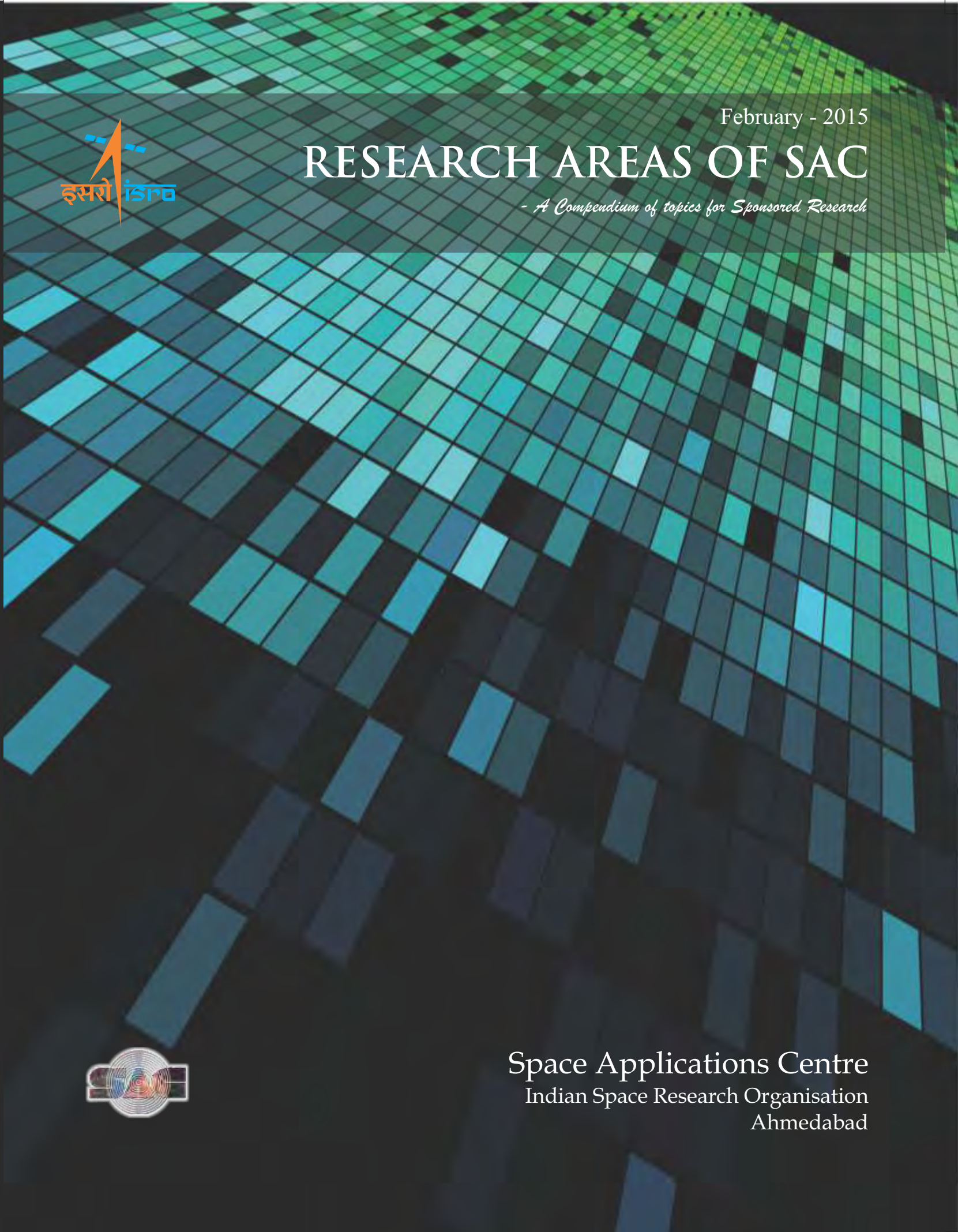


February - 2015

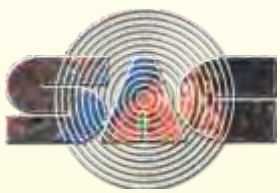
RESEARCH AREAS OF SAC

- A Compendium of topics for Sponsored Research

Space Applications Centre
Indian Space Research Organisation
Ahmedabad

Research Areas of SAC

A compendium of research areas
for soliciting proposals from academic sector
under RESPOND program of ISRO



Space Applications Centre (ISRO)
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February 2015

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FOREWORD

The Indian Space Research Organisation (ISRO) has evolved a RESPOND programme through which financial support is provided to Indian Universities and Institutes for conducting space technology related research and development activities. As a consequence, academic sector has contributed to technology development as well as human resources development in the country. In turn the recipient institutions have gained by way of infrastructure and expertise build up. The level of engagement however needs to be raised at par with industry participation by focusing on the problem and the associated deliverables and time schedules. This is necessary in view of rising volume and complexities of space related services and programmes vis-a-vis a near-static pool of human resources at the avail of Dept of Space. Against the backdrop of increasing research orientation and professional culture of academic institutions in the country, it looks feasible and opportune.

The document puts up a road map for diversification of RESPOND projects in the Centre. The variety of subjects dealt within the centre dictates the involvement of a large number of institutes with diverse capabilities. The first step towards defining the topics of relevance where academic sector can contribute was taken by Space Applications Centre in July 2006 by preparing first version of this document. The revision of document is done once in two years. The present version is the fourth revision of document and it incorporates Research Areas relevant to current activities of SAC.

To enable faculty of Universities/Institutes to prepare suitable proposals of relevance to Space programme, the document have been worked out as per major programmes of SAC. The faculty/researcher may select a suitable topic/problem and prepare the proposal. I invite all the universities and institutes to participate in R&D programmes of the Space Applications Centre.

Tapan Misra
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February 2015

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Acknowledgments

Space Applications Centre (ISRO) has a large number and variety of activities under one roof. To capture the diverse lines of research in lead units is difficult and would not be possible without the support from the very top. The guidance and initiative from Director SAC have been crucial in this regard. The support provided by Dy Directors, Group Directors and Division Heads of key areas is gratefully acknowledged. All of them deserve special thanks for the inputs.

The "Research areas of SAC" document compiled by Ankita Vishal Patel & Dr. Parul Patel, RRCD/PPG.

Contents

1. Overview

1.1 Introduction

SAC interfaces with large number of industry, Government departments and academic sector commensurate with its activities. While academic sector and Government departments form its collaborative network, industry provides valuable outsourcing support to SAC activities. Academic sector in India is a vast and growing network of universities and academic institutes. This infrastructure has contributed in many ways to research activities related to space and has much greater potential for contribution. The present document provides a brief summary of research areas of relevance to this Centre. This is intended to encourage universities and academic organization to come forward with focused proposals for funding under RESPOND program of Indian Space Research Organisation (ISRO) through this Centre (SAC). The document is inspired by a need for pro-active request for research proposals from academic sector in addition to usual mode of receiving and processing funding proposals. The backdrop for this initiative comes from realization of deepening and broadening research fronts at the Centre and the greater professionalism and sophistication of domestic academic sector. Through this document, an effort is made to compile sector wise details of research activities and a list of the specific topics where research proposals from academic sector are invited.

The first step towards defining the topics of relevance where academic sector can contribute was taken by Space Applications Centre in July 2006 by preparing first version of this document. The revision of document is done once in two years. First revision was done in October 2008, second revision was done in December 2010 and third revision was done in February 2013. The present version is the forth revision and it incorporates Research Areas relevant to current activities of SAC.

1.2 Overview of SAC Activities

Space Applications Centre (SAC) is one of the major ISRO centers located in Ahmedabad, Gujarat. SAC focuses on the design of space-borne instruments for ISRO missions and development and operationalisation of applications of space technology for societal and national development. The applications cover communication, broadcasting, navigation, disaster monitoring, meteorology, oceanography, environment monitoring and natural resources management. SAC designs and develops various transponders for the INSAT, GSAT and IRNSS series of communication as well as navigation satellites and the optical and microwave sensors for IRS series of remote sensing satellites. Further, SAC develops the ground transmit/receive systems (earth stations/ ground terminals) and data/image processing

systems. In order to carry out these above tasks, SAC has established highly sophisticated payload integration laboratories, electronic and mechanical fabrication facilities, environmental test facilities, systems reliability/assurance group, image processing and analysis facilities, project management support group and a well-stocked library. SAC also conducts nine-month post graduate diploma courses for students from the Asia Pacific region under the aegis of the Centre for Space Science and Technology Education (CSSTEAP) in satellite meteorology and communication areas. SAC also works closely with industry for out-sourcing and indigenization, involves Indian universities in space research and propagates space technology and applications amongst students and public through in-house and mobile exhibitions.

Highlights of SAC activities

- Communications and Navigation Satellites and its Applications
  - » Payloads
  - » Antenna
  - » Ground Systems
  - » SATCOM and Navigation Applications
- Remote Sensing Satellites and its Applications
  - » Electro-Optical Sensors
  - » Microwave Sensors
  - » Image Processing
  - » RS Applications
- Fabrication and Test Facilities
- Library and Information Services
- Projects and Programme Management

In Addition, SAC has Development and Educational Communication Unit (DECU) on its campus. DECU is involved in the system definition, planning, implementation, production of educational/communication material and socio-economic research & evaluation of societal applications which include Tele-education, Tele-medicine, Village Resource Centre (VRC), Disaster Management and other Sat-Com Applications.

1.3 Research Sponsored (RESPOND) Programme

The world is witnessing an exponential growth of technology in every domain of life. It is of utmost importance for any organisation to keep itself abreast with the latest and futuristic technical advancements. The research and development is the engine for futuristic technical advancement.

The Indian Space Research Organisation (ISRO) provides financial support under RESPOND programme for conducting research and development activities related to Space Science, Space Technology and Space

Application in Universities and academic Institutions in India. The main objectives of the RESPOND Programme are to establish strong links with academic Institutions to carryout quality research and developmental projects of relevance to space and derive useful outputs to support ISRO programmes. RESPOND programme aims to enhance academic base, generate human resources and infrastructure at the academic Institution to support the space programme. Under the broad umbrella of Respond, ISRO runs Space Technology Cells at IITs, IISc and Pune University which coordinate research proposals within the respective institutions.

Respond at SAC is implemented under the umbrella of ISRO Respond programme and caters to specific research topics pertaining to SAC activities related to payload development, data processing and applications in the areas of Satcom, Satnav & Remote Sensing. The program is running at SAC with the continuous support of academic institutes and universities geographically located in different states of India. The esteemed institutions/ universities like NIT, NIAS, CEPT University, DA-IICT, IITs, Nirma University etc. have participated in the RESPOND program at SAC. The programme at SAC has evolved into a dynamic & responsive face of Respond and contributes significantly to ISRO programme on Sponsored Research.

The academic sector in India having vast and growing network of universities and academic institutes contributed in many ways to research activities related to space and has much greater potential for contribution.

With the proactive approach for Research Solicitation, nine Interest Exploration meetings were held at Ahmedabad (2005), Shillong/Patna (2006), Allahabad (2008), Dehradun (2009), Srinagar (2009), Jodhpur (2011), Bhopal (March 2012), Aizawl-Mizoram (July 2012), BISAC, Gandhinagar (January 2014) and GTU, Ahmedabad (November 2014). The interest exploration meetings resulted in a well-distributed Geographical spread of the ongoing RESPOND projects in East, North-East, North, North-West, West and Central regions of the country. The ongoing projects are reviewed at SAC every year in the month of November/December alongwith potential new RESPOND proposals. The performance of the completed RESPOND projects is also evaluated and each project is given rating on a 10 point scale.

A brief outline and possible set of topics for research funding under RESPOND is given for each of the key areas of SAC in subsequent chapters.

2. SATCOM Technology

C-band Receiver

Satellite Communications and Navigation: Opportunities for Academic Collaboration

One of ISRO's major tasks is to provide space-based assets, applications and services related to telecommunications, broadcast and navigation. These programs fulfill a wide range of national and societal needs. Space Applications Centre, Ahmedabad plays a key role in this mission.

ISRO's flagship communications program is GEOSAT, for which the space platforms come from the GSAT series of satellites -- whose payloads come from SAC Ahmedabad. Likewise, the IRNSS series of satellites is building up the space segment for India's regional navigational service IRNSS. Another branch of the navigational program is GAGAN, which is a system that is already being inducted into operational use for the civil aviation sector in the Subcontinental and Indian Ocean region. A noteworthy thrust area is the development of high throughput satellites offering broadband data connectivity such as GSAT-11, featuring 16 beams at Ku-band to provide 10 GHz effective usable bandwidth (this is roughly equivalent to about 220 conventional transponders of 36 MHz each). GSAT-11 will be followed up by the High Throughput Satellite in Ka-band, which will provide broadband data services over Indian region through 72 spot beams generated with an ensemble of 4 reflectors fed with a feed cluster. An S-band Geo-mobile satellite is being designed to support hand-held terminals through the use of advanced techniques like 12-m unfurlable reflector, phased array feeds with onboard beamforming and digital channelization.

Each GSAT or IRNSS payload will typically contain a range of subsystems, for example:

- Receivers
  - » Low Noise Amplifiers
  - » Mixers
  - » Frequency Generators
- Microwave and RF High Power Amplifiers and associated Building Blocks
  - » Solid State Power Amplifiers
  - » Traveling Wave Tube Amplifiers (TWTAs)
  - » Driver amplifiers
  - » Linearizers

- Modulators and Demodulators
- Microwave / RF Filters, multiplexers and demultiplexers including microstrip, cavity and SAW types
- Digital processors, controllers and DSP based subsystems
- Other experimental or specialized hardware to meet special users' requirements\

The specialist teams at SAC are working on the entire vertical

ecosystem within the SATCOM / SATNAV arena, as shown by these examples of the activities and

disciplines involved:

- System engineering and conception of advanced architectures for satellite communications and navigation
- Channel modeling and link optimization for satellite-based and hybrid applications

Ku-Band IMUX for GSAT-9

GSAT-7

- Design, development and characterization of RF and microwave subsystems for satellite equipment
- Digital subsystems and hardware technologies
- Modulation, coding, multiple access, encryption and spread spectrum technologies
- Applications of Digital Signal Processing in various on-board subsystems

- Controllers and beam-formers for versatile multiple-beam antenna systems, as well as agile jamming-resistant antenna concepts
- Photonics and optical communications technologies for inter-satellite links
- Time and frequency standards of extremely high accuracy and reliability for navigational payloads
- MMIC, MEMS, LTCC and other implementation technologies
- Power electronics, including switched mode DC to DC converters for space electronics
- Multi-physics problems and optimization studies across the electronic, mechanical, structural and thermal domains

There are excellent opportunities for researchers from Academia to participate in this rich, diverse and highly relevant set of challenges. There is room for specialized collaborations in individual disciplines, as well as work of a more interdisciplinary nature spanning system studies, electronics, mechanical engineering and thermal aspects – to name just a few.

Multi Port Amplifier

Faculty and researchers from Indian universities and institutes would be in a position to identify a promising research problem that would address one or more of the directions indicated in this brief outline. It is hoped that, following the well defined RESPOND process, specific research proposals will take shape that will help to shape the future progress in many of the disciplines listed above.

The following sections will focus on examples of specific research possibilities that could be pursued under the RESPOND program, in the field of satellite communications and navigation.

» *System Studies for SATCOM and SATNAV Architectures*

1. Studies related to IRNSS system

The IRNSS satellite constellation is now being deployed with around two launches a year. As the system becomes operational with growing functionality, there is a need to build up understanding on how best it can be leveraged to support existing and novel applications, and also to look ahead towards the future evolution of the system itself. This opens up a host of interesting problems for

research and study, such as:

- Integration of IRNSS signals with existing GNSS signals at the receiver level to demonstrate the inter-operability.
- Use of IRNSS signals for navigation with "signals of opportunity" of terrestrial networks.
- systems studies can be undertaken for autonomous satellite navigation, eliminating the need of ground support.
- The applicability of bandwidth efficient modulation schemes such as GMSK, APSK etc for satellite navigation systems.
- Development of simulation tools for situation awareness for navigation end users supporting their mission planning. Such tools will consider the complete navigation systems and provide the information about the system accuracy, availability, integrity and reliability for any operational situation.

2. Systems simulation of advanced multibeam satcom systems

The simulation of multibeam satellite systems for broadband and mobile applications involves scenario definition, computation, and visualization challenges. The spatial variation of different parameters such as atmospheric conditions, receive and transmit antenna gain and traffic necessitate stochastic computation of satellite throughput. The simulation scenario definition involves the definition of coverage, antenna patterns, channel, and traffic conditions. In case of dynamic simulations, which offer a more realistic view of system behavior, one or more of the above given parameters vary with time, thus increasing simulation complexity manifold.

The different forms of throughput and capacity estimation also require computation over large number of geographic points across different scenarios, and subsequent optimization of payload configuration.

Research areas in this direction are:

- Spatio-temporal simulation of traffic and channel conditions such as rain fields
- Tools for computation and visualization of different performance parameters across coverage
- Incorporation of physical layers of different standards such as DVB-S2, DVB-S2X and DVB-RCS2, along with capacity optimization algorithms like Adaptive Coding and Modulation (ACM) and Dynamic Rate Adaptation (DRA.)

3. Architectures and algorithms for AIS receivers onboard LEO and GEO platforms

The Automatic Identification System (AIS) is based on VHF radio transmissions of ships' identity, position, speed and heading, in addition to other key parameters. AIS, in its original form, is a terrestrial system. In space based AIS (SB-AIS), satellite receives AIS messages transmitted from the ships and relays the signals to the ground station. In terrestrial mode, AIS operates in Self Organized Time Division Multiple Access (SO-TDMA) scheme. The challenges involved in space based AIS are large number of SO-TDMA cells in satellite field of view and large number of uncoordinated messages from ships belonging to different SOTDMA cells in same time slots. It results in decrease in ship detection probability.

The research areas in this field include the algorithms development to improve the ship detection probability in presence of intra/inter system interference and miniaturization techniques for on-board hardware to meet the constraints for hosted payload.

4. Algorithms and techniques for dynamic resource allocation in multibeam mobile and broadband satellites

Multibeam satellites offer the prospect of dynamic allocation of resources (power and bandwidth) across the coverage, based on geographical and temporal variation in demand. The demand variation may be a result of varying channel conditions (e.g. rain), or traffic variations. Similarly, the reuse plan may be made dynamic to accommodate varying frequency allocations.

Research areas in this direction include:

- Strategies for resource allocation while maintaining desired QoS across different beams. This includes consideration of increased interference to other beams while power/bandwidth in certain beams is increased.
- Use of resource allocation as a technique for fade mitigation in the EHF bands. This is an area of significant interest considering the tropical climate in the Indian region.
- Identifying and developing onboard technologies for enabling transfer of resources from one beam to another. Currently, technologies for power distribution, namely multiport amplifier and flexible TWTA are under investigation. Other options, for power and bandwidth flexibility can be explored.

5. Investigation of channel models for S-band geo-mobile system

The link performance of conventional satellite systems is well established on the account of simple AWGN channel in line of sight communication. However, the development of geo-mobile system,

with user services in urban, rural and metropolitan areas, shall require consideration of shadowing and multipath channels. Some models for L-band and S-band land mobile satellite (LMS) channels are available.

