DVELOPMENT		
		Ongoing carried forward from 10th plan		
200	212	9.1 GSLV MK I	1405	10
80	49	9.2 CUSP	336	1
1685	1614	9.3 GSLV MK III DEVELOPMENT	2498	1000
900	632	9.4 GSLV Operantional F01-F10	2270	1600
765	493	9.5 PSLV Continuation C1-C13	1345	300
		9.6 SRE 2 & followon	120	120
		Subtotal	**7974**	**3031**
		Operational missions of 11th plan		
		9.7 GSLV Operantional F11-F13	438	438
		9.8 PSLV Continuation C14-C28	1330	1330
		9.9 GSLV Mk III Operational F01-F03	1365	800
		Subtotal	**3133**	**2568**
		Advanced Launch vehicle programmes		
50	35	9.10 RLV-TD	330	330
		9.11 DMRF-FTD	34	34
		9.12 Manned Mission Initiatives	10000	5000
		9.13 Air breathing Propulsion	100	100
		9.14 RLV-TSTO	70	70
		9.15 Advanced Propulsion systems development	2500	2500
		Subtotal	**13034**	**8034**
3955	**3246**	**SUBTOTAL - 9**	**24141**	**13633**
30	**15**	**10. SMALL SATELLITE SYSTEMS**	**100**	**100**
220	**190**	**11. TECHNOLOGY DEVELOPMENT PROGRAMME**	**693**	**693**
120	**105**	**12. ADVANCED R&D**	**126**	**126**
900	**820**	**13. TECHNICAL FACILITIES - REPLACEMENT/AUG.**	**2017**	**2017**
80	**189**	**14. INDIGENISATION DEVELOPMENT**	**487**	**487**
		SPACE MATERIALS AND COMPONENTS		

(RUPESS IN CRORES)

10TH PLAN OUTLAY APPROVED	10TH PLAN OUTLAY ACTUALS	PROGRAMME	*Total Cost (Projects)*	*11th plan Cashflow*
158	195	15. INDUSTRY INTERFACE / PRODUCTIONISATION	296	296
80	42	16. ADVANCE PROCUREMENTS / STOCK PILING	156	156
		OF CRITICAL COMPONENTS		
25	15	17. INTERNATIONAL PROGRAMME	25	25
80	54	18. SPONSORED RESEARCH	150	150
10		19. COMMERCIALISATION EFFORTS	10	10
3367	3297	20. ORGANISATION & INFRASTRUCTURE	7160	7160
		MAINTENANCE, FACILITY		
		OPERATIONS, HRD, ETC.,		
300	199	21. LAND & GENERAL CIVIL WORKS	450	450
175	55	22. HOUSING	300	300
15,250	**13,242**	**GRAND TOTAL**	**54,062**	**39,750**
13,250	**11,502**	PLAN COMPONENT		**36,750**
2,000	**1,740**	NON-PLAN COMPONENT		**3,000**

APPENDIX - A

Department of Space

TENTH FIVE YEAR PLAN (2002-2007)

PROGRAMMATIC TARGETS AND ACHIEVEMENTS
(Achievements up to March 2006 and Targets for 2006-07)

1. The Tenth Five Year Plan proposals have been formulated under the framework of a long-term Plan after extensive interactions, detailed studies and consultations within the organisation as well as with user community. The programmes and the Mission Profile have been based on the national developmental needs in the social and economic sectors. The following are the major highlights of the plan programmes envisaged during the Tenth Plan in the area of Launch Vehicle Development, Earth Observation Systems, Satellite Communications & Meteorology (INSAT, GSAT & METSAT), Space Science Programme and Space Applications Programme including Disaster Management Support.