Research areas in this direction are:

- Channel modeling over Indian regions and desired frequencies. A comprehensive propagation model will allow accurate dimensioning of the payload system, thereby resulting in optimized implementation.
- Propagation characteristics for hybrid space/ground mobile system

6. Hybrid Satellite Terrestrial Network

With satellites becoming capable of providing services to handheld terminals, it is envisaged that a hybrid network with terrestrial and satellite systems complementing each other shall be developed.

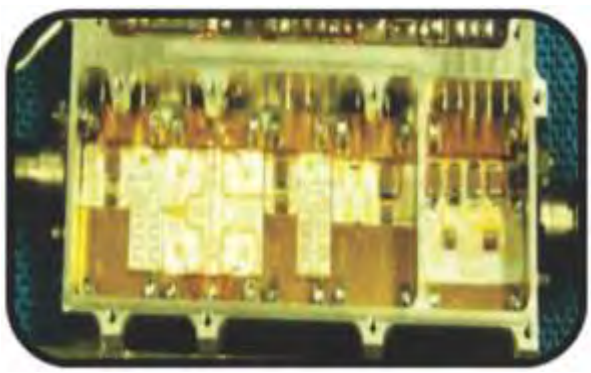
Research areas in this direction are:

- Investigation of possible satellite –terrestrial system architectures
- Handover strategies and related protocol modifications
- Physical layer design for simultaneous operation of satellite and ground component considering different channel characteristics

» Active RF and Microwave Circuits and Subsystems

1. Development of temperature dependent models of PHEMTs, MHEMTs and InP HEMTs, their validity at cryogenic temperatures and application in design of LNAs for DSN in S, X and Ka-band :

Presently limited data and models are available for simulation of active microwave circuits over temperature range including cryogenic temperatures. Circuits are designed at ambient and their response is studied practically at these temperatures. If proper models of basic devices are available over temperature and Ku frequency of operation, it will be helpful in designing circuits optimized for cryogenic temperatures.



Ku-Band linearizer for MPM

Reference

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IEEE Aerospace Conference Proceedings - Volume 2, 10-17 March 2001 Page(s):2/829 - 2/842 vol.2

Design of GISAT transmit module in LTCC Technology

Advantages:
1) Hermetic sealing possible.
2) Number of feedthrus can be removed
3) Compact size and smallest weight of the module
4) Repeatability in the performance
5) Package with embedded RF Connectors
6) Cost effective due to bulk production (GISAT-2 onwards)

Design of Digital Linearizer on ASIC

Advantages:
1) Universal Linearizer can be used in any frequency
2) Simple and easy to use
3) Can be use for any type of distortion (GaAS, GaN, TWT etc)
4) ASIC can be made outside based on our requirement
5) better performance compare to present topology

» Passive Microwave Subsystems

Flexible filters with in-orbit reconfigurability:

Modern era is the age of dynamic evolution of satellite technologies. Satellites are becoming smarter day by day. A flexible satellite can be very useful from the application point of view in modern communication for which reconfigurable HW (amplifiers, filters, antennas, etc.) are highly desired since they allow real-time system adaptation and optimization to varying user demands in terms of bandwidth, coverage and frequency allocation. At present, one of the major bottlenecks in the development of reconfigurable payloads is the input and output filtering section, where filters of fixed centre frequency and bandwidth are

employed. The utilization of reconfigurable IMUX/OMUX could allow substantial reduction of mass, dimension and costs with respect to today's switched multiplexer solutions. Thus, the necessity to design a new filtering section whenever a new payload has to be developed could be reduced, while at the same time also last-minute changes in the development of a payload/system could be absorbed. Onboard tunable filters with a fast tuning speed, high quality factor and broad tuning range are key elements in reconfigurable systems. Tunable filters effectively utilize the frequency, bandwidth, suppress interfering signals and ease the requirement for oscillator phase noise and dynamic range. Universities/Research Institutes can considerably contribute in the field of RF-MEMS based filters, DR filters with MEMS based bimorph tuning element as well as stepper motor based tunable cavity filters.

» *Power Electronics*

Design of active input filter for switching power supply:

An input filter is an essential and critical circuit elements in DC/DC converters for payload equipments. It should be designed to achieve the required EMI compliance as per the conducted emission limits defined in the latest revision MIL-STD-461. The brute force passive filter designed to achieve the necessary compliance is usually very bulky and attributes for large space and size in the power converter package. An input filter with low mass and volume can be designed by inductor and capacitor values enhancement techniques using active devices. Also, impedance of the input filter must be designed to compensate for the negative input of power converter. A project on active input filter design shall be aimed at defining the filter requirements, synthesis of the filter circuit for the desired performance, developing the step by step design methods for realizing the input filter for given attenuation and impedance characteristics and practical verification of the design on a specific DC/DC Converter.

» *Optical Communcations Systems*

Development of Microwave Photonics terminals for free space optical link design, simulation & analysis:

It is anticipated that future trends in satellite communications will make it essential to implement very high bandwidth data links between different satellites. Examples would include LEO-GEO links for transfer of remote sensing data, GEO-GEO links for networking applications, internetworking of micro satellite clusters etc.

Experimental Optical Link

Optical Inter-satellite Links are now poised to grow rapidly in the coming years. There is a new surge of OISL-related interest projected applications are foreseen in many areas, including high bandwidth data relays, real-time transmission of earth observation data, internetworking of satellite constellations, military communications, signals intelligence and monitoring, and many others.

Microwave photonics is an integration of optoelectronics with microwaves. It offers very large bandwidth, high data rate, small size, low mass, low prime power, negligible interlink interface and improved control mechanism. Some novel, opto-microwave devices are optical modulator, photo detectors, mixers, frequency converters, optical sources, optical amplifiers, laser terminal for operational inter satellite links. Design, simulation & analysis can be proposed for such type of components.

In this case, many new optical devices or optical technology applications will be needed. Bandwidths ranging into the gigabit region are envisaged by using the future optical transponders.

- To explore and develop in the core areas involved in the free space optical link design. Comparative link parameters have to be established for the optical transmitters and receivers for different optical links starting form short distances (100s of meters) to LEO to LEO or LEO to GEO etc with varying data rates. Accordingly hardware has to be developed for optical transmitters and receivers.

- A comparative study of different tracking mechanisms having the hardware suitable for working in space environments with sufficient power margins have to be envisaged.

3. SATCOM Applications

DCTG (Satellite Navigation Inputs) MBOC(6,1,1/11) signal acquisition and tracking For new signal identification in L1 Band, MBOC(6,1,1/11) modulation is one of the candidate for IRNSS SPS signal. Its acquisition, tracking and performance in multi-path and interference scenario can be simulated and analyzed.

RF terminal at the site

n-PSK BOCCOS(12,2) signal acquisition and tracking for IRNSS signal

n-PSK BOCCOS(12,2) is totally new modulation scheme for GNSS scenario. Its acquisition, tracking performance and demodulation schemes are to be studied and simulated. Whether this type of modulation gives any advantage in multi-path and interference environment, that has to be also seen.

- **GNSS Spoofing – Detection and Mitigation**
- **GNSS Jamming – detection and mitigation**
- **Integration of GSM with Navigation Receiver**
- **Development of Space-Borne GNSS Receiver**
- **Integration of Inertial navigation system with Satellite navigation receiver**
- **Low cost low power Multi GNSS RF Front End development**
- **TTFF improvement in Navigation Receiver**
- **Acquisition & Tracking of GLONASS Signals**
- **Acquisition & Tracking of Galileo Signals**
- **Acquisition Tracking of Beidou (COMPASS) signals**
- **Iono delay processing Techniques in GNSS receiver**
- **GAGAN Applications**
- **Characterization of On-board Atomic Clock performance**
- **Innovative IRNSS Applications**
- **SDR based GNSS Receiver**
- Key Exchange algorithm for RS Receiver:

  IRNSS RS service involves encryption and to improve security, encryption keys are changed regularly to avoid brute force attack and cryptanalysis from unauthorized users. IRNSS RS receivers deployed in field will have to be communicated with changed keys. ECC offers highest security and almost

impossible to break the algorithm. Public Key exchange mechanism based on Elliptic Key Cryptography is to be developed for IRNSS RS service.

- Software defined radio based GNSS simulator

SDR is a novel concept and can be used for GNSS simulator applications. This requires high computation power to process 20 Mhz of signal in each band for each satellite signal and involves huge data transfer from PC to DAC. Development of efficient algorithms to process and compute high bandwidth signals. Mechanisms to transfer high date rate transfer between FPGA and PC using ARM processor.

- IRNSS receiver with Mapping service integration

IRNSS receiver provides PVT and this should be integrated with other Google/NOKIA/Apple map services based on this PVT solution in Android/IOS/Windows8 environment. More services like showing best routes from one place to other places, tracking the fleet using IRNSS receiver kind of services are to be explored.

- Design, development and implementation of Lightweight authentication algorithm

Development of lightweight authentication protocols can be taken up as an activity which would be useful in IRNSS where authentication of some sort can provide security against spoofing kind of attacks. However, any kind of authentication mechanism should not incur too much overhead on IRNSS receiver for which it is must that the authentication algorithm should be resource efficient. Moreover, the implementation should be such that it is safeguarded against side channel kind of attacks.

- Study and Performance estimation of a Multi Carrier –Code Division Multiple Access System

Today, in parallel with multi-carrier transmission, the field of multi-carrier spread spectrum communications is considered to be an independent and important research topic. Multi-carrier spread spectrum is considered a potential candidate to fulfill the requirements of next-generation (4G) high speed wireless multimedia communications systems, where spectral efficiency and flexibility are considered as the most important criteria for the choice of the air interface.

The MC-CDMA technique is based on a serial concatenation of direct sequence (DS) spreading with multi-carrier modulation technique. It offers the advantage of both the proven technologies.

The DS-CDMA system is a multiple access technique that relies on spreading the data stream using an assigned spreading code for each user in the time domain. The capability of is given by the cross-correlation properties of the spreading codes helps in minimizing multiple access interference. Whereas the auto-correlation properties of the spreading codes provides the capability of distinguishing one component from others in the composite received signal in the case of severe multi-path propagation in

mobile communications. However, The performance of a DS-CDMA system strongly depend on the number of active users, the channel characteristics, and the number of arms employed in the rake-receiver. The system capacity is limited by self interference and multiple access interference, which results from the imperfect auto- and cross-correlation properties of spreading codes.

The basic principle of multi-carrier modulation relies on the transmission of data by dividing a high-rate data stream into several low rate sub-streams. These sub-streams are modulated on different sub-carriers by using a large number of sub-carriers, a high immunity against multi-path dispersion can be provided since the useful symbol duration Ts on each sub-stream is much larger than the channel time dispersion. Hence, the effects of ISI are minimized. The main advantages of multi-carrier

transmission are its robustness in frequency selective fading channels and, in particular, the reduced signal processing complexity by equalization in the frequency domain. OFDM, a multi carrier modulation system offers high spectral efficiency and effectively combats the problems with multipath propagation in mobile communications.

Thus the advantages of multi-carrier modulation on the one hand and the flexibility offered by the spread spectrum technique on the other hand have motivated for the Multi carrier –CDMA systems design.

Two different technologies called MC-CDMA (OFDM- CDMA) and MC-DS-CDMA have emerged as a combination of these two independent technologies. Thus the study and performance estimation of a MC-CDMA system in a multipath fading channel can be a very interesting and useful topic of research which can help in designing of an optimum MC-CDMA system for a fading channel.

- Tamper Proof Hardware Technology:

IRNSS RS Receiver design and development is taken up at SAC. RS receiver is to be protected for the secret key and code inbuilt to the receiver in case of RS receiver is compromised by opening the unit. Tamper proof hardware technology will provide this protection to RS receiver.

» *Research & Development topics of Interest To SSTG*

1. Development & Adaptation of GMR (Geo Mobile Radio)like standards & Technologies for seamless communication between Terrestrial & ISRO SATCOM networks

GEO-Mobile Radio Interface (GEO stands for Geostationary Earth Orbit), better known as GMR, is an ETSI standard for satellite phones. GMR standard is derived from the 3GPP-family terrestrial digital cellular standards and supports access to GSM/UMTS core networks. It is used by ACeS, ICO, Inmarsat, SkyTerra, TerreStar and Thuraya for high speed internet as well as audio and video

services. Under this topic, it would be worthwhile to develop and implement standards, that are similar to GMR or GMR itself for seamless communication between GSM and ISRO's MSS terminals.

2. Design for popular broadcast/communication standard like DVB-SH/DVB-RCS etc to facilitate satellite communication on the move. Efficient techniques for implementation of OFDM over satellite.

   DVB-SH is a published standard from ETSI for broadcast services using satellites to handheld devices. Under this topic, the development and implementation of techniques like DVB-SH in MSS band is expected.

3. Wideband Spectrum Sensing and Interference Cancellation techniques in Compressive Sensing Domain for next generation Broadband Satellite communication & efficient spectrum utilization

4. Design, Simulation and Implementation of PSK Modems with Higher order Coding to meet the communication requirements of LEO satellites and for Indian Data Relay Satellite System
   The proposal could include building a Doppler compensated PSK MODEM for communication from a LEO platform to GEO platform.

5. Mixed signal ASIC: Design and Development of miniaturized, multiband (S, L, UHF band) Low Power transceiver ASIC for future SATCOM terminal.

   This proposal could include development of low power custom ASIC to support miniaturization of handheld and portable satcom terminals.

6. Design, Simulation and Development of Receiver with Signal Processing Techniques for improving the probability of ship detection in space (Satellite) based AIS (Automatic Identification System) network

   This proposal should address issues and algorithm for improved probability of detection of ships while implementing AIS over satellite using LEO constellation of satellites in VHF band.

7. Low bit rate fast acquisition burst demodulator or Preamble-less/minimum preamble demodulation

   The proposal of design and development could address techniques to improve the burst to burst gap and reduce the preamble size of low bit rate burst demodulator for Satcom applications.

8. Design & Development of RF-MEMS based monoscan converter for Single-channel Monopulse Tracking System:

Monopulse tracking is used for precise pointing of onboard as well as ground station antennae. It is used in three configurations: Single-Channel, Two-Channel and Three-Channel. Single and two-channel configurations are commonly used in practice. Since single-channel configuration has advantage in terms of weight, size, power and phase-optimization, it is a preferred choice for most applications. But, the simplicity results in increased complexity at feed end, where three RF signals (Ka / Ku Band for example) need to be combined into one RF-signal using monoscan converter. It is also called autotrack modulator/combiner. The proposal could aim for developing RF-MEMS based (Ka / Ku Band) monoscan convertor technology, which should have potential to meet reliability requirements of onboard applications.

9. Development multi-mode mobile terminal

Multimode smart phone is going to be future trend. The same phone will operate in different radio technologies and there is requirement of seamless transition between the networks. Media Independent Handover (IEEE 802.21) has been standardized for the seamless communication between different radio technologies. The proposal should aim for network design and mobile terminal development.

10. Hybrid Terrestrial-Satellite DVB/IP Infrastructure for Triple-Play Services

With the advent of digital video broadcasting (DVB) technology and its exploitation over terrestrial links (DVB-T) along with its inherent characteristic to combine heterogeneous traffic into the same data stream (i.e., MPEG-2 and IP data), presents the possibility for the creation of a converged DVB/IP networking infrastructure, which is able to provide triple-play services within the broadcasting footprint.

11. Design, Simulation and Implementation of electronic beam steering techniques for satellite mobile communication

Mobile satellites provide coverage over large regions. Large number of small beams is essential to cater the higher G/T requirements of small user terminals. In the conventional single feed per beam option, there are two major shortcomings:

i) It requires large number of feeds and ii) Higher complexity in de-pointing correction. Using digital beam-forming, a large number of beams can be formed using a relatively smaller number of feeds with the following advantages:

» Electronic steering of antenna beams is possible.

» Antenna miss-pointing error correction is possible without any physical movement of antenna parts, protecting sensitive antenna geometry.

» Reconfiguration of beams caters specific requirements including optimization for C/I, anti jamming capability etc.

12. Design of miniaturized low cost S-band antenna with near omnidirectional coverage for mobile hand held terminals.

The requirement is to develop transmit only, receive only and transmit-receive antenna for different S-band MSS terminals & applications. An active antenna system will add value to the receive only system. The proposal should preferably address all the above issues.

13. Design and development of RF transceiver ASIC for S-band handheld SATCOM terminals for MSS applications.

This proposal should address development of low power custom RFIC for S-band transceiver to support miniaturization of handheld and portable satcom terminals.

14. Design and development of advanced pulse shaping techniques with lower roll off for efficient spectrum utilization.

15. Design and development of robust and power & bandwidth efficient waveform for SATCOM services.

16. Development of GPS based auto pointing system for 1.2m C-band antenna system

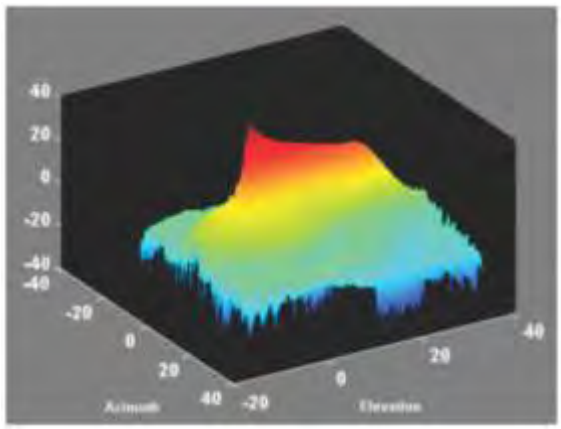
4. Antenna

In the field of antenna system technology, SAC is involved in the development of the state-of-the-art antenna system for (i) Communication payload (ii) Earth observation payload (iii) Navigational payload (iv) Air-borne system (v) Earth stations and ground terminals. A number of antenna technologies have been designed and developed at Antenna Systems Group covering frequency range from VHF to 200 GHz. ASG also has antenna measurement facility including compact, near field and plane polar test range. Some of the highlights of antenna includes the broadband symmetric dual mode waveguide rotary joint for microwave remote sensing program, dual frequency common aperture broadband multilayer printed antenna for planetary mission, dual gridded reflector with minimum thermo elastic distortion to get optimum in-orbit performance for GEOSAT programs, broadband patch antenna with surface mounted horn for enhancing directivity illuminating large size un-furlable meshed reflector for sweepSAR, wide scanning active phased array antenna for tracking multiple targets and ground terminals for navigation system. Antenna group at SAC is also engaged for the new technologies such as

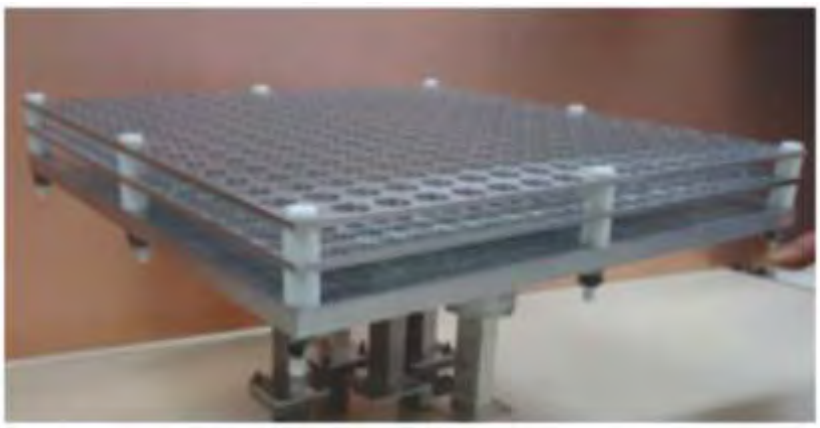
1. Barium Strontium Titanate (BST) based reconfiguration antenna
2. High Efficiency Broadband slotted waveguide array antenna
3. Four Channel C/Ku band High Power Rotary joint
4. Quasi-optical antenna system at millimeter wave
5. Computational electromagnetic techniques for antennas
6. High frequency surface integrated waveguide antenna technology
7. High Efficiency Single Aperture Single Feed per Beam Multiple Beam Antenna (SASFB-MBA)

Unfurlable antenna measurement with planar array(3x8 array) feed antenna at L-band.