Launch Vehicle Development:

10th Plan Targets:

2. In the area of ***Launch Vehicle Development***, the major target for the 10th Plan was to complete the development flights and to operationalise the GSLV (with indigenous cryogenic upper stage) for launching 2T INSAT class of satellites. It was also planned during the 10th Plan to initiate the development of an advanced GSLV Mk III capable of launching 4T INSAT type of satellite with a target to realise the first development flight during the beginning of 11th Plan. PSLV would remain as the work horse vehicle for Earth Observation and Space Science and Meteorology Satellites and further improvement in capability and performance of PSLV would continue. The construction of Second Launch Pad at Srlharikota was also targeted for completion during the 10th Plan period. Besides this, in tune with the long-term vision of low cost access to space, advanced R & D in Reusable Launch Vehicles (RLV) would be pursued and towards this, smaller-scale technology demonstrator in the areas of air breathing propulsion technology and space capsule recovery missions were planned in the 10th Plan.

3. *Achievements up to March 2006 and Targets of 2006-07*

(a) GSLV has been operationalised after its second successful test flight GSLV D2 on 8th May 2003 launching GSAT-2 satellite into orbit followed by the first operational flight GSLV F01 on 20th September 2004 launching GSAT-3(Edusat) into orbit. This has been a major milestone of achieving self-

reliance in launching 2 tonne class of satellites into geosynchronous transfer orbit. India is one among the six countries in the world that possesses this type of launch capability. The next flight GSLV F02 carrying INSAT-4C satellite is planned for launch in the first quarter of 2006-07.

(b) PSLV, India's workhorse launch vehicle, recorded its Eighth consecutive successful flight with the launch of Cartosat-1and HAMSAT satellites on 5th May 2005. The next PSLV flight is slated for launch during 2006-07 carrying Cartosat-2 and SRE-1 into orbit.

(c) PSLV's geosynchronous launch capability has been demonstrated through launch of dedicated meteorological satellite METSAT-1(950 kgs) on 12th September 2002.

(d) PSLV's payload liftoff capability has been enhanced with high performance motor for third stage and improved tankages for fourth stage. Development of dual launch adopter is in progress.

(e) Indigenous Cryogenic Engine has been successfully qualified after a series of tests for accumulated duration of more than 7000 seconds. Work on Cryogenic Stage (to replace the Russian supplied stage in GSLV) is in progress. The qualification tests on the indigenous Cryo Stage are in progress. The realisation of flight version of the Cryo stage is targeted for 2006-07.

(f) Significant progress is achieved in development of GSLV Mk III capable of launching 4T satellites to GTO – Design completed, fabrication activities and establishment of critical facilities in advanced stages.

(g) Second Launch Pad has been realized, tested and commissioned at Satish Dhawan Space Centre, Sriharikota. Second Launch pad will enable operational launches with quick turn around time besides accommodating advanced launch vehicles like GSLV Mk III. The Second Launch Pad is now ready to launch PSLV and GSLV. The maiden launch from Second Launch Pad took place on 5th May 2005 for PSLV C6.

(h) An integrated R & D programme for Reusable Launch Vehicles has been initiated. A Space Capsule Recovery Experiment (SRE-1) – an important initiative in this direction, is planned for launch onboard PSLV in 2006-07.

Earth Observation Systems

10th Plan Target:

4. The ***Earth Observation (EO) System*** during 10th Plan was directed towards enhancing the imaging capability and maintaining the leadership with a constellation of multi-spectral, high resolution, stereo imaging sensors and providing continuity of EO data for resource management applications. One of the important targets of 10th Plan was to undertake the Radar Imaging Satellite (RISAT-1) mission with active microwave sensor, such as, Synthetic Aperture Radar which provides all-weather capability crucial for many vital applications. Besides completion of the ongoing IRS-P5 (Cartosat-1) and IRS-P6 (Resourcesat-1) projects which were spill over missions of 9th Plan, the other EO missions planned for 10th Plan included Cartosat-2 with stereo mapping capabilities for urban and rural applications, and Oceansat-2 for ocean and coastal applications.