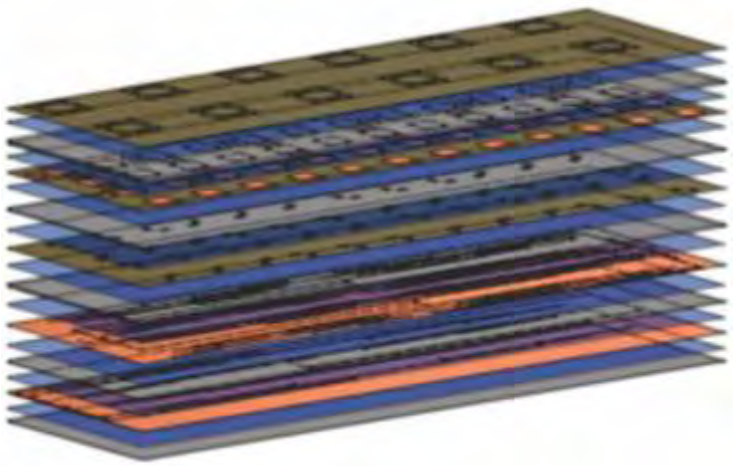
Broadband Dual Channel Rotary Joint



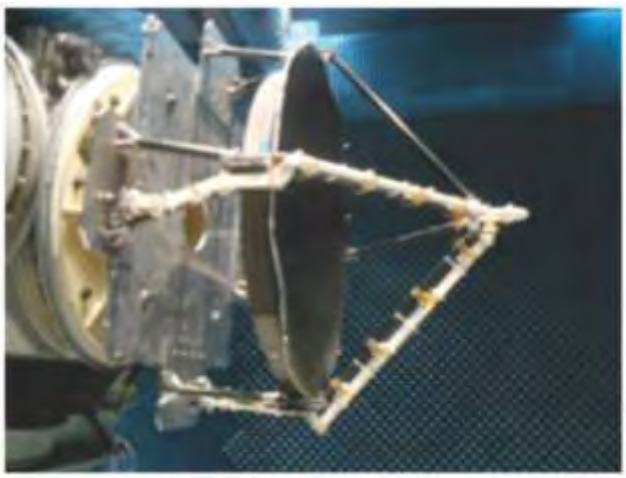
Cosec square Radiation Pattern Using Shaped Reflector



Dual PRS based High Gain 5-horn feed cluster

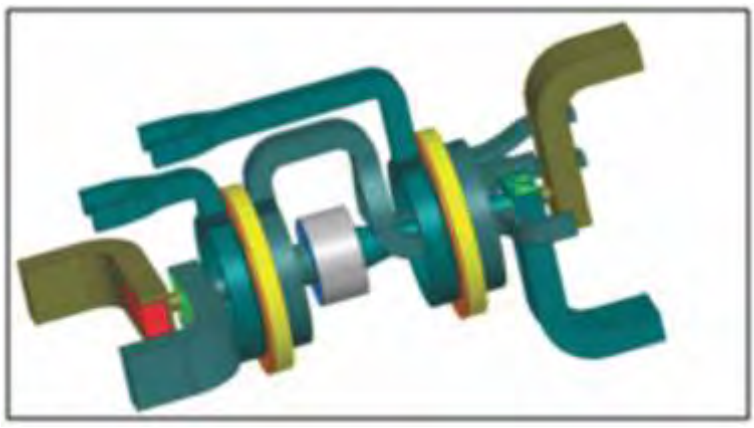


Dual frequency Common Aperture Antenna

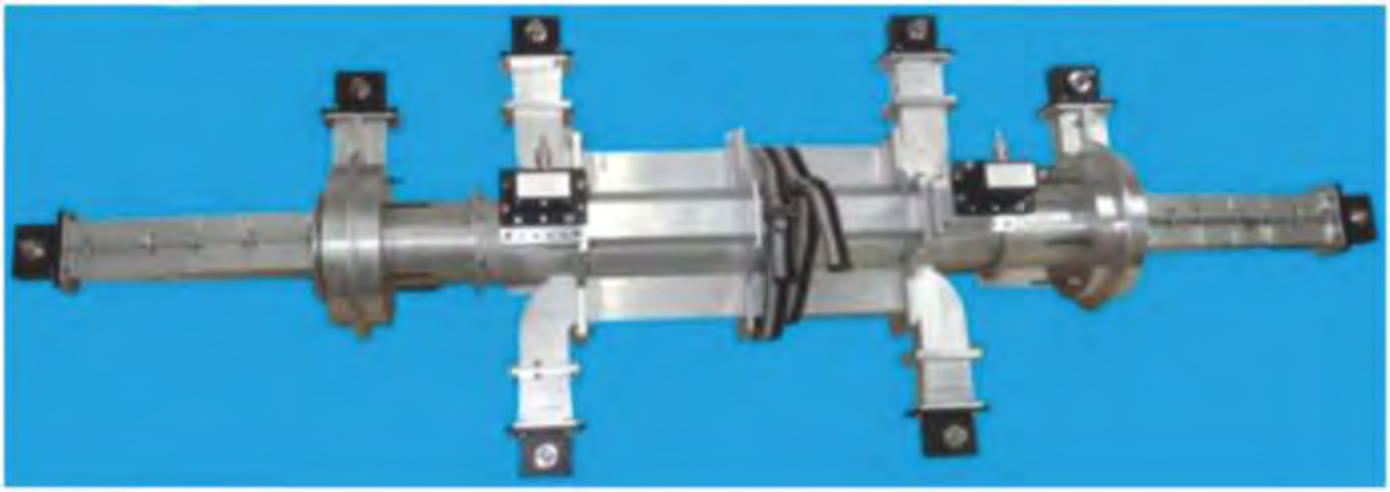


1.4m Prime focal shaped reflector antenna(F.M.) with Waveguide Plumbing

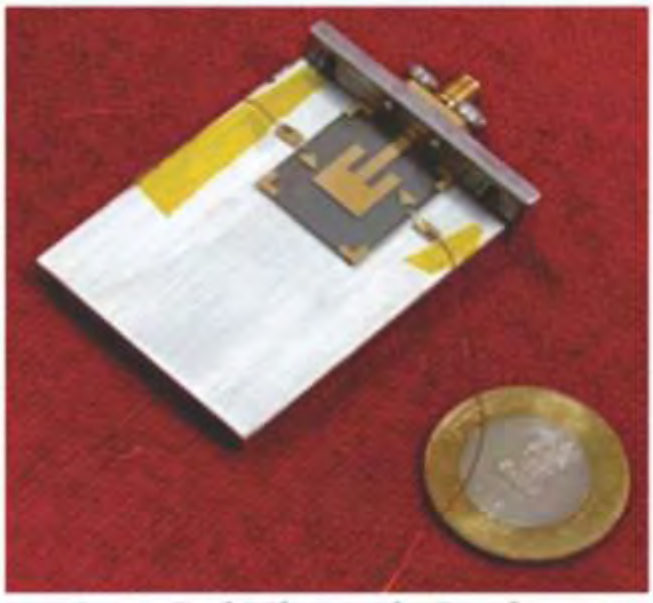
2.4m x 2.2m C-Band Tx-Tx DGR Antenna with Spacecraft mock-up and MLI Blanket



Four Channel C/Ku band waveguide Rotary Joint



Integrated TE_{21}/TE_{11} mode coupler



Inset Fed Microstrip Patch Antenna integrated with coplanar capacitors

Microstrip Phase Shifters integrated with coplanar capacitors

» *Research Areas:*

1. Electromagnetic Analysis of 3D geometries:

This work includes the development of codes using suitable CEM techniques like FEM, FDTD, High frequency asymptotic techniques of PO/PTD,GO/GTD and hybrid techniques like FEM/BEM, GTD/MoM etc for analyzing the scattering and radiation parameters of antennas and its components. The developed codes should have also the capability to analyze the scattering

properties of the 3D arbitrary objects by estimating RCS. The development of algorithm and computer codes for mesh generation for arbitrary boundary of 3D geometry with details of data-structure for co-ordinates of each node with respect to local and global coordinate system is the pre-requisite for the development of Electromagnetic codes. The computer code should be capable of generation of adaptive meshing depending on the geometry and field values at different parts of the geometry depending on the electromagnetic boundary conditions and electromagnetic computation based on the above cited CEM techniques.

2. Barium Strontium Titanate based Phased Array Antenna :

Barium Strontium Titanate (BST) based tunable components falls under a category of Ferroelectric materials, possessing nonlinear dielectric constant which can be altered by application of external electric field, material composition ratio or with the changes in the ambient temperature. The tuning dielectric constant with bias voltage of BST find many applications such as antennas, varactors, phase shifters, non volatile memory etc. Due to its lesser impact time, high power handling capabilities, low losses at microwave frequencies BST is the most preferred choice in antenna reconfigurability. These phase tunable microstrip lines can be used at the inputs of the individual Patch Antenna elements in a Phased Array Antenna so as to electronically steer the radiation pattern in a desired direction. The study needs to be carried out for variation in RF properties due to change in material composition.

3. Characterization of Dielectric materials at High Frequency

Ferroelectric thin film can be used at its maximum potential for phased array antenna only when its material properties like dielectric constant, loss tangent, tunability are accurately characterized as a function of frequency, bias voltage applied, temperature at higher frequency setup. This requires the antenna material characterization for its dielectric properties and suitable techniques needs to be developed for the characterization.

4. Broadband Conjugate Matched Feed Horn for Offset Reflector Geometry

In radiometric applications or satellite communication, generally offset parabolic reflector antennas are preferred due to their inherent advantages of reduced aperture blockage, isolation between the reflector and the feed, lesser spurious radiation and suppressed side-lobes. But the performance of offset reflectors is satisfactory in terms of cross-polarisation components only when the larger F/D is selected. Space constraints limits the selection of large F/D. The concept of conjugate matched feed provides the solution for this contradicting requirement where low cross

polarization can be achieved with smaller F/D. There is a need to design conjugate matched feed for 20 % bandwidth with cross polar performance better than -35 dB. SAC has already achieved 8 % bandwidth for the design of conjugate matched feed.

5. FEM/BI method for Finite Frequency Selective Surface(FSS) Analysis

There is a requirement of analyzing finite FSS based on hybrid Finite element method(FEM) and Boundary Integral (BI) method. FEM used to solve the electric fields inside and on the boundaries of FSS(metal or dielectric based) by discretizing the FSS into finite number of tetradedral elements. The source used to excite the FSS can be corrugated feed horn or Gaussian source. The BI method is used solve the radiation characteristics of the FSS i.e. transmission and reflected radiation pattern by using the boundary fields solved by FEM.

6. High frequency Substrate Integrated Waveguide (SIW) Antenna technology:

Generally coplanar corporate feeder networks distributes the transmit/receive signal to the individual elements for less phase dispersion. At higher frequencies ohmic and dielectric losses of the connecting microstrip line dominates and results into undesired radiation. Among all transmission line hollow metallic waveguide feature extremely low losses up to very high frequencies but it is very bulky. Substrate integrated waveguide(SIW) technology provides a solution with ease of manufacturing and low cost of microstrip line and with the performance of the waveguide. LTCC , micromachining technique can be used for fabrication of SIW. The feeding mechanism needs to be developed using SIW technology for different antennas like planar cavity backed antenna, slot array antenna, Vivaldi antenna, horn antenna ,reflector antenna and planar microstrip antenna can be replaced by SIW. The system on chip and antenna on package may be studied in connection with this technology.

7. Estimate Measurement Uncertainty from Probed Quiet Zone Quality data:

The analysis part includes the development of algorithm/computer code for estimating error in different antenna measurement parameters viz. Gain, Sidelobe, Radiation pattern from acquired raw probe data. It provides amplitude & phase vs. linear position data which are sufficient to characterize the volume of quiet zone. The quiet zone of an anechoic chamber is a defined volume within the chamber where a device under test (DUT) is to be placed for evaluation.

8. Accurate prediction of far field pattern using different topologies of near field data:

This research problem involves the conversion of near field data, acquired using various scan geometries, into far field pattern. The objective of thestudy is to find out accurate and efficient near field to far-field conversion using various acquisition geometries as well as transformation scheme. Suitable interpolation techniques e.g. Optimal Sampling Algorithm, Bivariate Lagrange Interpolation etc. can be developed to convert the polar/spiral and other formatted data to rectangular grid using various interpolation schemes. Direct transformation techniques e.g. Jacobi-Bessel can also be explored to achieve accurate performance.

9. Analysis of Radomes on radar antenna performance

The efficient operation of delicate microwave antennas in the presence of adverse weather conditions requires in many circumstances the covering of the antenna by a radome. Radome is a protective cover for the antenna and is used extensively on terrestrial, weather radar systems, air traffic control, telemetry, satellite communications, satcom uplink and receive-only terminals. Radome structure is a framework structure (metal or dielectric) of interconnected columns (beams/seams). Foam and honeycomb cores are often added between inner and outer skins of the radome to function as low dielectric constant spacer material (reduced reflections) providing structural strength and rigidity. Investigations may be carried out for electromagnetic modeling of radome structure and the analysis to estimate the effects of radome on the antenna radiation characteristics may be carried out using suitable analysis techniques.

10. High Efficiency Dual polarized wideband slotted waveguide array Antenna:

Waveguide slotted array antenna finds its application for its inherent advantages of good phase stability, low losses, high power handling capability and rugged structure. Open literature is available for narrow band waveguide slotted array like longitudinal shunt slot, series inclined slot and compound coupling and radiating slots. This investigation and design of slotted waveguide array intended at X & Ku band frequencies for technique to provide wide band width around 14-15 % with common antenna operating for dual linear polarization. The radiating aperture needs to be analyzed along with coupling slot feed array.

11. Electronic band-gap antenna:

Design and analysis of high efficiency/compact printed antenna array using electronic band gap structure such as mushroom type, fork type, unipolar type structure to improve the mutual

coupling and making it suitable for wide angle scanning active phased array antenna. These structure can be integrated with microstrip antenna, waveguide slotted array antenna and horn array antenna to study the change in radiation properties. The electronic band gap structures integrated on intercostal structures has to be simulated for its RF transparency to improve the gain performance of the DGR antenna.

12. Quasi-optical techniques for Millimeter-wave Antenna:

This type of antenna system are of paramount use in millimeter wave (30-300 GHz) and Sub-millimeter wave (>300GHz) frequency bands. This type of antenna system has a reflector-antenna that transforms the wide received signal-beams into beams of intermediate width (intermediate gain) that pass through a train of reflectors or lenses before being focused into the low-gain feed-horns of the receivers. The research problem includes the formulation using different techniques like long Fourier optics, Physical optics and Geometric theory of diffraction to design the train of the reflectors so as to optimize the overall gain of the antenna.

13. Multiband high efficiency feed antennas:

Design, simulation and fullwave analysis of multiband antenna structure such as sierpinski, appollian packaging monopole and koch geometry is required to estimate various antenna parameters like return loss, gain variation over frequency. These multiband geometries are being used for ground terminals for MSS type D, navigation satellite. Multifrequency operation of antenna feedcan also be achieved by developing the common aperture feed catering dual/triple frequency and technique has to be developed so as to suppress the generation of higher order mode. Analysis and design of high efficiency antenna feed and its Orthomode Transducer, polarizer, diplexer etc are required for multiple beam antenna. Various types of feed horn catering different applications such as Trifurcated feed horn, Quasi integrated horn for high frequency application, horn with high power handling capability, Single aperture feed at C/Ku/Ka band for ground segment, profiled compact horn etc are to be designed. The navigational satellites will be radiating a composite signal covering the three bands simultaneously. There is a requirement to receive these three bands using a single compact ground terminal antenna covering L1, L% & S band. The common aperture antenna needs to be designed with single feed and it has to provide good axial ratio over large coverage angular extent upto 60-70 degree. The RESPOND investigator should study and demonstrate an optimum design for these requirements.

14. Feed Array for reflector antennas:

Feed array or multiple feeds illuminating reflector is required for multiple frequency or multiple polarization applications. Effect of mutual coupling between focal array feeds and its effect on antenna performance parameterslike cross polarization, gain, beamwidth have to be studied. Beam shaping as well as the phase errors correction due to surface deformation may be accomplished by using cluster of feeds with proper beam forming network at the focal plane of the reflector. Investigation is needed to calculate the array excitation coefficients through the derivation of focal region fields for a shaped pattern or a reflector with deformed surface.

15. Flexible coverage antenna:

Various reconfigurable antenna system for flexible coverage on the antenna need to be studied and designed. This requires design & study of multiple beam antenna, computation of excitation distribution to get the required beam shape and position. Development of various beam-forming algorithm and its implementation required to be explored.

16. Antennas based on Micro-machined / Wafer-borne Substrates

At mm-wave frequency ranges, antennas & feed may be realized on thin substrates and / or wafer-construction. The RESPOND investigators should study the various techniques and propose optimum fabrication methodology for design and development of such antenna systems for future linkage.

17. Medium- or High-Gain UHF Antennas for Satellites

In recent times, the need for satellite-borne UHF antennas has emerged. Configurations for antennas with medium- or high-gain that may be mounted on satellites need to be studied and evolved. The RESPOND investigator should undertake this study and propose optimum antennas for this requirement. Prototype demonstration may be included in the scope.

18. Conformal Antennas for Omni-directional Coverage Patterns

Due to upcoming space-science and inter-planetary missions, satellites need to carry antennas that are conformal to the cylindrical / arbitrarily-shaped satellite body. Also, pointing mechanisms may be expensive / unviable on such missions. Hence, RESPOND investigators should develop antenna configurations that provide omni-coverage including the effect of the satellite body on the radiation pattern.

19. Ultra Wideband antenna at VHF band.

Design and development of suitable compact antenna element at 10-50MHz with 150-200% bandwidth with the constraints of mass & volume for interplanetary mission of ISRO may be taken up by the investigators under RESPOND.