5. *Achievements up to March 2006 and Targets of 2006-07*

(a) *RESOURCESAT-1 (IRS-P6), the state-of-art remote sensing satellite has been launched on 17th October 2003 onboard India's PSLV and operationalised for natural resource management applications. RESOURCESAT-1 data is received globally through a network of international ground stations.*

(b) *CARTOSAT-1, an advanced Satellite for mapping applications has been successfully launched on 5th May 2005 onboard PSLV C6. The satellite is functioning satisfactorily and the quality of the imageries sent by the satellite are found to be very good. The data from the Cartosat-1 satellite is used for generating / updating large scale cartographic maps, generating digital elevation models for engineering and environmental applications, rural and urban infrastructure and utility planning, micro level water shed planning and disaster management support applications.*

(c) *Work on development of Cartosat-2 is in advanced stages. The payload systems have been realised and the integration of the satellite is in progress. The launch of Cartosat-2 is planned in 2006-07. Development of the microwave payload for Radar Imaging Satellite (RISAT), a satellite intended to provide all-weather remote sensing capability with microwave sensors has been progressing well. RISAT is an important initiative in Indian Remote Sensing Programme crucial for applications in the area of Disaster Management, Agriculture & Forestry. RISAT is targeted for launch in 2007-08. Government have approved the followon satellites Oceansat-2 and Resourcesat-2 and the work on payload realisation and spacecraft design has been initiated.*

INSAT System (including GSAT & METSAT):

10th Plan Targets:

6. The major thrust of the ***INSAT programme*** during the 10th Plan was towards augmenting the space segment capacity of the INSAT system to about 175 Transponders, based on the demand for transponders in governmental and social sectors. Towards meeting this requirement, it was planned to complete the ongoing INSAT-3A & 3E satellites followed by next generation INSAT-4 series comprising of seven satellites out of which three (INSAT-4A,4B & 4C) were planned to be launched in 10th Plan period. Besides this, low cost experimental GSAT satellites viz., GSAT-2,3 & 4 for the developmental flights of GSLV were also planned. An Advanced Communication Technology Satellite (ACTS) to develop and demonstrate advanced communication techniques and technologies for future generation INSATs was planned to be initiated during the 10th Plan period. Meteorological *services* were planned to be substantially enhanced during the 10th Plan through establishment of dedicated meteorological satellites (METSATs) as well as through advanced missions (INSAT-3D) incorporating improved / new payloads.

7. *Achievements up to March 2006 and Targets of 2006-07*

(a) INSAT-3A and 3E have been successfully launched on 10th April 2003 and 28th September 2003 respectively. EDUSAT (GSAT-3), a dedicated satellite for spreading education in the country has been launched successfully on 20th September 2004 onboard India's GSLV.

(b) Work on fourth generation INSAT-4 has been initiated. The first satellite in the series, INSAT-4A with high power transponders has been successfully launched onboard Ariane on December 22, 2005 and operationalised. The INSAT / GSAT system currently have 175 transponders in C, Ext-C, Ku and S bands, thus meeting the 10th plan target.

(c) The INSAT-4C, carrying 12 C band transponders was launched onboard GSLV F02 on 10th July 2006, but the launch was unsuccessful due to malfunction of one of the L40 strapon stages. Work on replacement satellite INSAT-4CR has been initiatied. Work on INSAT-4B is in progress and is planned for launch during first quarter 2007. Work on INSAT-4D/GSAT-5 and INSAT-4E/GSAT-6 (for multi-media video broadcast applications) has also been initiated.

(d) GSAT-4, incorporating advanced communication technologies like Ka band regenerative payloads, onboard processing and other broad band technologies is progressing well. The payload development is in progress and the satellite is targeted for launch in 2006-07.

(e) METSAT-1 (redesignated as Kalpana-1), a dedicated meteorological satellite has been launched and operationalised on 12th September 2002 onboard India's PSLV. Work on advanced meteorological satellite INSAT-3D is progressing well and the launch is targeted for 2007-08.

(f) An application specific micro satellite HAMSAT has been successfully launched as a co-passenger payload on 5th May 2005 onboard PSLV C6. HAMSAT is a significant contribution by India to the international community of Amateur Radio Operators.

(g) Studies on finalisation of payload and spacecraft configuration for Advanced Communication Satellite are nearing completion. Some of the advanced communication technology initiatives have already been incorporated in GSAT-4 mission.

Space Science Programme:

10th Plan Targets:

8. The thrust of the Space Science Programme during the 10th Plan period would be towards investigations in the new, emerging and challenging areas of Space Science research including Planetary Science / Exploration and Micro Gravity Science. A dedicated and state-of-art Indian Multi-wavelength Astronomy satellite "ASTROSAT" was planned during the Tenth Plan for detailed scientific investigations on celestial X-ray sources. An ISRO-CNES (France) joint mission "MEGHA-TROPIQUES" for study of tropical weather system was yet another important climatic research mission planned for 10th Plan. It was also planned to undertake work on Indian Lunar Mission during 10th Plan dedicated for planetary exploration / studies.

9. *Achievements up to March 2006 and Targets of 2006-07*

(a) Work on Chandrayaan-1, India's first scientific mission to the Moon has been initiated after obtaining approval of the Government in September 2003. The primary objectives of the mission are to expand the scientific knowledge about the origin and evolution of the Moon, upgrade India's technological capabilities and provide challenging opportunities to the young scientists working in Planetary Sciences. Chandrayaan will image the Moon's surface using high resolution remote sensing instruments in the visible, near infrared, low and high energy X-ray regions. The spacecraft and payload design and development is in progress. The evaluation and selection of payloads from international Institutions for Chandrayaan-1 have been completed and six payloads from USA and Europe have been included in the Mission. An Impactor payload has also been incorporated in the Mission to study the composition of near-moon surface as well as to derive

technological inputs for possible future moon landing mission. Chandrayaan-1 is slated for launch in 2008 using India's PSLV.

(b) The ASTROSAT, a multi-wavelength Indian X-ray astronomy satellite, for spectral studies of galactic and extra-galactic sources of X-rays has been approved by the government in August 2004 and the Payload development is in progress. Launch is scheduled in 2007-08 onboard PSLV.

(c) The work on Megha-Tropiques, an ISRO-CNES joint mission for climatic and atmospheric research in tropics, approved in October 2004, is in progress. A Memorandum of Understanding has been signed between ISRO and CNES (French) for implementation of this project.

(d) A five-year research programme on Middle Atmospheric Dynamics (MIDAS) has been initiated in November 2002 involving launching of a series of 180 sounding rockets, 80 balloons and 80 radiosonde. About 117 sounding rockets and balloons have been launched so far (up to March 2006) as a part of this programme. The study is expected to enhance the understanding of the Indian Monsoon variability.

(e) A special programme on measurement of aerosols employing land-campaign measurement, balloons, aerial surveillance and satellite data have been undertaken. Two major land campaign measurements with well calibrated instruments has been conducted in February 2004 and December 2004. The data derived from the programme on ambient air quality in the country will form an important input for atmospheric radiation budgeting and Global Change Studies.

(f) Two scientific payloads viz., Coherent Radio Beacon Experiment (CRABEX) for ionosphere studies and Solar X-ay spectrometer (SOX) for study of solar flares have been flown onboard GSAT-2 satellite launched on 8th May 2003.

(g) An instrumented Balloon Flight with Indian built Cryo Sampler has been conducted on April 20, 2005 for scientific investigations on the Microorganisms at stratospheric heights. The analysis of the air samples collected during the flight is in progress.

Space Applications Programme:

10th Plan Targets:

10. The major thrust of the space programme during 10th plan was on large scale applications of space technology in the priority areas of national development. Expansion of the Satellite based communication network for socially and nationally relevant services in the area of education and literacy, health-care and

rural development would be a thrust area of application. The Natural Resources Census and hot spot identification, Natural Resource Data Base (NRDB) and improved data for weather forecasting were among the vital applications initiatives planned with Earth Observation (EO) data. Besides this, Disaster Management Support was identified as a key area of space applications to provide space based services to the Disaster Management System in the country on a timely and reliable basis.