20. Soft computing techniques for shaped reflector antenna design

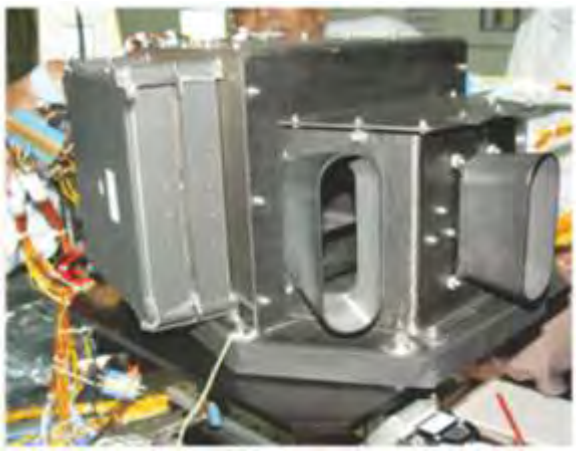
Different evolutionary techniques like back propagation algorithm, radial basis function and quantum/binary particle swarm optimization technique may be developed for shaped parabolic hyperbolic and elliptical reflectors to generate required secondary pattern and scattered pattern of sub- reflector at both. These technique may also be studied for optimization of antenna performance parameter.

21. Un-furlable/Inflatable Antenna

Emerging requirement of achieving higher EIRP and G/T with achievable edge of coverage gain gives the birth for ultra-light reflector technology. There is the requirement of simulation of large size unfurlable/inflatable antenna. The simulation has to include the number of segment needed so that radiation pattern performance is close to true parabola. It can also include the optimization of number of facets and buttons needed, the material and gas to inflate the reflector. It also include the study of RF feed through and compact size antenna with active element for required beam steering.

5. Remote Sensing-Sensor Technology

5.1 Electro-Optical Sensors



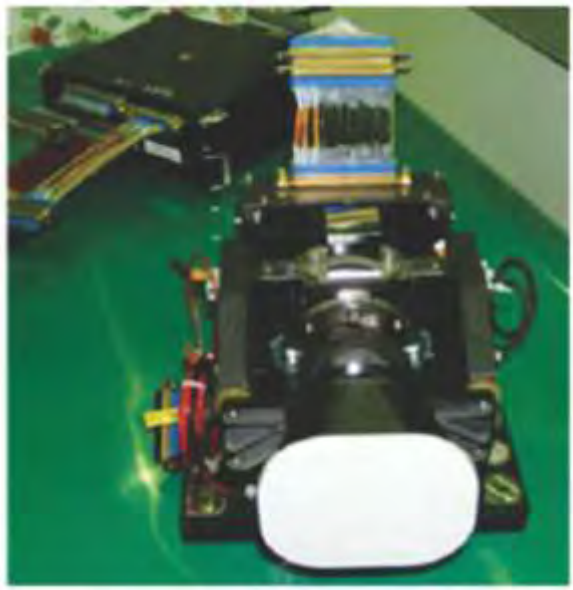
Chandrayaan-1 TMC

ISRO is engaged in electro-optical (EO) imaging sensor development activities since last four decades and Non-imaging sensors for scientific requirements such as Limb viewing, Aerosol monitoring, Green House Gas sensors etc. The era of operational remote sensing, in the visible and near infrared bands, began with the launching of IRS-1A in mid eighties. Simultaneously, development of Very High Resolution Radiometer (VHRR) for metrological observation was also taken up. What was started with 72 m ground resolution has come to sub-meter resolution over the years and from four spectral bands to 512 spectral bands. This has emerged with adaptation of state-of-the-art technologies, innovative designs, shrinking the size of the sensor and shedding weight. The final products have elevated performance, more features, agile operation and sharpest world class imagery. These matured technologies found their use in sensors for IRS and INSAT missions for land and ocean resources survey including atmospheric, meteorological and limb view study of the earth and its environment. Technology development of industrial and commercial technologies are also tried in Indian Mini-satellite mission (IMS-1) which had four band multispectral sensor and 64 bands Hyper Spectral Sensor. Also, planetary missions such as Chandrayaan-1 used these newer technologies for development of Terrain Mapping camera, Hyper-spectral Imager and Moon Impact Probe. The net outcome is reflected in terms of better performance, newer features, smarter operations and higher compactness in most of current and near future payloads. The research and innovation are continuing activities and are to be pursued either in-house or in collaboration with academia/industries. Following is a list of areas where academic institutions can contribute to this endeavor of EO sensor development team.

» Research Areas in Electronics:

Speed of operation of onboard electronic circuits has a direct bearing on the geometric resolution of a camera and also on the number of colors in which a camera captures a feature. As the resolution improves, the circuit operation becomes faster. Compaction calls for miniaturization of electronics and development of specialized multi-function, ultra-low power circuits. Following are the areas of research for electronics.

1. Ultra-low power, High-speed analog front-end devices for processing of detector signals and interfacing devices
2. Miniaturization of electronics in the form of low power ASICS and Read Out Integrated Circuits (ROIC)
3. On board data processing, loss-less data compression and generating theme based data output using radiometric, spatial and spectral compression techniques
4. Analog, mixed signal and digital ASIC design, simulation, verification
5. Advanced PCB technology for miniaturization of high speed and high power front-end electronics including its thermal management
6. Onboard high speed data transfer, interfacing and networking
7. Extraction of very low signal from noise – Techniques
8. High power capacitance/inductance drivers with multilevel voltages
9. Modeling of special devices – Techniques
10. Modeling of devices for Cryogenic temperature operation
11. Mitigation techniques for radiation environment in space (TID/SEL/SEU etc) - Device level, System level
12. Topologies for High Speed design and digitization
13. Design of >30 bit Digitizer
14. Chip on board technology for space hardware
15. EMI susceptibility analysis for co-existence of low noise, high speed, high power analog/digital circuits
16. DSP based real /near real time data processing for signal analysis and image processing with emphasis on frequency and spatial domain. Tentative applications are
    - Hardware and/or software with Image Based attitude determination electronics.
    - Spacecraft docking system electronics
    - Real Time decision making for Landing System
17. Onboard computer electronic system (including volatile, nonvolatile mass memories, processors, standard interfaces, RTOS etc.) for space environment supporting soft computing of complex algorithms and real time applications



Chandrayaan-1 HySI

18. Development of high power (100W) high efficiency (>90%) power amplifier working over unregulated raw bus for driving low impedance load (< 4 Ω)
19. Algorithm to minimize jitter at cold tip of pulse tube cooler or sterling cycle cooler using close loop active vibration control
20. Development of algorithm or MATLAB model to estimate/optimize PID coefficient for optimum response based on overall close loop transfer function or any industry defined PID tuning method. Also, development of cooler transfer function based on empirical data or close loop response measurement.
21. Very Low noise (⩽ 1mV), Low power (<10W), highly efficient (>90%) space grade miniaturized (12W/in^3) isolated power supply /module including advance features for protection and output control.

» *Research Areas in Optics:*

Hyper spectral Systems are replacing multi-spectral type instruments. Finer resolution implies larger and bulkier optics. There is a great scope in this area for compaction, innovative focusing, alignment techniques and swath improvement. Multi purpose large area array detectors are replacing the present day linear detectors. Mathematical modeling and optical domain processing are envisaged to be implemented. Following is the list of research areas where academic institution can contribute either in terms of study, algorithm development or prototype development.

LiV HySI

1. Compact optical systems
2. Studies and solution for gravity effect on large diameter light weight optics
3. Adaptive optical elements
4. Development of extremely thin and deformable mirrors
5. Metal mirror optics for VIS / NIR imaging
6. Interferometric sensing system
7. Optical butting to increase swath at higher resolution
8. On-board focusing
9. Development of wedge/ strip filters
10. Athermalization of optics using phase plate
11. Studies on super resolution techniques

12. Image quality analysis of catadioptric (Reflective and Refractive) systems
13. Origami lenses
14. Diffractive Optical Elements (DOEs) and development of hybrid lenses (diffractive + refractive)/Binary Optics
15. Super Lenses (using meta-materials)
16. Foveated Optics

» *Research Areas in Detectors:*

1. Modeling of CCD based imaging sensor charge transfer scheme.
2. Minimization of Charge of transfer efficiency degradation when irradiated with high energy radiation
3. Mathematical simulation of Quantum Dot Infrared detector performance
4. Development of Si photodiodes with high responsivity in blue and NIR spectral regions.
5. Surface treatment approaches for photodiode Quantum Efficiency improvement (NIR to Blue and/ or selected wavelength regions). Graded antireflection coating for minimization of reflection as a function of wavelength, in area array Si CCD
6. Surface treatment for dark current minimization
7. APD development (Si and InGaAs)
8. Development of MCT based PV detector sensitive in the spectral region SWIR-LWIR regions
9. Multiband (SWIR/MIR, MIR/SWIR - detector Infrared detector Development (including Quantum/ Type-II Strained layer type detectors)
10. Development of Multi-band high quantum efficiency detector arrays.
11. Hemi sphere/ flexible Focal plane arrays
12. High speed high performance APS arrays
13. Miniature gas sensors for CO, CO_2, CH_4, NH_3, O_2, N_2O, $SO_2$and other Greenhouse gases.
14. Optical Fiber based gas sensor

» *Research Areas in Electro-Optical Systems:*

1. Fourier transform spectrometers for space
2. Imaging spectrometer- VNIR and TIR
3. Compressive sensing techniques
4. Tera-Hertz imagers

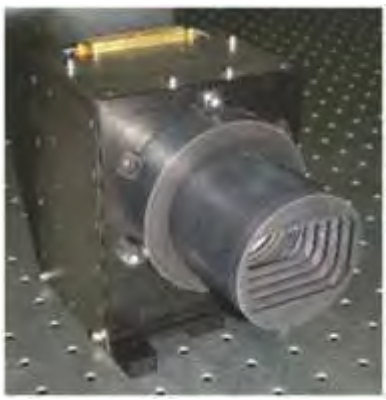
5. Compact optical systems
6. Formation Flying EO systems
7. Imaging Science – Modeling of complete imaging chain – simulation and advancements
8. Miniaturization of EO sensors/imagers through use of MOEMS
9. Space LIDAR/LADAR
10. Precision calibration sources for ground and onboard use
11. Precision scene simulators
12. Fibre Optic based image relay system
13. Studies on 360º imaging optical systems relevant to space based remote sensors.
14. Micro Mirror based scanners and imagers.
15. Inter-calibration of hyper-spectral sensors having different spectral response.
16. Development of models for radiometric and background radiation performance evaluation of Payloads
17. Identification of trace gases using mass spectrometry data

» Research Areas in Electro- Ground Checkout Systems:

1. Embedded firmware for Real time Data processing, continuous data acquisition (data rate of up to 2 Gbps), Real time video streaming (@ 15fps of frame size 2560x2160) and real time Image display.
2. Drivers for multi-core DSP system, with RTOS and algorithms for real- time object identification as well as tracking.
3. General purpose graphics processing based systems for high speed real time image display.
4. Very high speed Data acquisition of the order of 40Gbps sustained for about 2 TB volume.
5. 3-axis precisely controlled mounts for distortion free imaging.
6. Extraction of finer spectral resolution information from Hyper-spectral Imagery, given a large number of relatively coarser resolution images with overlapping spectrums.
7. Algorithm/software to create a super straddle of workstations towards effective utilization of computing resources for electro-optical payload development environment.
8. Development of algorithms/software to generate 3D images using DMD based scanning of targets.
9. Development of Mathematical Models for an Electro-Optical System and
10. Software to simulate the final image, with sensitivity to design parameter/system environment/onboard processing/viewing geometry.
11. Firmware for Baseband Reception of high speed serial data and real time extraction and dissemination of raw data from FEC coded/CCSDS formatted/Compressed/Encrypted data stream.

» *Research Areas in Integration and Testing:*

Assembly, integration and testing of space-borne EO imaging systems is a multidisciplinary task and requires state of the art test and evaluation setups and methodologies. In a complex EO system environment, system performance needs to be optimized to achieve goals. Technology trends coupled with growing user demands has propelled the development of very small size systems to very large size EO systems. Integration and testing of these systems are very challenging and requires custom development. During various phases of testing, large amount of ground test data is generated, which is used for system performance characterization. Integration and testing of space-borne imaging systems requires development of test setups, system performance estimation models, performance optimization and characterization methodologies, in-orbit performance prediction models, data analysis and interpretation, troubleshooting etc. Following areas of research is of interest in the field of Assembly, integration and testing of EO imaging systems:



1. Space-borne electro-optical performance estimation models
2. Automation of imaging system test setup
3. Precision test setups
4. Development of innovative techniques/methodologies for integration and testing
5. Development of imaging system performance optimization and characterization techniques
6. Development of In-orbit performance prediction models and performance evaluation techniques
7. Development of methodologies and fast algorithms for analysis of large amount of test data

5.2 Microwave Sensors

Since the inception of microwave remote sensing in India in mid-1970s, with the launch of SAtellite MIcrowave Radiometers (SAMIR) onboard Bhaskara-I/II; it has grown consistently and in last 3 decades many major milestones have been achieved. During 1980-2000, various passive and active microwave sensors like X-band Side-looking Airborne Radar (SLAR), 2-18 GHz Ground based

Scatterometer for radar signature studies, C-band airborne Synthetic Aperture Radar (ASAR) for airborne imaging and a Multi-frequency scanning microwave radiometer (MSMR) onboard Oceansat-1 for oceanographic applications were developed.

In recent years, ISRO's Earth Observation (EO) and Science & Inter-planetary mission capabilities have been enhanced to a great extent and operational activities have been consolidated with the successful launch and usage of data from state-of-the-art passive & active microwave sensors like Oceansat-2 Scatterometer (23 September-2009) for deriving ocean wind vectors, Megha Tropiques MADRAS (12 October-2011) for meteorological applications, Airborne SAR for Disaster Management (DMSAR) for flood mapping etc. The crowning glory, C-band multimode high resolution SAR onboard RISAT-1 (Launched on 26 April-2012), consisted of 6m x 2m active phased array active antenna and comprised nearly 1500 subsystems working in unison and help India join the exclusive club of nations having the unique capability to design, build & operate very complex space-borne multi-mode active array microwave imaging sensors. Oceansat-2 Scatterometer data were utilized globally by agencies like ISRO, NASA/JPL, NOAA and Eumetsat and proved India's capabilities to create a spaceborne instrumentation base providing climate quality data for the service of humanity. RISAT-1 SAR data have also been commercialized to international user community.

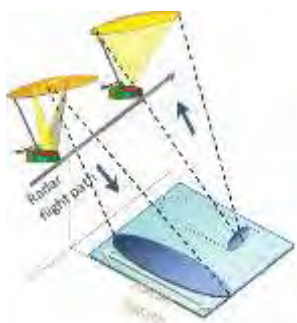
Presently, system design & configuration and realization of Design Verification Proto and Flight model realization exercises are underway for Ku-Band Pencil Beam Scatterometer for Scatsat-1, L & S-band dual freq. SAR onboard Chandrayaan-2 orbiter and Ka-band radar Altimeter for Indigenous Lander, X, L & S-band Space-borne & Airborne SARs, S-Band SweepSAR for Dual Band NISAR and Mmwave temperature & humidity sounders. Many new technology developments like Ground Penetration Radar (GPR), Ground based Scatterometer (GBScat), Dual channel C-band Active Radar Calibrator (ARC), Solid State Recorder (SSR), Digital & Mixed Signal ASICs, MMICs and advanced R&D activities including indigenization and miniaturization efforts initiated in recent years have also resulted into varied & noteworthy technological accomplishments.

For the proposed & other future Microwave Remote Sensing activities in MRSA, the following broad Research Areas have been identified.

» *Research Areas :*

1. System Design and Configuration:

High resolution, wide swath SAR system configurations using **Digital beam-forming and SweepSAR;** mm-wave atmospheric **temperature and humidity sounding; scatterometer** systems; **Ground-Penetration**



Sweep SAR Concept

Radars (Stepped Chirp/CW-LFM/ Impulse-type Ultra wideband); **Active Radar Calibrators; High accuracy Altimeter** for Hazard Detection, Navigation and Guidance; **GNSS-Reflectometry;** MTI-SAR from spaceborne platforms, SAR Polarimetry and Polarimetric Interferometry, new algorithms for Polarimetric Decomposition using hybrid polarimetry, Precipitation Radars, Doppler Weather Radars, Mini, Micro & Nano SAR systems at RF & mm-wave, Advanced Microwave sensor Calibration techniques, Inverse SAR systems etc.

2. Transmit-Receive Technology:

GaN Based 210W S Band

Wideband, high power Miniaturized TR Modules and Pulsed TWTAs in L,S,C & X-bands, **High Power MMIC Designs,** compact Microwave Power Modules (c-MPM) & Combiner, **High Efficiency Pulsed & CW SSPAs (MOS/GaAs FET, GaN HEMT/HBT) with associated thermal & power management, High power & low loss X-Band Ferrite Switch** assemblies, ultra low noise & ultra high freq. (mm & sub-mm freq.) technologies like mHEMT/pHEMT/ Schottky/RF-CMOS for linear (LNAs/Gain Blocks), non-linear (mixers/multipliers/VCO) & control circuits (Phase shifters/ Attenuators/Switches), Multi Chip Module technologies (multi-layer soft substrates/LTCC/HTS), Highly stable & Coherent Phase Locked (VCO/DRO) compact Frequency Generators, Metamaterial structures, MMIC, RF MEMS and RF-CMOS Receiver Designs, etc.

3. Power Supply Technology:

Point of Load Coverter

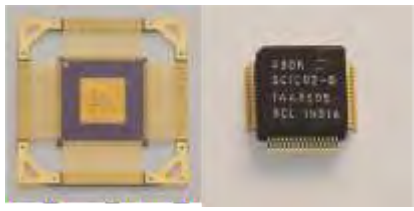
Miniaturized & high efficiency, pulsed power supplies with higher current capabilities, Low Drop-Out Regulators (LDO) & **Point Of Load (POL) Hybrid HMC/ASIC, soft switching DC-DC converters, Reconfigurable (FPGA/ Power ASIC based) Converters etc.**

4. Digital and Mixed Signal Technology:

1Tbit Solid state Recorder

Mixed Signal ASIC Design & Development (8-14 bit ADCs & DACs @ 1.5 GSPS), Ultra-High Speed SERDES (>2.5 Gbps), SAR processor ASIC / SoC with huge on-chip Memory, Fault tolerant Reconfigurable 32/64-bit MicroProcessors/DSPs/SoCs, Ultra-High speed/Capacity (>5 Tbits) Scalable Solid state mass storage, Wideband waveform synthesizer (>1GHz BW), Opto-electronics devices & Transceivers,

Ultra-High Speed Serial/ Parallel Interfaces (wired/wireless), wireless active antenna Tile Electronics, **Ultra High Speed (>1.5 GSPS) and Ultra-High Precision Data Acquisition Electronics (16-32 bits), Design of** Radiation Hardened Cell libraries for 0.18um SCL Foundry, Radiation Tolerant/Hardened Package design, SEL/SEU-Immune Designs, Soft & Hard IP developments for peripherals, Signal Processing modules, Interface modules etc..



OBC-1.1 & ASDR ASICS

5. Onboard Payload Data processing Technology:

Real Time SAR Data Compression and Signal Processor, Real time signal processing for Radar Altimeter, Real time feature/hazard detection for planetary landing assistance, onboard Radar backscatter (0) computation for Scatterometer, Multi-channel Complex Correlator for Synthetic Radiometer, Geometric and Radiometric calibration of microwave sensors, etc.

6. Signal and Image processing Algorithms:

SAR raw Data Compression using Compressed Sensing/Wavelet Transforms, Signal Processing and Tracker algorithms for Radar Altimeter for Navigation, Guidance & Control, Complex Correlation Algorithm for Synthetic Aperture Radiometer & Performance Analysis, Onboard SAR Processing algorithms, Linear & Hybrid Polarimetric Data Processing and Analysis, Interferometric SAR Data Processing and Analysis, Super Resolution Image Processing Algorithms, Feature Extraction Algorithms for Microwave Data, **Extraction of Subsurface Dielectric properties for Ground Penetration Radar, GNSS-Reflectro\metry & GNSS Remote sensing Receiver etc..**

RISAT-1 Hybrid Polarimetric SAR Image of Ahmedabad City

6. Remote Sensing-Image Processing and Applications

6.1 Image Processing

Signal and Image Processing Area (SIPA) is responsible for the design, development, Operationalization and maintenance of software for remote sensing data processing related to earth, planetary and astronomical observations for Indian as well international user community. SIPA is also engaged in design & development of custom-made software for specific ISRO/ANTRIX clients. The Area specializes in design of algorithms for signal & image processing, geo-spatial techniques & methodologies for efficient computing for the development of Data Products & Data Quality Evaluation Software systems and services for **Multi-spectral CCD Sensors** (e.g. RESOURCESATs , Ocean Color Monitor) and optical radiometers (e.g. on Geostationary platforms: INSATs, GISAT) **High resolution and stereo data** (CARTOSATs) from optical sensors, **Hyper spectral** sensors from space borne and airborne platforms, **Microwave sensors** (Scatterometer, altimeters, SAR, radiometers, radio beacons and GPS-RO), **Ultra-violet** and **X-ray** sensors, **Calibration & Validation methodologies** and adoption of software engineering standards.. Keeping in view the prevalent global scenario in EO and planetary missions, gap areas, information needs, user demands, latest trends in Data Processing, advances in computing technologies and taking cognizance of the long term vision of ISRO especially with respect to Data Processing is geared to take up challenges that involve design of improved algorithms/methodologies, simulations, modeling, development of advanced techniques and efficient software and its Qualification, Operationalization and Maintenance for achieving state of the art Data Products Specifications. This calls for identifying thrust areas and carrying out a large number of R&D exercises in data processing for upcoming missions like, RESOURCESAT-2A, CARTOSAT-2C/2D, INSAT-3DR, ASTROSAT, Chandrayaan-2, CARTO-3, GISAT, HYSI, RISAT-2A, NISAR, OCEANSAT-3 and SCATSAT-1 etc. The focus areas identified are the following.

- Advanced Algorithms & Software for Optical Payloads
- Advanced Algorithms & Software for Microwave & X-Ray Payloads
- Data Services & Data Package Development for Advanced Applications
- Advanced Signal & Image Processing Techniques
- Simulations & Visualization
- Software Architecture & Processing Optimizations

» *Research Areas:*

Advanced technique and algorithm development for in-flight Geometrical Calibration and its Standardization for Optical Remote Sensing payloads

In-flight geometric calibration exercises are carried out usually during initial phase of the mission and necessary algorithms and corresponding s/w are developed for each mission separately. Special efforts are put for conducting a large number of exercises and analysis of results. This makes the in-flight experiments purely mission dependent calling for s/w changes for any new mission. Further, different modeling approaches are available with the DP team. So a need for generalized s/w is felt based on the current experiences while giving scope for flexibility to extend the approach for new sensors like TDI and other high-resolution imaging modes. A scheme for standardization/generalisation of this activity is being evolved in terms of the following viz.

- Establishing necessary set of pre-identified test bed areas where adequate number of accurate control points are available, for use by any mission
- Development of mission independent techniques/algorithms and necessary s/w to work with or without control.
- Provision to incorporate new techniques, various modeling options to work with/without control points, options for single sensor, stereo sensors, triple sensors, multi-strips, multi-bands, TDI sensor, imaging modes etc.
- Identifying a set of common in-flight geometric parameters for adjustment for any mission as well as mission specific features.
- Approach should be able to characterize interior and exterior orientation of the sensors.
- Standardization of definition, convention for in-flight geometric parameters and their use
- Estimation and separation of attitude biases from spacecraft alignment and payload alignment angles etc.
- Standardization of Input/Output file formats and contents
- Scope for adding any additional, new features pertaining to in-flight procedures.

This research aims at development of new procedures (both technology development as well as R&D work for development of algorithms and s/w) and standardization/generalization of the approaches for in-flight

geometric calibration of the sensors onboard remote sensing satellites, which will result in high accurate data product realization at system level, apart from improving registration and mosaicking accuracies across missions for handling heterogeneous data sets. This can also give a future direction to the calibration procedures in terms of the requirements of some of the hardware onboard so that they can be useful in the future remote sensors (Cartosat-2C/2D, Cartosat-3, Cartosat-1A/1B, Chandrayaan-2 etc) of different configuration.

Modelling for Multiple Satellite/Sensor/Strip/View data in block adjustment sense

The aim of this research is to develop approaches/techniques (both parametric and non-parametric) to model simultaneously data from multiple satellite/sensor/strips/Views from Cartosat-1/2/2A/2B and future missions to generate terrain corrected products with high accuracy. The scope of the proposal includes development of techniques for generation of Digital Elevation Models and Orthoimages without using the control points so that it can meet the Global requirements. This can be achieved by increasing the redundancy in the datasets. Both Physical and RPC models will be built in block adjustment such a way, it can be easily adopted for planetary missions Chandrayaan-1 and Chandrayaan-2.

It is planned to make use of this approach with global missions like Quickbird, IKONOS, Worldview for available data sets. The proposed research will be able to handle and model full pass duration with limited control or no control and pave way for realising highly accurate DEMs and good quality data products especially for future HR missions like Cartosat-2C/2D, Cartosat-3 & other upcoming carto series of satellites & other High resolution missions.

Data Simulation

a. High resolution data simulation for future Cartosat series and HYSI mission

There is a need of data simulation towards understanding the TDI devices in terms optical butting (used to make swath larger), high bit depth (radiometric resolution) and spatial resolution (0.5 m or higher). Therefore TDI sensor data simulation will be taken up in near future by using the other TDI devices data already flown globally like IKONOS/Quick Bird etc. This simulation will help in calibration, and testing the data processing and data compression s/w of Cartosat-2C and 3. Data simulation is also required for HYSI sensors for testing of data processing algorithms, simulation of agile platform effects as well as testing of data compression algorithms.

b. Simulations for microwave sensors

There is a need of data simulation for testing effect of various sensor parameters like chirp bandwidth, slice bandwidth and resolution, SNR etc. on performance of pencil beam scatterometer.

Simulations of wave-forms are required for deciding on optimum sensor parameters and tracking algorithms for spaceborne altimeter system. Simulations are required to develop robust phase unwrapping algorithms for sar interferometry techniques. Simulations to understand concept of sweepsar for acquiring data over large area with better geometric resolution. Data simulation will also help in testing of data processing algorithms.

Data Visualisation

An immersive satellite image navigator with human gesture recognition

This research may brandish a complete suite to visualize the image data with gesture recognition features. This kind of navigation will enable swift display and browsing of satellite image data with the help of no contact, gesture driven device (like Wii). Also, it can be used in discussion panels, exhibitions and presentations which intend to use this type of visualization as an approach for technology demonstration.

Development of Image fusion techniques

This research is aimed towards development of image fusion techniques by spatial and frequency domain methods for merging HR PAN & MX data as well as optical and microwave data. The scope includes

1. Development of Image fusion method to generate merged product of Cartosat-2C.
2. Study & implementation of suitable algorithm and in-house software development from the existing approaches for HR data and
3. Development of Image fusion methods to generate merged products from various optical bands and microwave multi-polarised data acquired at different look angles.
4. Initially testing can be done by existing Cartosat-1, IRS-P6 and RISAT-1 data sets.

Image Matching for DEM generation

One of the most important components of DEM generation from stereo/ multi-view imagery is the generation of high density match points and their structuring. Current version of CartoDEM based on Cartosat-1 stereo pair is based on advances in template matching to produce high density match points and structuring by TIN. Further research areas taken up in this include feature-based matching, better shadow and outlier detection, and improved DEM regularization/ conditioning for end-use. Another area of research in this field is development of robust algorithm for triplet matching, which will be enhancing the current version of Lunar DEM generated from Chandrayaan-1 TMC as well as for future Chandrayaan-2

TMC. R&D efforts are required to generate very high quality DEM from Aerial TMC stereo/triplet data sets by extending the above methods in terms of improvements in techniques/algorithms

Image Quality Improvement

The image component of Data products are a result of correction for systematic errors/ variations in Radiometry and Geometry. Development of techniques for restoration (MTF correction) of high spatial resolution imagery (e.g. Carto-2 series), de-striping of narrow-band sensors like OCM, and spectral de-convolution of Hyper-spectral imagery are areas of research in this category. Currently operational MTF restoration for Cartosat series are based on techniques developed here.

Quality Indices for quantifying Data Quality

Delivery & maintenance of operational system for DQE (Data Quality Evaluation) for all ISRO sensors being the primary responsibility of IAQD of SPDCG, there is continuous R&D in terms of identifying suitable quality parameters for each sensor, development of algorithms for evaluating the parameters from data, and quantifying uncertainties in the process.

Generation of quality flags for INSAT-3D products (INSAT-3D, INSAT-3DR)

A study on identification of quality flags for data products of Imager and Sounder is planned to be initiated. Quality flags will be formulated to capture end-to-end quality related to sensor performance, data processing approach and calibration quality, keeping in view quality requirements of climate quality data.

Some of proposed scene-wise quality flags for Level-1 products are a) Radiometric quality – visual, calibration accuracy, sensor noise and b) Geometric accuracy - navigation accuracy, channel mis-registration. Additional flags as per requirement may be identified. Effect of above quality flags on usability of geo-physical products (eg. SST, OLR, UTH, Atmospheric winds) on identified sites will be studied. Validation exercise with references/in-situ measurements is also planned to be carried out

Identification of quality parameters for Hyper-spectral Data

Quality parameters to quantify Geometric, Radiometric and Spectral quality of Hyper-spectral data are required to be identified. Quality aspects specific to Planetary or Land applications such as spectral signature identification for mineral mapping can be explored. Effect of basic data quality on usability and accuracy of higher level products generated for applications can be analysed.

Study area can be identified with available hyper-spectral data (Hyperion/AHYSI sensors), where sensor performance and data quality can be studied and validated with ground observations.

Integrated Work-bench for Quality Analysis of remote sensing images

A work-bench for quality analysis is proposed to be developed that would support data visualisation and quality evaluation of remote sensing images. The software should support visualization of different types of satellite images (Medium to High resolution, Multi/Hyperspectral, Optical/SAR) and geo-physical data products (SST/UTH/WV etc). It should have capability of overlaying Vector Layers (District/State boundaries), Ground Control Points (GCPS), Google-Maps available in public domain on images. Use of Open source libraries/GIS packages can be explored for implementation. Domain specific techniques for semi-automatic quality evaluation will be integrated with the proposed software.

Post-launch Calibration of space-borne sensors

This is carried out for medium resolution optical land-imaging sensors' radiometry based on natural calibration sites, for narrow-band Ocean Colour sensors based on Moon-imaging, for high resolution sensor MTF based on artificial targets, and for SAR sensor geometry using corner reflectors and radiometry from natural sites. Development of suitable models for ground radiometry assimilation, Top-of-Atmosphere radiance generation, Moon-image irradiance modeling, target design and modeling for MTF evaluation, and for modeling of calibration parameter determination for SAR targets are areas of research in this category. In each aspect operational methods are based on R&D carried out here.

SAR radiometric calibration is one of the important aspect to characterize and maintain image quality throughout the mission and to provide stable, quantifiable image products to the users. This exercise is carried out throughout the mission in different manners.

- For SAR sensors, continuous monitoring of gamma naught and sigma naught on non-variant calibration sites like Amazon rainforest, Boreal forest is done to observe antenna pattern and consistency in gamma0
- Radiometric parameters like sigma0, speckle index and radiometric resolution are observed from other distributed targets for the data sets with same instrumental parameters (beam, polarization). This exercise is used to estimate noise equivalent sigma0 to ensure the data quality
- Scalloping and banding are the distortions needs to be quantified for ScanSAR mode
- Corner reflector based calibration is done to compute the impulse response parameters. A regular and systematic analysis helps to estimate the radiometric accuracy and stability using corner reflector based data

» Monitoring of SAR instrument subsystem components is used to study gain variations or linearity

A novel approach for **Data quality evaluation of Scatterometers** (OceanScat or upcoming mission ScatSat-1) is being worked out where one can relate the parameters available at different levels of product to geophysical parameters. In Scatterometer the vector wind is retrieved by combining several backscatter observations made from multiple viewing geometries.

From Level0, Leve1 and Level 2 data products, behavior of each sensor parameter is studied and suitable flags are generated if any deviation is observed. Pre-requisite of this exercise is first to have proper understanding of the instrument and algorithm characteristics which gives an insight into the factors controlling data quality. This monitoring and stringent flagging of required parameters at each level ease the traceability in order to relate the end product with Level 0 or intermediate level of products.

Scatterometer calibration includes the monitoring of onboard calibration data to keep a check on transmitted power. Invariant sites like Amazon rainforest, Sahara Desert, Antarctic snow are required to be monitored regularly and time series of backscattered or brightness temperature can be generated to check the system behavior. Regular such feedbacks help data processing to fine tune the DP system in order to generate high accuracy data products.

Earth Observation Data Processing:

1. Advanced sensor models for optical & Microwave data Geo-referencing
2. Techniques for multi-date data registration and mosaicing
3. Techniques for Geospatial Data Analysis
4. Atmospheric correction procedures implementation for Visible, NIR and HYSI
5. Data Processing for Smart Satellites
   - Carry out the technology demonstration of carrying out complete Data processing on-board and disseminating products/Information
6. Time Series Data Processing
   - Re-Processing all IRS, land and ocean data for generation of Atmospherically corrected orthozrectified (water leaving radiance and ground reflectance) products, which can be used for Time Series analysis and generation of climate quality products
7. Data Mining: A Data mining framework for information extraction
8. LIDAR Data Processing: Space Based, Ground Based and Aerial LIDARS
9. Data Processing for Atmospheric studies using space borne platforms

10. INSAT-3DR, Resourcesat-2R, GISAT Improved Processing algorithms and techniques to support real time users requirements and generation of Atmospherically corrected Land Products
11. Generalized Data Processing Software for Air-borne HySI Optical sensors
12. Development of Advanced SAR Image Formation techniques including sweepsar, Polarimetric techniques for air-borne & space-borne payloads
13. Development of general SAR processor to process C, X, L and S band data
14. Development of techniques to process squint mode and spotlight mode SAR data
15. Calibrated Climate Quality Products generation and global dissemination from Scatterometer & Altimeter type of Payloads
16. Techniques for SAR interferometry and differential interferometry using SweepSAR repeat pass data.
17. Techniques for Sea Ice detection and kinematics of ice using SAR and scatterometer data
18. Development of techniques for processing of synthetic aperture radiometer data
19. Augmentation of analysis and applications packages for microwave Sensors
20. New retrieval Algorithms – FSI (Full Spectrum Inversion) of ROSA data Processing
21. Loss less data compression solutions for various levels of products of Airborne and spaceborne HYSI sensors.

Image Processing and Pattern Recognition:

1. Relative Radiometric Normalization Techniques
2. Advanced image Registration models/frameworks/software/libraries
3. Image classification and intelligence
4. Kernel based Learning/Machine Learning for Change detection analysis
5. Super resolution Approaches for Remote Sensing Images
6. Resolution enhancement approaches for scatterometer and radiometer data
7. Automatic Feature Extraction and Labeling Techniques
8. Noise Modeling, Blur removal
9. Image Representation
10. Image Based Modeling and 3D re-construction
11. Techniques for Classification of Hyper spectral images
12. Techniques for Textural feature extraction from multi-spectral and hyper spectral images

Planetary Data Processing:

1. Vision based horizontal velocity estimation of lander craft using optical flow methods - which will involve study of algorithms and development of software for vision based horizontal velocity computation, useful for soft landing of lander craft (Chandrayaan-2).

2. DTM generation from terrestrial stereo images & Path guidance algorithm development for rover instrument:

This calls for (i) study and understanding the methodology/techniques and related software development for deriving DTM from terrestrial stereo images using close range photogrammetry concepts (for Chandrayaan-2 Rover camera) and (ii) Derivation of optimum path between two points using the terrain information over moon surface

Astronomical Data Processing and Analysis:

1. Autonomous Spacecraft navigation using Pulsars –

   - » To evaluate the usability of fast spinning and strongly magnetized neutron stars, also known as pulsars, in defining and external reference system suitable for deep space navigation.
   - » To propose a methodology that can be used in deep space navigation for operational purpose

2. Study of Anomalous X-Ray Pulsars

   - » The objective of this study is to review and add understanding of recent observation as well as analysis of Anomalous X-Ray Pulsars with an emphasis on timing, variability, and spectra. This study should contribute in deeper understanding of AXP in terms of its high and variable magnetic field, its evolution and its importance in life cycle of a star. Astrosat Data will be used for study and other contemporary satellites data will be used for validation.

Visualization, Cloud Computing & Software Architecture:

1. Developing Advance Techniques for Earth & Planetary Data Visualization

   - » Real Time Visualization of robots
   - » Visualization of astronauts space walks
   - » Identification of landing sites on other planets

2. Immersive Data Visualization for Earth Observation Applications

3. Establishment of a Virtual reality and data/ Information visualization facility for earth and planetary missions

4. A private cloud infrastructure for Image processing and highly compute intensive applications so as enable designers/developers to dynamically use computing and storage resources in HPC environment.