11. *Achievements up to March 2006 and Targets of 2006-07*

(a) ***Tele-medicine**: The Tele-medicine network - a novel application of space technology to bring health care to remote locations of the country – has been established on a pilot basis connecting 134 District Hospitals in rural and remote areas including the Andaman and Nicobar, Laksha Dweep, North-East areas and J&K to 42 speciality hospitals in major cities. The implementation of an operational system for delivery of Tele-medicine services to remote and rural areas covering the entire country would be undertaken by the Health Ministry and the respective State Governments in a progressive manner and the Ministry of Health have constituted a National Task Force in this regard.*

(b) ***Tele-education**: EDUSAT pilot projects have been set up in Karnataka (885 satellite terminals) , Maharashtra (75 terminals) and Madhya Pradesh (25 terminals) as a precursor to the nationwide EDUSAT programme. As a follow-on of the pilot phase, various users have shown keen interest in setting up EDUSAT based network in the country. Currently, more than 8000 EDUSAT class rooms are operational in the country benefiting more than 2 lakh students. The expansion of the EDUSAT network is progressing well.*

(c) ***Disaster Management Support**: Creation of national level digital data base for all the hazard prone districts of the country to support hazard zonation and facilitate quick decision making process for Disaster Management applications has been taken up. Setting up of a Decision Support Centre as a real time single window agency to provide space based services for the Disaster Management System of the country has been completed. During the flood season in 2003, 17 major flood events were monitored in Assam, Bihar, Orissa, West Bengal and UP using the IRS and other satellites data. Similar support has been extended during the major floods in Jun-July 2004 in the States of Assam, Bihar, Meghalaya, Tripura and Arunachal Pradesh. Monitoring support for the Pareechu artificial lake formed in August 2004 in the Sutlej basin due to land slide and the associated flood hazard has been provided using satellite data. Space services (Emergency Communications, Tele-medicine, Airborne survey and*

Satellite data) have been provided to facilitate relief, rescue and rehabilitation operations in the areas severely affected by Tsunami that struck Indian coasts in December 2004. Development of INSAT based Emergency Communication terminals for rapid deployment in disaster prone areas has also been taken up. Initiatives on setting up of a Virtual Private Network (VPN) connecting Ministry of Home Affairs with 20 district Nodes for real time exchange of critical information and data related to floods, cyclones, drought, land slides, forest fires, etc., is in advanced stages of completion.

(d) ***Village Resource Centres**: Initiatives have been taken for establishment of Village Resource Centres (VRC) to provide integrated space enabled services through a single window system. The services of VRCs include tele-medicine, tele-education, Geo-spatial information on natural resources, natural disasters, environment and infrastructure along with other community-centric e-governance related services. The first 4 VRCs have been established jointly with M/S MS Swaminathan Research Foundation, Chennai in October 2004. Currently, 109 VRCs are functioning in various parts of the country and locations have been identified for setting up additional 219 VRCs.*

(e) ***Remote Sensing Applications**: Several application missions of national importance have been undertaken. Under the National Drinking Water Mission, preparation of Ground water prospect maps using IRS data has been completed for 10 States under Phase I & II covering about 2 lakh habitations in the country. IRS data is used for generating advisories to Fishermen on the potential fishing zones. A comprehensive mapping of the Waste lands of the country has been carriedout using IRS data as in input for Waste land development. The other applications included crop acreage and yield estimation for major crops, bio-diversity characterisation of the major regions – Central India, Eastern Ghats and Mangroves of the East Coast, Water shed development, urban planning, infrastructure planning.*

(f) ***NNRMS**: Initiatives have taken to establish a Natural Resource Repository focussing on the spatial data assets generated through various projects and to enable Natural Resource based services at government, citizen and at commercial level through a well designed NNRMS portal. Preparation of the land use map of the whole country using IRS data on 1:250,000 scale has been taken up to provide annual assessment of status and changes in land use / land cover on district-wise basis as an important input for natural resource planning and management.*