5. GRID enabled Global Data Processing Model

6. Parallel Processing approaches for real time data processing and re-processing in HPC environment and using GPGPU platforms as well as accelerators like Intel-5

7. Consolidation of Software Library and adapting in SIPA Projects

6.2 Earth, Ocean, Atmosphere, Planetary Sciences and Applications Area (EPSA)

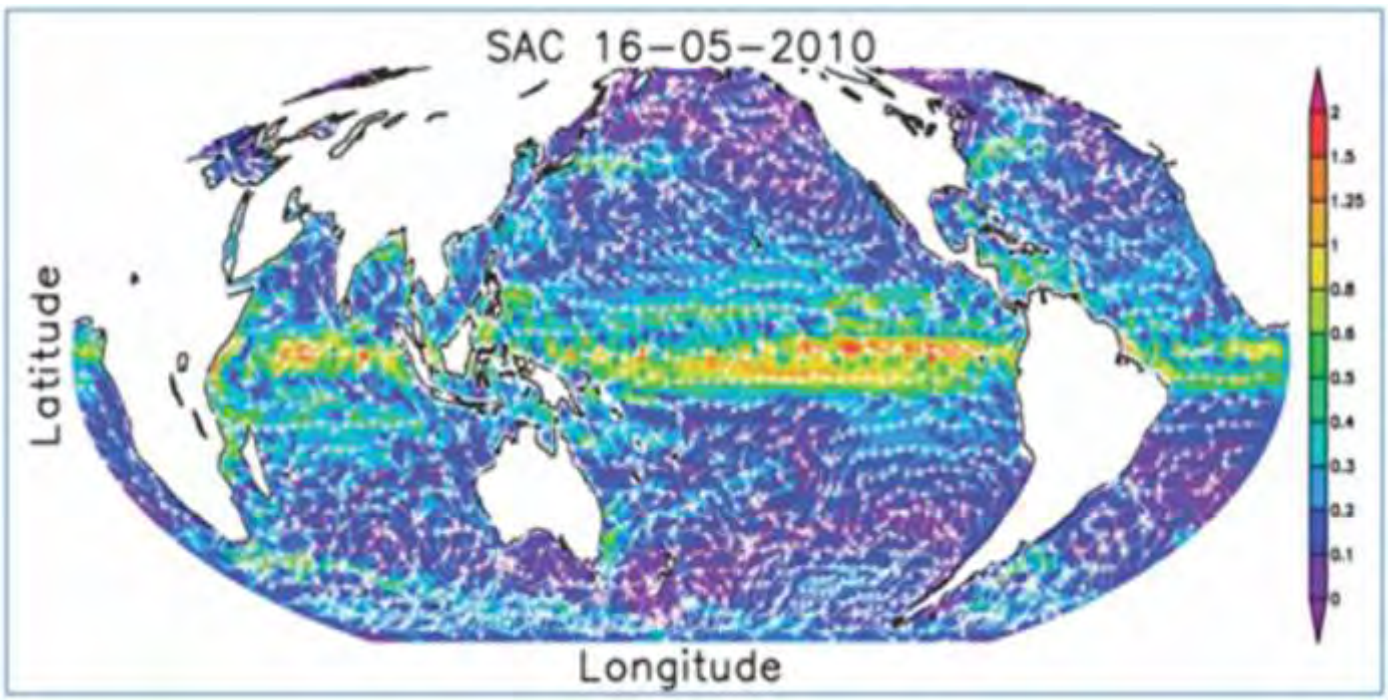
» *Research Areas in Atmospheric and Oceanic sciences:*

1. Retrieval of geophysical parameters from satellite data

ISRO has planned for launching a number of meteorological and oceanographic satellites in near future. It has already, Megha-Tropiques, Oceansat-2 INSAT-3D, and SARAL satellites in the orbit. In near future it has plan to launch GISAT. It is a challenging work to retrieve geophysical parameters from the sensor data of these satellites. This involves Radiative Transfer modeling and the Inverse modeling techniques.

2. Assimilation of satellite data in numerical weather and ocean prediction models

Advance research is being carried out for assimilation of satellite derived parameters in numerical weather and ocean prediction models. This involves development of various assimilation techniques for improving the initial condition in the models. Recently special emphasis is on direct assimilation of satellite measured radiance into the input. This involves Radiative Transfer modeling and optimization techniques.



OSCAT & Altimeter derived ocean currents

3. Numerical weather prediction with general circulation models

Real time weather forecast is an essential component during satellite launches from the launch pad as the launch vehicle is exposed to weather 2-3 days before the launch. Short range weather prediction is made using numerical weather prediction model and assimilation of satellite data. The same technique is also used for All India weather forecast in 5 km resolution. This involves dynamic modeling, physical parameterization and assimilation of satellite data.

4. Ocean state forecast with global and regional numerical dynamic models

Ocean state forecast is being done by using Ocean general circulation model and wave models. As there are only a few observations are available over the ocean, there is large uncertainty in the initial condition. Assimilation of satellite data is an important component to generate the initial condition and the forcing field. This involves advance assimilation technique for ocean data assimilation.

5. Air sea interaction studies

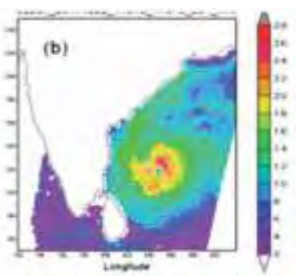
To understand some of the atmospheric and oceanic processes near ocean surface, air sea interaction study is very important. Because of scarcity of observed data over the ocean, it is important to understand these processes with the help of satellite data. This involves diagnostic studies of the processes with satellite data.

6. Diagnostic studies for Monsoon

For better prediction of Indian Monsoon, it is necessary to understand the physical mechanism of convective processes. For this purpose, a lot of diagnostic studies are being carried out using satellite data like vertical profiles of atmospheric temperature and humidity. These profiles help to understand the stability of the atmosphere.

7. Cyclone track and intensity prediction using satellite data and numerical models

Cyclone track and intensity prediction is very important activity as there is huge damage occurred due to cyclones. Improvement of cyclone track is being done by using numerical models and satellite data. Satellite data is used to determine the present location of the cyclone when it is over the ocean and away from the coast. The exact determination of the current and past location is useful for prediction of its future movement and intensity prediction. This involves both empirical and dynamic modeling and assimilation techniques.



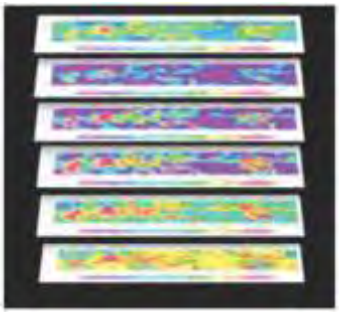
Winds from OSCAT standard & High-Res Thane Cyclone

8. Polar ice dynamics studies

To study the impact of climate change on polar ice cover, satellite data are used for monitoring the ice cover over the Polar Regions. Research is being done for identifying different type of ice cover using various satellite measured parameters.

9. Climate prediction with coupled Atmosphere-Ocean-Land-Ice models

For long term prediction of climate, Coupled model of Atmosphere, Ocean, Land and Ice is very important component. In these models, coupling is an important area of research as different components have different spatial and temporal variability. This involves balancing the fluxes at the interface boundaries of each component of the model.



SAPHIR derived RH Profile

10. Advanced system study for new sensor definition

For new measurements of atmospheric and Oceanic parameters, new advance sensors have to be defined for future satellites. System study is being done with the help of Radiative transfer models to define the appropriate frequency and bandwidth of new sensors.

» Research Areas in Geosciences:

1. Himalayan Cryosphere:

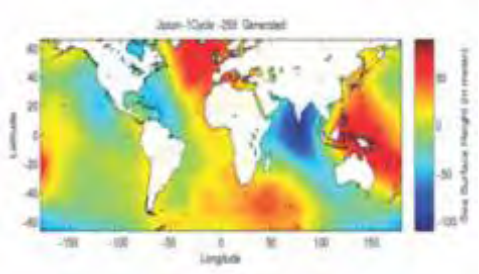


Image of Sea Surface Height

- Improvements and development of snow melt run-off models
- Applications of snow melt run off for irrigation and hydro-power requirements
- Improvements and development of glacier mass balance models
- Understanding glacier dynamics
- Modeling snow and glacier depth
- Development of algorithms for auto extraction of glacier features from multi-sensor satellite data with particular reference to Hyperspectral and thermal data
- Microwave remote sensing for snow & glaciers including interferometry techniques
- Comparative study of Himalayan glaciers with other mountain glaciers
- Impact of climate change on Himalayan snow & glaciers
- Snow and glacier hazards including avalanche forecasting, crevices detection and modeling burst of moraine dam lakes

2. Marine Geosciences:

- Development of techniques to retrieve gravity/geoid using satellite altimetry over oceans
- Modeling marine lithosphere using gravity and other geophysical data
- Understand subsurface tectonics and associated processes
- Tsunami modeling
- Hydrocarbon exploration in offshore regions.

3. Coastal Processes:

- Understanding Holocene and Quaternary coastal evolution
- Understanding processes leading to coastal erosion and predicting shoreline changes
- Sediment budgeting with reference to identification of sediment cells,
- Coastal vulnerability models and risk assessment
- Developing models for integrated coastal zone management plans

4. Geo-Hazards:

- Earthquake precursors
- Modeling geodynamics
- Modeling geohazards in particular reference to urban areas
- Early warning of landslides
- Risk Modeling due to storm surges/tsunami

5. Geo-Archaeology:

- Developing approach to analyze multisensor satellite data (Radar and high resolution multispectral data in particular) for identifying hitherto unknown surface/buried archaeological sites.

- Validation using geophysical techniques such as GPR, pitting and trenching.

6. Mineral Exploration:

- Methods to analyse multisensor satellite data (including Hyperspectral, RADAR, Thermal and Geophysical data of various spaceborne/airborne missions) for mineral exploration

- Develop GIS based models to identify mineral prognostic zones by integrating geological, geophysical and geochemical data.

» *Research Areas in Planetary Sciences and Marine Biology related activities:*

1. Lunar Surface Sciences

The main research themes for research includes Lunar Surface composition, Lunar morphology, Hypespectral data analysis for Lunar Surface, Thermal Remote Sensing of the Moon, Spectral charactisation of Lunar analogues, Lunar surface dating and lunar volcanism.

2. Lunar Gravity and Crustal thickness studies

Using the surface elevation and satellite tracking data lunar gravity can be deduced and this gravity data can be further modeled using gravity reduction methods to find out the lunar crustal thickness, which provide information about the lunar interior processes. The main research themes include Lunar gravity modling, inversion modeling for crustal thickness and lunar interior.

3. Studies related to Martian surface and Polar Ice

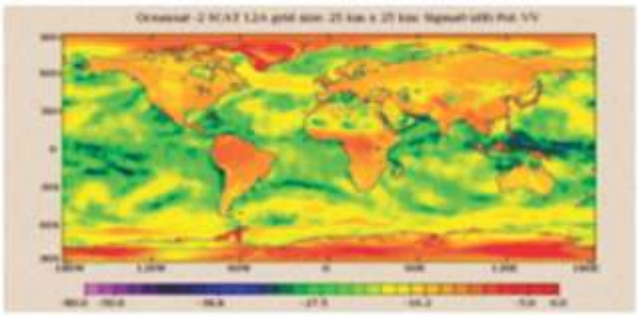
Major research themes are Charactisation of martian analogues rocks in India, Hypespectral analysis of Mars data, Thermal remote sensing of Mars, Martian Atmosphere. Surface composition of mars Remote sensing for Trace gases.

4. Development of coastal algorithm for ocean colour remote sensing

Development of Case-2 geophysical algorithms for Indian coastal waters, Atmospheric correction models for turbid waters, Development of CDOM and TSS algorithms and Bathymetry estimation in optically shallow waters.

5. Coastal Carbon Dynamics in Oceans

Bio-geo-chemistry of the coastal oceans, Study of various components of the carbon cycle, Nitogen cycle and phytoplankton blooms, Fish stock assessment, Primary and New production modeling.



Sigma Naught VV Pol at finer grid

6. Marine Living Resource Management

GIS based marine resource living management systems, Species specific fisheries forecast , conservation for engendered marine organism

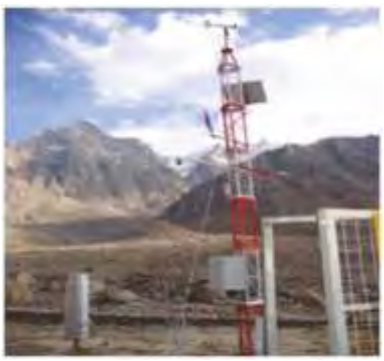
7. Atmospheric Aerosol Research

Algorithms for atmospheric aerosols using satellite over land and oceans, Aerosol transportation and climate studies.

» *Research Areas in Agriculture and agro-ecosystem studies:*

The remote sensing (RS) based crop production forecast technique has achieved reasonable degree of technological maturity. The multiple forecasts of major crops are being taken up by Department of Agriculture and Co-operation, New Delhi. Some of the components of agro-ecosystems analysis such as cropping systems analysis, methane emission from rice and livestock, impact of climate change on agriculture and characterizing vegetation-atmosphere energy and mass exchange processes at various scales have been addressed with remote sensing inputs.

New vista of application opportunities need to be explored keeping in view the availability of multiple sensors over wide range of electromagnetic region (optical, thermal, SAR, laser) at multiple spectral (multi channels and hyperspectral) and spatial resolutions (fine to coarse) and high and hyper temporal resolutions (weekly to hourly) from different platforms. The ground based observations can make modeling and validation components more product worthy.



Automatic Weather Station

The trust areas in agriculture and agro-ecosystem studies in respond are mentioned below:

1. Integrated approach (including remote sensing inputs) for multi-crop assessment in sparse cropped regions.
2. The remote sensing techniques of crop assessment in hilly terrains/ high altitudes
3. RS based indices/techniques for agro-ecosystems characterization/evaluation
4. Ingestion of RS inputs/products in Climate change analysis/modelling of agro-ecosystems
5. Development of GHG models for agro-ecosystems under different conditions
6. Parameter retrieval techniques with Hyperspectral data
7. Algorithm development for agro-ecosystems product generation from geostationary platform
8. Concepts of multidate/multisensor fusion of different scales and resolutions and uncertainty analysis in relation to agro-ecosystems.
9. Newer tools and techniques development for quick assessment of temporal dynamics of crops/vegetations using Indian multi temporal satellite data.
10. Development of mathematical/matching algorithm in spectral library development using hyperspectral data.

11. Modelling soil carbon sequestration in relation to cropping systems and climate change
12. Development of farming systems models with RS inputs/products
13. Applications of RS/GIS in horticulture studies.
14. Technical development of geometrics.
15. Geostationary data utilization in crop assessment.

» *Research Areas in Environment Sciences and Hydrological Modeling:*

1. Sensor System Studies for Environmental studies

Sensor system studies involve feasibly experiments and radiative modeling activities to arrive at suitable sensor parameters for monitoring earth and planetary objects. Development of spectral library, ground based experimentation in field of agriculture, forest and other ecosystem are required to propose suitable spatial, spectral and radiometric resolution of satellites. Modeling codes such 6S code, MODTRAN etc are used to study the sensitivity of surfaced and atmospheric parameters. It is needed to carry simulation experiments to propose optimum sensor parameters and develop retrieval algorithms for geophysical parameters from future Resourcesat series, NEMO-AM, ENVSAT Series and GISAT satellites for environmental applications.

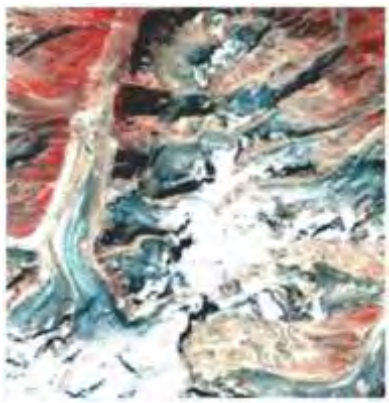
2. Green House Gases Estimation

One of the recent trends in remote sensing understands the climate change trough space measurements. Atmospheric Green house gases concentration and measurements of flux are important research Area. Currently available sensor system includes GOSAT, ENVISAT-SCIAMACHY, MOPITT etc. India has plans to launch such mission (ENVSAT Series) in future with other countries (OCO of USA, GOSAT-2 of Japan). There is need to develop radiative transfer scheme to model and retrieve the gases concentration. There is need to in situ measurement of CO2, CH4, N2O etc fluxes for validation of satellite products.

3. Aerosol Optical Thickness and Atmospheric Correction over Land

Calibration and radiometric normalization is the key issue in future remote sensing activities related with biophysical parameter retrieval and climate change. Atmospheric correction of the satellite data is a challenge. Most important input for atmospheric correction involved estimation of

Aerosol optical thickness (AOT) either from network of ground observations or satellite data. Retrieval of AOT sensors like Resourcesat series is an challenge. There is need to develop simplified correction approach including AOR inputs using dark dense vegetation approach. There is further need to develop instrumentation with capability of polarized measurements and LIDAR sensing. Radiative transfer modeling with polarized calculations is a challenge in future remote sensing activities.



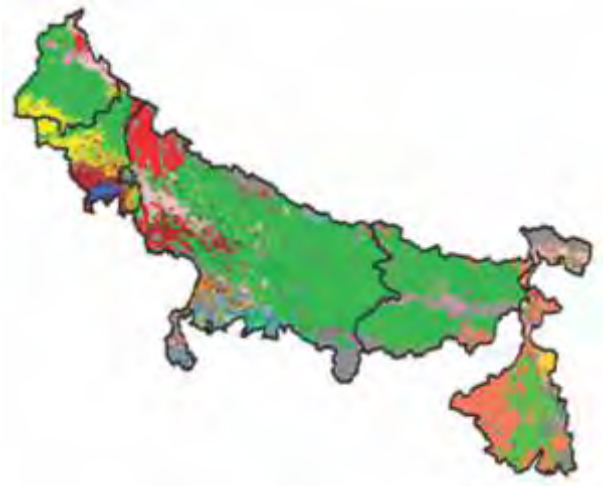
4. Hydrological Modeling

Hydrological modeling at Basin as well as India level is needed to understand the distribution and balance of water balance components. The projecting the water requirements in the future climate scenario are another area of important research. SAC has initiated hydrological modeling activities related with role of forest ecosystem in influencing the hydrological component over a large region using satellite and ground based measurements. There is need to develop model to retrieve hydrological variables (rainfall, Soil Moisture, Evapotranspiration) using satellite data. Snow and glacier hydrology is an important thrust area of research at SAC.

Inland waters level monitoring using altimeter data.

5. Forest Meteorology and Ecosystem Modeling

Forest plays an important role in governing the energy and mass exchange over a region. Quantification of energy fluxes helps in modeling regional climate. SAC is involved in development of 24 Micrometeorological station network in India which are taking continuous measurements in agriculture and natural vegetation system. There is need to develop land surface process models to quantify the fluxes with reference to surface and atmospheric forcing. Most of the biogeochemical modeling depends on phenological understanding of different vegetation types. There is need to carry out ground experimentation as well as satellite modeling to estimate the phenological matrices of different vegetation types. Such efforts would lead to develop the forest growth simulation models.



Modeling NPP using satellite measurements such as INSAT-CCD is an important future thrust area.

There is need to develop process based model to quantify the net primary productivity and ecosystem level productivity. Network of annual biomass measurements are needed to validate the NPP products.

It is known that biomass modeling is limited with optical measurements due to saturation of optical light in denser canopy. Radar based approaches provide improved assessment. It is proposed to develop LIDAR based modeling to account the height of the forest in the estimation of forest biomass.

Detection of forest fire and development of fire alarm system based on bioclimatic indices is an important research area which will be carried out using INSAT-3D satellite data.

6. Alpine Ecosystem and Climate Change Studies

Alpine ecosystems exist in low temperature region and are veryu sensitive to changing patterns of temperature (global warming). Sensitive alpine tree line species are found responding to already changing climate scenarios. SAC has carried out benchmark studies in mapping the alpine tree line and modeling responses of tree line species to climate change scenarios. There is need to create permanent monitoring stations for continuous observation of on sensitive ecotones. Moreover high altitude lakes freeze thaw cycle is an also important indicators of such changes. SAC has made atlases of high altitude lakes however there is need to study the physico-chemical properties of these lakes in relation to climate change scenarios.

7. Mangrove ecosystem analysis and its role in climate change

Mangrove ecosystem and its important in costal environmental studies is well recognized. Satellite based mapping and modeling the photosynthesis response is an important area of research presently being carried out at SAC. It is needed to develop network of experimental sites to quantify the biophysical characteristics of mangrove and develop model to predict the effect of climate change on mangrove system.

8. Coral Reef Mapping and Modeling

Coral reef is known as important indication of climate change. Satellite plays an important role in mapping the coral reef habitat regions. There is need to develop hyperspectral remote sensing techniques to detect different types of corals. Modeling is required to assess the effect of SST on coral bleaching observed at different regions.

9. Wetland Ecosystem

Wetlands mapping has been carried out by SAC at 1:50,000 scale for India. There need to develop scheme to map the wetlands using improved and integrated approach involving microwave and optical data. Wetland eutrophication need to be studied using temporal high resolution optical sensors. Efforts on modeling Methane Emission from Wetlands is an important future thrust area.

7. Technical Facilities

In order to support the above research and development activities, SAC has established excellent electronic and mechanical fabrication and test facilities. These facilities are continuously augmented to keep up with the demand of the technology being developed. Some of the major facilities are: Microelectronic Facility supporting Microwave Integrated Circuit (MIC) and Surface Acoustic Wave (SAW) devices fabrication, Payload Fabrication facility, Environmental Test Facility having hot and cold chambers, Thermovac chambers, vibration and shock test facility etc., Precision mechanical fabrication facility with computer controlled CNC and EDM machines, components screening facility and Bonded store. Mechanical and electronic Computer Aided Design (CAD) facility is also available for design and drawing generation.

7.1 Electronics Support Services

Realization of Complex payload systems demands a strong technological infrastructure which is continuously upgraded to leverage state of the art development. The research areas are concerned to following.

» Manufacturing the Hi-Rel subsystems/systems including MICs and PCBs; design & development of activities related to the processes to be qualified.

» Design, development, realization, maintenance and operation of environmental test facilities, like, thermovac and climatic test chambers.

» Design, development and fabrication of MMICs, SAW devices, RF MEMS.

» Online QC inspection etc.

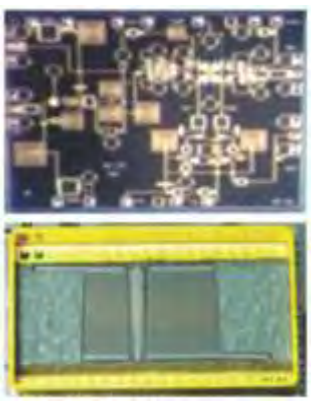
» Research Areas in Microelectronics:

· Design, development, fabrication and test of Surface Acoustic Wave (SAW) devices.

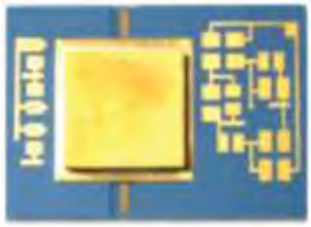
· Design and testing of Monolithic Microwave Integrated Circuits (MMICs), RF MEMS, mm-wave components, sensors.

· Development and fabrication of micro optics elements.

· Design, fabrication and test of RF subsystems using packaging



technologies like MCM, LTCC System in Package (SiP), advanced System-on-Chip (SoC) & Wafer Level Packaging for both space and ground applications.

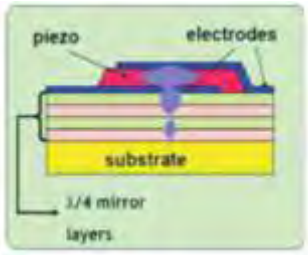


· Research area also include fabrication technologies like fabrication and assembly of HMIC based subsystems, fabrication process development like thin film processes, optical and electron beam lithography, wet/dry pattern generation techniques, LTCC processes, device assembly and hermetic sealing of microwave packages.

Each of these advanced technology areas pose challenges in every field - design, simulation, optimization, CAD tool development, modeling of devices and fabrication processes.

1. Film Bulk Acoustic Resonator based RF filters

Film Bulk Acoustic Resonator (FBAR) is used in high frequency RF filters because of its very high Q factor and low temperature coefficient. The scope of the research will include fabrication & modeling of FBAR and design of filter using FBAR. S-band filters are required for both space and ground application.



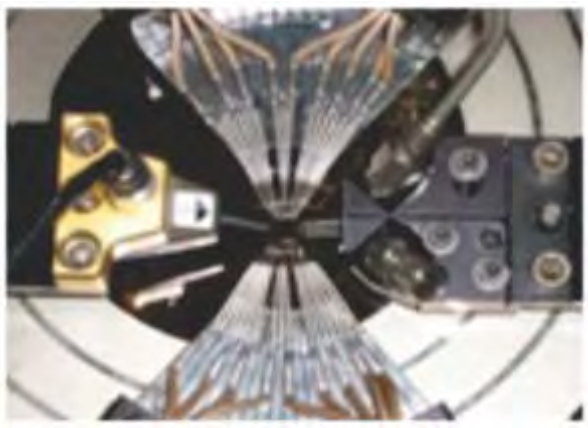
Ref. [1] S.-H. Zhao et al.: Modeling of RF Filter Component Based on Film Bulk Acoustic Resonator. - IEEE Transactions on Consumer Electronics, Vol. 55, No. 2, MAY 2009

2. RF SAW filters

Leaky Surface Acoustic Wave (LSAW) Resonator based RF filters offer several performance advantages in a compact size in the frequency range of 800 MHz to 3 GHz. One-port resonators acting as Impedance Elements are connected in ladder/lattice configuration to obtain filtering characteristics. The scope of the work shall include modeling and design of SAW resonators and RF filters based on these resonators. The deliverables shall include CAD tool for the synthesis and design of these filters. SAC, Ahmedabad shall extend fabrication support for these devices.

Ref. [1] Plessky V.P., "SAW Impedance Elements", IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, Vol. 42, No. 5, Sep. 1995

3. Semiconductor device (GaAs PHEMT, MHEMT, InP & GaN based) modeling (linear, non-linear, noise) including statistical process variation and temperature dependence



Very few MMIC foundries give complete device models, which are required for simulation and design of MMICs, specially in non-linear simulations like frequency converter, frequency multiplier, gain control amplifier, voltage controlled oscillators. In most of the cases limited models are available from foundry. Scalable models including linear, noise, non-linear, statistical process dependence and temperature dependence needs to be developed which can be integrated with EDA software.

Ref. [1] Signal Generation, Control, and Frequency Conversion AlGaN/GaN HEMT MMICs Valery S. Kaper, Student Member, IEEE, Richard M. Thompson, Student Member, IEEE, Thomas R. Prunty, and James R. Shealy, Member, IEEE, IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 53, NO. 1, JANUARY 2005, pages 55-65.

4. Development of temperature dependent models of PHEMTs, MHEMTs and InP HEMTs, their validity at cryogenic temperatures and application in design of LNAs for DSN in S, X and Ka-band

Presently limited data and models are available for simulation of active microwave circuits over temperature range including cryogenic temperatures. Circuits are designed at ambient and their response is studied practically at these temperatures. If proper models of basic devices are available over temperature and frequency of operation, it will be helpful in designing circuits optimized for cryogenic temperatures.

Ref. [1] Cryogenic, X-band and Ka-band InP HEMT based LNAs for the Deep Space Network Bautista, J.J.; Bowen, J.G.; Fernandez, N.E.; Fujiwara, Z.; Loreman, J.; Petty, S.; Prater, J.L.; Grunbacher, R.; Lai, R.; Nishimoto, M.; Murti, M.R.; Laskar, J.; - IEEE Aerospace Conference Proceedings Volume 2, 10-17 March 2001 Page(s): 2/829 - 2/842 vol.2, Ref. [2] Extremely low noise amplification with cryogenic FETs and HFETs: 1970-2004, Marian W. Pospieszalski., -IEEE Microwave Magazine, September 2005, pages: 62-75, Ref. [3] Deep Space Network Array, Mark Gatti, IEEE MTT Workshop.

5. Non-linear stability analysis of multi-transistor MMIC

Though nonlinear stability is an established field, presently no microwave CAD software is available which can easily predict the stability of a nonlinear circuit and they do in linear case. For multi-transistor MMIC, presently few alternative methods like, convergence of harmonic balance simulator, S11 at all the active device points etc. are used, which are time consuming and empirical in nature. CAD software to easily predict nonlinear stability is desirable.

Ref. [1] A unified approach for the linear and non-linear stability analysis of microwave circuits using commercially available tools.Mons, S. et. al. - IEEE trans. MTT, Vol 47, Dec. 1999, Dec. 1999. Pages: 2403 - 2409

6. Application of exact synthesis methods in design of microwave and millimeter wave non- linear circuits

Design of microwave circuits and components uses both non-synthesis and exact synthesis methods. Exact synthesis methods are generally used in filter and matching circuit designs. This design method is extended to linear active microwave circuit design where input and output of the active device is approximated by simple equivalent circuit.

There is a need to extend this powerful exact synthesis method to non-linear microwave circuit design, like mixer, modulator, frequency multiplier etc., which will lead to best optimized designs requiring less time for computer optimization. Use of non-uniform transmission lines in synthesis method may also lead to interesting solution.

Ref. [1] John-Paul Rooney et. al., "A Filter Synthesis Technique Applied to the Design of Multistage Broad-Band Microwave Amplifiers," IEEE Trans. MTT Vol 50, No. 12, December 2002, pp 2947-2953.

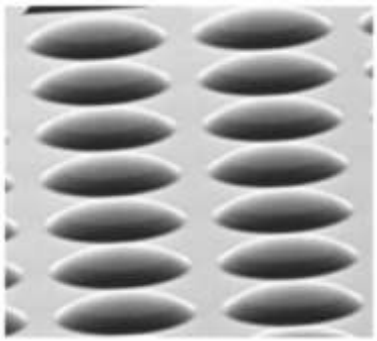
7. Wafer level packaging technology

Ka-band receiver MMIC SoC containing GaAs MEMS, as well as other MMIC and MEMS based devices (designed and developed by SAC) need wafer level packaging for maintaining performance and size advantage of chip. Heterogeneous integration and packaging at the MMIC wafer level is an attractive and enabling technology, following reference projects one such development.

Ref. [1] MMIC Compatible Wafer-Level Packaging Technology P. Chang-Chien, X. Zeng, K. Tornquist, M. Nishimoto, M. Battung, Y. Chung, J. Yang, D. Farkas, M. Yajima, C. Cheung, K. Luo,

D. Eaves, J. Lee, J. Uyeda, D. Duan, 0. Fordham, T. Chung, R. Sandhu and R. Tsai 2007 International Conference on Indium Phosphide and Related Materials Conference Proceedings TuA2-1 (Invited), 19th IPRM 14 - 18, May 2007 Matsue, Japan.

8. Development of Electron Beam / LASER Beam Sensitive Glass



This requires development of types of glasses that are sensitive to electron beam/ LASER Beam and upon exposure to these change their optical density (OD) or transmittance. The development will be useful in the development of optical elements like sinusoidal calibration targets for optical payload calibration, gratings, Fresnel lenses etc. using grey scale electron beam or LASER lithography.

Ref [1] Continuous-tone grayscale mask fabrication using high-energy-beam-sensitive glass, Thomas Dillon, Anita Sure, Janusz Murakowski, Dennis Prather. - J. Microlith., Microfab., Microsyst., Vol. 3 No. 4, October 2004, pages-550-554.

9. Development of nano structured magnetostrictive thin films for Surface Acoustic Wave device applications

Surface Acoustic Wave (SAW) devices are widely used in communications such as filters, delay line etc. Conventional SAW devices consist of metallic IDT on top of a piezoelectric film or substrates. Research involves the development of high quality thin films of giant magnetostrictive materials (e.g. Fe-Si) which exhibit high magnetostriction coefficient suitable for low insertion loss SAW devices.

Ref. [1]: "Magnetically tunable SAW – resonator" Smole, P. Frequency Control Symposium and PDA Exhibition Jointly with the 17th European Frequency and Time Forum, 2003 IEEE international.

» *Research Areas in PCB Fabrication, wiring and assembly:*

1. Defects Analysis of solder joints in Electronics Fabrication for space use & algorithm development

Fabrication data collection, compilation and methods can be developed to understand the cause of defect, quantification in various categories, impact of reviewed/reworked defects in solder joints under various environment conditions ,impact on life span long term space missions as well as on

interplanetary missions, co-relation of that data in various orbits by preparing the samples, measuring relevant parameters. Subsequently, Algorithms development Monitoring and improving PCB assembly quality by statistical optimization of processes and materials.

Ref.[1] A data mining algorithm for monitoring PCB assembly quality. Feng Zhang, Timwah Luk. - IEEE Transactions on electronics packaging and manufacturing. Vol. 30, No. 4, October 2007. Pages 299-305.

2. Lead free soldering and surface finish

Solder materials used in assemblies pervade many forms of electronic platforms used by Space. Therefore, any change in soldering technology will have major implications for space operations. Lead-free soldering is fast becoming the norm for commercial applications. Before long, there will be a push for a similar switch to lead-free solder for high-reliability electronics, as is seen in Space applications. While lead-free solders are purported to reduce environmental and health risks, these solders present certain technical risks. Of concern, the reliability of most lead-free solders is not well known for high-reliability applications and the adverse environments of space.

- Identify, develop and qualify lead-free PCBs & solders to replace conventional tin-lead solders used in circuit card assemblies, connectors, and other electronics etc.
- Identify and develop lead free dummy components.
- Identify, develop and qualify environmentally acceptable replacements to surface finishes and RTV/conformal coatings currently used in circuit card manufacturing meeting outgassing requirements.

Finally, ensure the reliability issues surrounding lead-free electronics in high reliability applications. Objective is to generate comprehensive test data (including inspection requirements) on the reliability of circuit cards newly manufactured with lead-free solder and subjected to simulated high-reliability environmental conditions.

3. 3D packaging

For space borne system, electronic packaging plays an important role for deciding about the weight & volume of the overall electronic system/sub-system. Discrete component design moved on to integrated circuits which in term moved to programmable devices. Even packaging graduated from DIP type to SMD to BGA/CCGA to flip chip to direct die attachment on printed boards. Printed circuit board technology also graduated from single side PCB to double side and in turn to multi

layer boards. Interconnection within PCB graduated from non plated through holes to plated through hole, blind via / buried via connectivity and to laser drilled micro vias. These still form the packing or interconnectivity in multiple boards as through conventional wired or though rigid flex boards. This needs a relook into packaging technology.

These different assembled boards can be moulded all together and the interconnection can be through patterning on these 3D structures. This is enable compactness of the packages and more electronics can be accommodated in the same volume or in the first volume is reduced, which will reduce overall size of the package. Following may be explored meeting the space usage requirements,

- Epoxy material suitable for such packaging
- High aspect ratio hole drilling
- 3D writing/structuring on moulded structure.

4. Advanced Thermal Management Solutions on PCBs for High Power

With increasing power loss of electrical components, thermal performance of an assembled device becomes one of the most important quality factors in electronic packaging. Due to the rapid advances in semiconductor technology, particularly in the regime of high-power components, the temperature dependence of the long-term reliability is a critical parameter. Two main drivers in the space technology are miniaturization and reliability. Whereas there is a continuous improvement concerning miniaturization of conductor tracks (continuous reduction in lines/spaces), miniaturization of the circuit carrier itself has mostly been limited to decreased layer-counts and base material thicknesses. This can lead to significant component temperature and therewith to accelerated system degradation. Thus, enhancement of the system reliability is directly connected to an efficient thermal management on the PCB-level.

- Development of base materials with advanced thermal performance and use of innovative build-up concepts.

5. Low temperature Soldering

Soldering of electronic components on printed boards generally takes place at temperatures of between 240 and 250°C. During soldering, the components and printed boards are exposed to thermal shock that affects their long-term reliability. A reduction in the soldering temperature to about 180°C using low melting point solders is expected to for specific temperature sensitive components to reduce risk of components failure

- Development of number of possible low temperature solders in combination with suitable low temperature flux without sacrificing reliability of solder joint.

6. Electroless gold plating for space applications

Gold is used extensively in the electronics industry, particularly because of its exceptional electrical properties. Electroless gold plating process is a promising candidate for deposition of gold on high frequency circuits leading to the miniaturisation. Autocatalytic electroless gold deposition process is preferred as it ensures minimum 2 micron gold for wire bonding and solder ball joint applications for mounting ICs on soft substrates without any undercoat.

- Under this programme a technology need to be developed to deposit minimum 2 micron of soft gold on a patterned circuits on various high frequency laminates having 4 mil line and spacing. Deposited gold should be non porous and ductile, should withstand environmental tests prescribed for space applications and ensure long term reliability.

» Research Areas in Surface Treatment Process Technology:

1. Process development to realize Electroforming process for Aluminum component

Electroforming is a technique used in fabrication of complex contoured components with high dimensional tolerances which are difficult to fabricate using conventional machining methodology. At present, electroforming process of copper components on Aluminum mandrels has been successfully realized at SAC. Copper has disadvantage of high density of 8.9 grams/cc.

Hence, efforts are invited to carry out in depth feasibility study to realize electroforming process of Aluminum components and develop detailed process & setup for the same. This process can be used for mm-wave components.

2. Non-cyanide based Electroless Silver Plating process development

Silver plated components are widely used in RF systems of satellites. With miniaturization of mechanical assemblies and usage of higher frequency bands like K-band & Ka-band, dimensions have decreased to around 4 mm & lower. Also long waveguides of the length of 1.2 meters are being used with twists and turns in various planes, making it extremely difficult to silver plate inside surface of the cavity using the conventional electrolytic silver plating methodology.

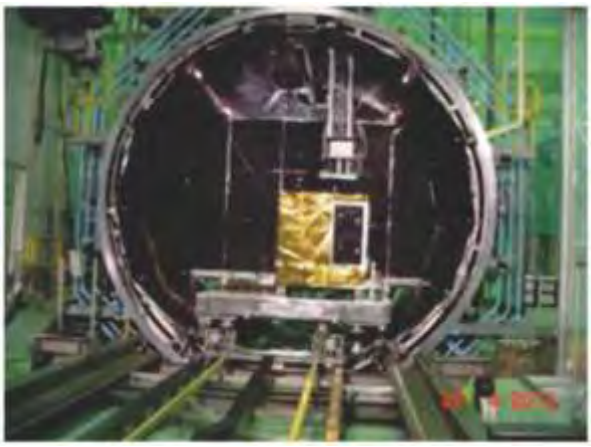
Hence, efforts are invited in the area of non-cyanide based Electroless silver plating chemistry for plating aluminum 6061T6 alloy components with plating thickness of $\geqslant$ 2 microns of silver inside complex multi planar wave guides.