(g) ***GAGAN-TDS**: A satellite based Communication, Navigation and Surveillance (CNS) / Air Traffic Management (ATM) system, "GAGAN" GPS And GEO*

Augmented Navigation) has been initiated jointly with the Airport Authority of India towards enhancing the air navigation services safety in the country. GAGAN will play an important role in providing satellite based navigation services in the Asia Pacific region. The establishment of ground segment facilities is in advanced stages. GAGAN will enhance the Air navigation services in the country with improved positioning accuracies. Participation in the Global positioning system and formation of an Indian Regional Satellite Navigation System is also under consideration for approval.

Mission Profile

12. The Mission profile envisaged for the 10th Plan (2002-07) period based on the demand for space services includes a total of 32 Missions comprising of 18 Satellite Missions and 14 Launch Vehicle Missions (excluding Space Capsule Recovery Experiment and Small Satellite Systems), is summarised below:

Year	Satellite Mission	Launch Vehicle Mission	*Current Status*
2002-03	1. METSAT-1	1. PSLV-C4	*Launched on 12th Sep 2002.*
	2. INSAT-3A	**Procured Launch**	**Launched on 10th April 2003.**
	3. GSAT-2	2. GSLV-D2	*Launched on 8th May 2003.*
	4. Resourcesat-1 (P6)	3. PSLV-C5	*Launched on 17th October 2003.*
2003-04	5. INSAT-3E	**Procured Launch**	***Launched on 28th September 2003.***
	6. GSAT-3 (Edusat)	4. GSLV-F01	**Launched on 20th September 2004.**
	7. Cartosat-1 (P5)	5. PSLV-C6	*Launched on 5th May 2005*
2004-05	8. INSAT-4A	**Procured Launch**	*Launched on 22nd December 2005.*
	9. INSAT-3D	6. GSLV-C	*Dev. in Progress* ***Spillover to 11th plan***
	10. Cartosat-2	7. PSLV-C7	*Planned for October 2006.*
2005-06	11. INSAT-4B	**Procured Launch**	*Planned for 2006-07*
	12. GSAT-4	8. GSLV-D3	*Planned for Feb 2007*
	13. ASTROSAT	9. PSLV-C8	*Dev. in Progress* ***Spill over to 11th plan***

Year	Satellite Mission	Launch Vehicle Mission	*Current Status*
	14. RISAT-1	10. PSLV-C9 / GSLV	*Dev. in Progress* ***Spill over to 11th plan***
	15. METSAT-2	11. PSLV-C10	*Schedule to be firmedup*
2006-07	16. INSAT-4C	12. GSLV-C	*Launched on 10th July 2006. (Launch unsuccessful)*
	17. OCEANSAT-2	13. PSLV-C11	*Dev. in progress.* ***Spill over to 11th plan***
	18. Megha-Tropiques	14. PSLV-C12	*Dev. in Progress* ***Spill over to 11th plan***
Planned	*18*	*14*	**32**

Financial Outlay:

13. Planning Commission have fixed the Plan outlay for Department of Space at Rs. 13,250 crores for the 10th Five Year Plan. With the expected Non-Plan component of Rs. 2000 crores, the total outlay for 10th Plan would be Rs. 15,250 crores.

14. The total expenditure of the Department during the 10th plan period would come to Rs. 13,242 crores approx. comprising of Plan component of Rs. 11,502 crores and Non-plan component of Rs. 1740 crores. Budget utilisation of more than 99% of the final approved grant has been maintained during the first three years of the plan period. The observed shortfall of Rs. 1748 crores under Plan is essentially due to Savings in INSAT-4 costs, Savings in Land/Civil works and Infrastructure operations cost and Phasing out of expenditure on PSLV/GSLV Continuation and EO followon missions based on programmatic schedules. However, final picture on financial status of 10th plan outlay would emerge during RE 2006-07, the last year of the 10th Five Year Plan.

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APPENDIX - B

Department of Space

Formulation of 11th Five Year Plan

SALIENT POINTS OF THE WORKING GROUP MEETING ON SPACE

Meeting Date: 23rd August 2006.

Venue : Vigyan Bhawan, Hall 3, New Delhi.

Time : 1030 hrs to 1600 hrs

The National level steering committee on S & T have constituted a Working Group under the Chairmanship of Dr. G Madhavan Nair, Chairman, ISRO / Secretary, DOS to suggest plans and programmes for the Department of Space for 11th five year plan. The Working Group met on 23rd August 2006 at Vigyan Bhawan, New Delhi and discussed the 11th plan proposals of Department of Space. The meeting, attended by about 22 working group members / representatives, evoked good response on various Programmatic and Policy aspects of the Space programme. Senior Scientists from ISRO / DOS including Directors of ISRO Centres and Additional Secretary also participated in the meeting. The day-long meeting centered around the draft 11th plan proposals document made available to the members in advance and the presentations on the Programme proposals by Programme Offices of ISRO Hq.

The salient points emerged during the meeting are briefly summarized below:

1. ISRO has given a very strong push to Satellite based Tele-medicine by setting up the network on a pilot scale and demonstrated its efficacy and we are now in a position wherein the user ministry can takeoff for country-wide implementation on an operational basis. It has vast potential to augment the health infrastructure of the country to rural and remote areas. It is necessary to workout a plan of action with Ministry of Health and Welfare for large scale expansion of Tele-medicine.

12. Semicryogenic development proposed in 11th plan is a very welcome initiative in the launch vehicle area and would eventually replace L110 of GSLV Mk III. Man rating of this vehicle with additional redundancies as required is important. With regard to concept of unified launch vehicle, it is necessary to keep the number of new stages to be developed to absolute minimum so that development time cycle is also reduced.

13. Life support systems for manned mission is a different kind of activity which ISRO has not got involved earlier. The close cycle of human waste, maintaining habitable environment and long mission life make it a different challenge. The Civil Aviation Institute in Bangalore will be a great help in this endeavour.

14. Several Space Science initiatives have been planned during 11th plan including Planetary exploration and the outlay proposed for space science during 11th plan is more than three times the 10th plan outlay. Analysis and utilisation of scientific data from Chandrayaan, Astrosat and Megha-Tropiques will be an important activity during 11th plan and the creation of required human resource development needs due attention. Also, it is necessary to evolve schemes to create interest in students at their 10th and 12th standard to peruse science career.

15. For the operationalisation of Village Resource Centres(VRCs) to cover the entire country, it is important to evolve self-sustaining models involving partners to set up and run VRCs for minimal support from the Government.

Concluding the discussions, Dr G Madhavan Nair, Chairman of the Working Group, mentioned that the day's deliberations has provided several inputs for the space programme, which will be incorporated in the 11th five year plan proposals of the Department and profoundly thanked all the members for their active participation in the meeting.

OBSERVATIONS AND RECOMMENDATIONS OF THE WORKING GROUP

The Working Group noted that the 11th five year plan proposals have been drawnup under the frame work of a long term plan keeping in view the national priorities, the need to ensure continuity of space services and global trends in Space research. It was observed that the proposed development of manned mission initiative holds immense promise of bringing greater economic benefit and technological growth to the nation. The draft plan document on 11th plan of the Department of space was appreciated for its comprehensiveness, programme clarity and its contents. It was noted that the progress achieved during the 10th plan in terms of programmatic output (Missions), technological developments and preparatory efforts for future presents a satisfactory picture and the proposals for 11th plan have been built upon the strengths of the space programme gained during the 10th plan period. Considering these, the working group recommended to adopt the 11th plan proposal of the Department of Space in its totality.

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Formulation of 11th Five Year Plan

Meeting of the Working Group on "Space" held on August 23, 2006.

List of Participants

Sl. No.	Name	Sl. No.	Name
A.	**Members / Representatives**		
1	Dr. G Madhavan Nair, Secretary, Department of Space, Bangalore.	13	Dr A K Bohra, Director, NCMRWF, New Delhi
2	Dr P S Goel, Secretary, MoES, New Delhi	14	Shri M C Aggarwal, Chief Engineer, DD, New Delhi.
3	Shri Deepak Gupta, Addl. Secy. Ministry of Health and Welfare, New Delhi.	15	Shri R R Prasad, Chief Engineer, AIR New Delhi.
4	Shri P K Garg, DOT, New Delhi	16.	Shri Pramod Tandon, VC NEHU, Shillong.
5	Dr R R Navalgund, Director, SAC, Ahmedabad	17.	Dr A K Singh, Director, IARI, New Delhi.
6	Prof J N Goswami, Director, PRL, Ahmedabad	18.	Shri C M Pandey, DAC, Ministry of Agriculture, New Delhi.
7	Prof S Santhakumar, IIT, Chennai.	19.	Shri R K Khanna, Chief Engineer, CWC, New Delhi.
8	Shri K T Gurumukhi, TCPO Ministry of UD, New Delhi.	20.	Shri C K Agrawal, Director, CWC, New Delhi.
9	Shri Mohd. Monis Khan, TCPO Ministry of UD, New Delhi.	21.	Shri R B Prasad, NEC, Shillong.
10	Shri G K Prasad, Addl DG, Forests, MoEF, New Delhi.	22.	Shri V Sundararamaiah, Scientific Secretary, ISRO
11	Lt.Gen. C B Vijan , HQ IDS (M/o. Defense)	**B.**	**Invitees**
12	Shri B Lal, Director General, IMD, New Delhi	23.	Dr P K Biswas, Advisor,S & T, Planning Commission, New Delhi.

Sl. No.	Name	Sl. No.	Name
24.	Dr.D Bharadwaj, Dy. Advisor, S & T, Planning Commission, New Delhi.	35.	Dr V Jayaraman, Director, EOS, ISRO Bangalore.
25.	Shri S V Ranganath, Additional Secretary, DOS, Bangalore.	36.	Dr V S Hegde, Programme Director, DMS, ISRO, Bangalore.
26.	Dr. K N Shankara, Director, ISRO Satellite Centre, Bangalore.	37.	Dr J Krishna Murthy, Prog. Co-ordinator, NRR, EOS, ISRO.
27.	Shri R V Perumal, Director, LPSC, ISRO, Valiamala, Trivandrum.	38.	Dr TGK Murthy, Programme Director, ASP, ISRO, Bangalore.
28.	Dr K Radhakrishnan, Director, NRSA, Hyderabad.	39.	Dr B Manikiam, APD, ASP, ISRO, Bangalore.
29.	Shri M Annamalai, Director, SDSC-SHAR, ISRO, Sriharikota, AP	40.	Dr S C Chakravarthy, Prog. Director, SSO, ISRO, Bangalore.
30.	Shri V Adimurthy, Associate Director, VSSC, ISRO, Trivendrum.	41.	Shri P S Sastry, Director, LVPO, ISRO, Bangalore.
31.	Shri A Bhaskaranarayan, Director, SCPO, ISRO, Bangalore.	42.	Dr. Rajeev Lochan, Asst. Scientific Secy, ISRO, Bangalore.
32.	Dr S V Kibe, Programme Director, Satnav, ISRO, Bangalore.	43.	Shri H N Madhusudhan, Director, BEA, ISRO, Bangalore.
33.	Shri C Varadarajan, SCPO, Bangalore.	44.	Dr Radhika Ramachandran, Technical liaison Officer, ISRO, New Delhi.
34.	Shri K R Sridhara Murthy, Executive Director, Antrix, Bangalore.	45.	Shri K S Krishnan, Director, DOS, Bangalore.