3. Development of Electroless Gold Plating process

Gold plating on aluminum 6061T6 boxes and Kovar carrier plates is being carried out for EMI/EMC requirements, corrosion protection, solder ability etc.

Hence, efforts are invited in the area of Electro less gold plating process using either cyanide based or non-cyanide based chemistry for plating aluminum 6061T6 alloy components/Kovar substrates with plating thickness of ⩾2 microns of gold. Once developed, this process will be used for all ISRO projects as per requirements.

» *Research Areas in Environmental Test Technology:*



Environmental Testing is an important activity in the process of Payload development. TTSD and CTSD have several hot and cold chambers and Thermovacuum chambers up to 5.5 m Dia. which meets the environmental test requirements of various payloads being developed at SAC, Ahmedabad. TTSD and CTSD are engaged in establishment of new facilities and augmentation of existing facilities to accommodate special test requirements. This demands innovative solutions to emerge in close collaboration with the academic institutions and industrial research units. Collaborative efforts are invited from academic institutions in following upcoming requirements/research areas as outlined below.

1. Development of compact, liquid nitrogen based, close loop controlled, highly energy efficient thermal systems for direct use with existing thermal vacuum chambers as well as climatic test chambers.
2. Development of non metallic, light weight, low loss cryogen transfer lines especially for efficient distribution of Liquid nitrogen.
3. Development of compact, low cost Pulse Tube cryo-coolers to facilitate testing tiny devices at low temperature as well as for low cooling requirement of IR/CCD detectors.
4. Development of acoustic coolers for small detector cooling application, handling high heat from the large heat sinks etc.
5. Development of thermoelectric cooling based compact climatic test chambers and thermal vacuum chambers.

6. Development of mixed gas refrigeration based compact climatic test chambers and thermal vacuum chambers.
7. Study and analysis of various forms of contaminations like surface and airborne particulates, surface and airborne molecular contaminants in and around thermo-vacuum chambers. Carryout in-depth measurement of such contaminants using APC, PFO, RGA, TQCM and CQCM available and carry out detailed process study as well as make recommendations in this regard for implementation.
8. Study and analysis of Liquid Nitrogen consumption in Thermo-vacuum test facility with respect to different type of tests being carried out in different LN2 based thermo-vacuum chambers. Study and analyze transfer, static and flash losses taking place in various system elements during thermo-vacuum tests and carry out detailed process study as well as make recommendations in this regard for implementation.

7.2 Mechanical Engineering Systems

» Research Areas in Structural and Thermal Analysis:

1. Development of Reconfigurable reflectors using Smart materials and Smart structural systems

Objective : To develop Mechanically Active Antenna reflectors which can illuminate different land masses by Reconfiguring the skin of the reflector, by using Two-way Memory trained radial and circumferential strands of Shape Memory Alloy(SMA) wire Actuators as smart back up devices. Using this approach a DVM for 1.0M diameter C-band parabolic reflector is being developed for CATF testing after demonstrating successfully the Proof-of- concept on 0.4m diameter parabolic reflector.

This approach may have possible spin-off applications and may waive off the requirement of imported Antenna pointing Mechanism nowadays being used for achieving rigid body movements of the reflector for covering different land masses.

2. Usage of new materials for developing Light weight spacecraft reflectors

Objective : To develop Light weight Metalized Antenna reflectors using Contemporary light weight and low CTE 30% carbon reinforced Poly Ether Ether Ketone (P.E.E.K) / bare PEEK combinations using Vacuum Forming Technique as an alternative to conventional CFRP reflectors

developed in Autoclaves using Co-curing techniques. A 0.4m diameter parabolic reflector using PEEK material is under development as a proof-of-concept.

This approach may make SAC stand alone in the field of developing reflectors without any external support. This approach may have possible spin-off applications in developing light weight SCATT. reflector in lieu of CFRP or Aluminum options.

3. Metallization of Fusion depositable materials, carbon composites / ceramics and development of segmented mirrors

Objective: Fusion deposited materials are emerging as a novel alternative for manufacturing precise and complex shapes for the future space industry and particularly for satellite components. While it has the advantages of producing virtually any shape that can be imagined, utilization of this manufacturing technique is limited to successful development of metallization and electroplating on the Fused Deposited Components. The work here involves developing Silver and Gold plating on Fusion Deposited ABS as per the space qualified procedures.

Another research work in progress is the development of proof-of-concept of segmented telescopic mirror and it's surface correction exercises are in progress using Piezoelectric Stacks and PZT Actuator devices.

4. TDP Support in analysis & development of RF MEMS based switches

Objective: The Structural analysis in the electrostatic field is supported in the precise displacement domain for 2 microns type of central deflection of the gold bridge of the RF-MEMS switch using the Coventorware Multi-physics software as per the detailed Boundary conditions and material properties to be furnished by the new FAB set-up at SCL Chandigarh. Two options of the switches are under taken for preliminary structural analysis and completed. Some modifications in design are in progress as per the recent visit to SCL FAB and the geometry is expected for analysis runs.

This approach will make SAC stand alone in the field of Analysis and RF design of RF MEMS based spacecraft switches.

» Research Areas in Antenna System - Mechanical:

1. Development of Inflatable antenna for Space use

Objective : Inflatable antenna offers very light weight option i.e. very high ratio of size to stowed weight for large deployable spacecraft antenna. Material selection, Inflatable structure design, development of inflation system, fabrication techniques etc will be the area of technology development.

2. CFRP feed systems

Objective : Feeds are subjected to thermal loads and structural loads. Also present practice of using metallic feed result into weight penalty. CFRP feed system will provide light weight thermally & structurally stable solution for onbord system.

3. Development of Graphite mould for CFRP reflector

Objective : Presently CI mould is used for the fabrication of CFRP reflector. The advantage of Graphite mould is that it will be having CTE matching with CFRP material of reflector leading to better surface profile on reflector. Also the realization cycle time will be reduced in case of Graphite mould.

» Research Areas in Optical Payloads - Mechanical:

1. Development of Nano-polishing technology for metal mirror

Metallic mirror machining by diamond turning process is being successfully used for precision surface profiling. Surface finish achievable is not adequate for the best performance of the instrument in visible wave length range. It is required to develop the Nano-polishing process to achieve surface finish commensurate with similar mirror made out of ceramic material.

2. Development of High capacitance bad conductive lining material

High resolution telescope has very large aperture for incoming beam. It is challenging to take care of unwanted sun radiation intrusion, especially for GEO Imaging instruments, during dawn and

dusk phase of orbit. It is required to develop polymers which does not conduct the heat across the thickness but it can withstand very high temperature. This would protect the metering structure from rise in temperature in any circumstances.

3. Development of precision sensors for feedback loop in auto focus system

Metering structure for large focal length telescope, required to provide very high dimensional stability under harsh thermal environment specially in GEO orbit. To compensate the thermo-structural behavior, auto-focusing mechanism is the way out. Linear dimension measurement sensor technology is required to be developed for giving the feed back to the focusing mechanism. It is required to be kept outside the field of regard as a parallel feedback system.

4. Shape Memory based actuation system for various deployment/shutter mechanism

Different mechanisms will be required to be developed for payload operations. Development of shape memory alloy based mechanism will make simplified and reliable payloads. Special type of shape and programming technique is to be developed.

5. Embedded structural health monitoring system

Large dimensionally stable telescope structures required to be maintained strain free through out the operational life. A SHM systems using many sensors like fiber Bragg Grating, Nano-accelerometer, Nano-temperature sensors etc, to be developed which can also be embedded into the composited structure.

6. Carbon fiber based efficient thermal strap development

Heat dissipation through conventional conductive material like Cu, is not adequate to handle the handle zone where high heat density heat dissipation exists. Carbon Nano-tube or carbon fiber strap can be used to transfer heat very efficiently with efficient weight saving. Technology also can be developed to embed the fiber in printed wire board to diffuse the heat from high heat concentrated zones.

7. Micro-heat pipe design and development

Research is required to design and develop optimized micro heat pipe, which can be efficiently used to maintain the temperature of certain components like detectors, of which performance is very much sensitive to temperature.

» *Development of Space Qualified Reconfigurable Spacecraft Reflector (Ka Band) using Shape Memory Alloys - Smart Materials*

Smart or intelligent materials / adaptive materials are the materials / smart structural systems, which have the capability to get adapted to the external load or stimuli. External stimulus can be in the form of vibration load, thermal load, pressure load etc.

Using smart materials and structural systems a Design Validation Model (DVM)of a typical Spacecraft Reconfigurable reflector has been envisaged to be developed which is able to change the shape and curvature of the reflecting surface using Shape Memory Alloys (SMA) Smart material. An innovative concept of smart backup beams will be developed for testing the re-configurability of the reflecting surface for satellite applications.

Reconfigurable reflector has been envisaged to be developed using new material called Poly Ether Ether Ketone (P.E.E.K) a light weight , Low Alpha material almost vying with properties of CFRP.

It has promising potential application in the field of developing futuristic reconfigurable reflectors. A 0.45 m dia. Ka-band MAA reflector (investigation for deflection of the reflector skin) with re-configurability features has been proposed to be developed using contemporary Light weight flexible substrate material- Poly Ether Ether Ketone (P.E.E.K) sheets.

Reconfigurability is proposed to be obtained using SMA wire strands trained in Austenite & Martensite states.

Metalization of substrate material has been envisaged using hither to fore unexplored novel technique of Magnetron Sputtering / VDP after surface activation using Radio Frequency Plasma Etching for better adhesion properties at SAC / IPR Gandhinagar .

Challenging aspect is realization of the DVM of reconfigurable reflector mechanically, structurally & electrically and the research element of the research problem is finalizing the most optimum configuration / geometric topology of the SMA Stiffeners after iterative process of analysis, to meet the Satellite specifications.

- The detailed work also includes Mechanical& Structural designs including Finite Element modeling and electrical / experimental investigations.
- Mould fabrication
- SMA & PEEK material characterization.
- The characterization of advanced reflector materials including high quality structural space adhesives,

- Space qualification tests e.g out-gasing properties viz, CVCM , TML etc, for the new materials.
- 8-10 microns thick copper metalization respectively for reflectivity of the flexible surfaces..
- The scope also includes space qualification of metalization process of the flexible material for the reflector surface .
- Development of the DVM .
- Electrical testing of the Reconfigurable antenna from the point of Reconfigurability at Compact Antenna Test Range (CATF) Facility SAC.

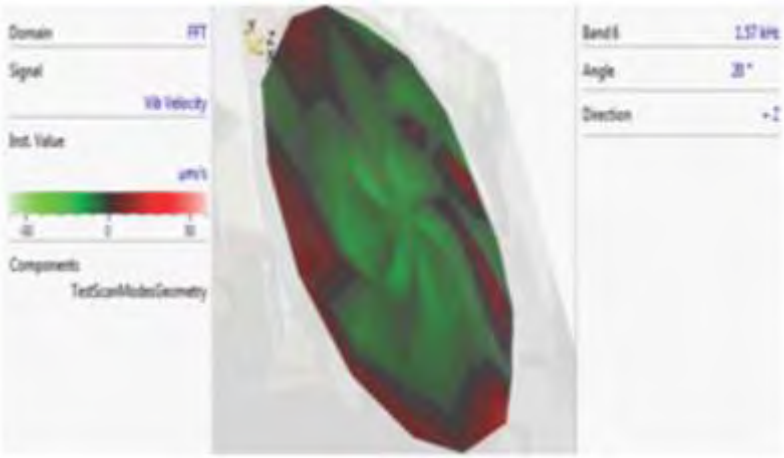
Salient Features / Specifications

Diameter	0.45 m dia.
Frequency	Ka-band
F/D	0.4
RMS (Structural)	10 microns

This Technical Development Programme will lead to the development of design validation model for futuristic Re-configurable antenna reflectors are required for the following applications:

Feed Back Control Loop Using Pid Controller & SMA Smart Material

- For advanced applications such as Beam steering / Beam reshaping of spacecraft reflectors using in-house indigenous approach for covering different land masses on the Earth without using imported Antenna Point Mechanism. In future, this approach can also be used for altering the satellite coverage from India Coverage (IC) to Extended Coverage (EC) for futuristic GEOSAT satellites using high frequency small size spacecraft reflectors (Ka band) by Mechanically Active Means (MAA). Practically, along with MAA, electrically fine tuned adjustments can be achieved using phase shifters / Phase amplification approach .
- It will also help in compensating the thermal distortion related RMS error of flexible reflectors for futuristic Ka band reflectors.



Peek Reflector Testing Using Laser Vibrometer

Reconfigurable Reflector Using SMA

» Development of Space Qualified Ultra Light Weight Ka Band Spacecraft Reflector using PEEK

Smart or intelligent materials / adaptive materials are the materials / smart structural systems, which have the capability to get adapted to the external load or stimuli. External stimulus can be in the form of vibration load, thermal load, pressure load etc.

Using smart materials and structural systems a Design Validation Model (DVM) of a typical Spacecraft Light weight reflector has been envisaged to be developed which is made up of new material called Poly Ether Ether Ketone (P.E.E.K) a light weight , Low Alpha material almost vying with properties of CFRP. An innovative concept of light weight satellite reflector is envisaged which will cater to all the environment test specifications of the spacecraft.

It has promising potential application in the field of developing futuristic light weight reflectors. A 0.45 m dia. Ka band spacecraft reflector is envisaged to be developed.

Metalization of substrate material has been envisaged using hither to fore unexplored novel technique of Magnetron Sputtering after surface activation using Radio Frequency Plasma Etching for better adhesion properties.

Challenging aspect is realization of the DVM of light weight reflector mechanically & structurally and the research element of the research problem is finalizing the most optimum configuration / geometric topology of the Carbon reinforced PEEK stiffeners after iterative process of analysis, vibration testing to meet the Satellite specifications.

The scope of the work in gist as follows:

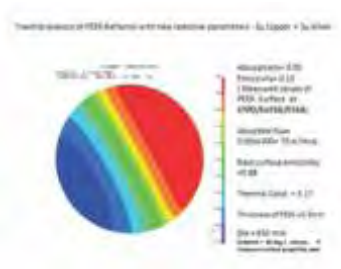
- The detailed work also includes Mechanical & Structural designs including Finite Element modeling and experimental investigations.
- Mould fabrication
- PEEK reflector bare skin and 30-34%-60% Carbon reinforced PEEK as structural stiffeners.
- The characterization of advanced reflector materials including high quality structural space adhesives,
- Space qualification tests e.g out-gasing properties viz, CVCM , TML etc, for the new materials.
- 8-10 microns thick copper metalization respectively for reflectivity of the flexible surfaces..
- The scope also includes space qualification of metalization process of the flexible material for the reflector surface .
- Development of the DVM .
- Mechanical testing of the Light weight antenna from the point of view of damping studies, frequencies and space qualification for sine, random & shock loads

Salient Features / Specifications

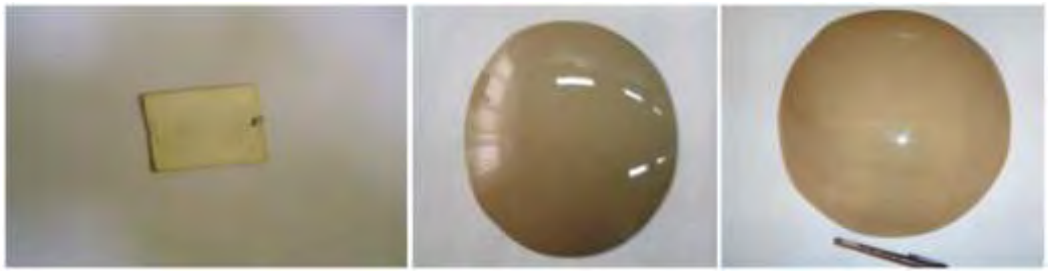
Diameter	0.45m dia.
Frequency	Ka-band
F/D	0.4
RMS (Structural)	20 microns

This Technical Development Programme will lead to the development of design validation model for futuristic Light weight antenna reflectors are required for the following applications:

- For advanced applications for high frequency light weight reflectors of U/V bands with stringent RMS & PE specifications



Peek – Metalized Coupon



Peek Parabolic Reflectro – 300 Mm Dia.

» *Research Areas Related to Thermal Engineering:*

1. Nano fluid based heat pipes: Heat load of various satellites payloads like Carto-3, GISAT-2, etc are increasing day by date and there is need for miniaturization of heat transportation devices. Use of nano fluid and other new generation fluids may improve the efficiency of conventional heat pipe drastically. This will lead to reduction in size of heat pipe. Various aspects like their performance in microgravity space environment, their continuous operation, mathematical modelling, simulation and optimization of various parameters, flow visualization studies, molecular level modelling of thermo physical properties of nano fluids need to be carried out for the development of space qualified nano fluid based heat pipes.

2. Phase change material (PCM) capsules: Various phase change materials can be used for thermal management of electronics packages dissipating heat for shorter duration or in pulsed manner. PCM based systems need to be developed for these kind of applications.

3. Surface coating technology: Various surface coating technology including coating with nano materials need to be developed to improve Thermo-Physical & Optical Properties.

4. Mini-heat pipe: Mini-heat pipes are required for transportation of heat from optical payloads and High dissipating electronic packages. Development of Mini Heat pipe embedded in Al-trays need to be carried out to meet different projects requirement.

7.3 System Reliability

1. Stress Analysis & Life Estimation of Solder Interconnections based on Physics of Failure (PoF) Methodology

Goal: To gain insight into the failure mechanisms that come into play in a solder joint and its thermo-mechanical behaviour, towards estimating the life of any solder joint and a reliability figure.

This study will, in general, define a methodology to obtain the thermo-mechanical reliability of solder inter-connections in an electronic-package-assembly using solder joint fatigue models. This study will help to estimate the life and validate life-estimation models for the new package styles, i.e. column grid array & land

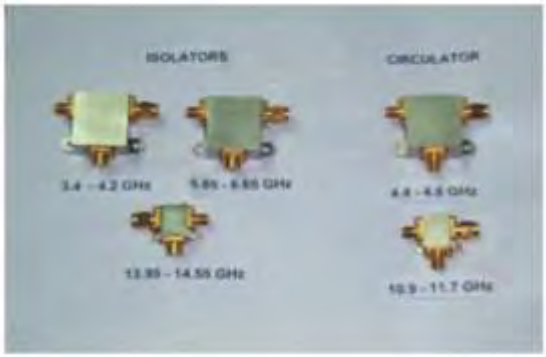
grid array, QFN etc., and for high reliability long term space missions. This study will involve generation of geometrical models for the various package styles having different configurations of solder joints; stress analysis by applying cyclic temperature loading, for the individual package styles and solder joint design configurations; and extraction of failure parameters regarding fatigue & creep, from the cyclic stress-strain hysteresis loop.

2. Development of Co-axial Isolator/ Circulators

Goal: Co-axial Isolators/ Circulators of S, C, ext-C, and Ku-band frequencies are used in bulk for space hardware applications. At present, these components are being procured from international market. In order to get these components indigenously made with acceptable performance, academic institutions can take-up this project as a research & development activity and once developed technology can be transferred to any Indian industry for mass production.

Major Specifications:

Frequency Range :S , C, Ext C, Ku band
Insertion Loss :< 0.15 dB
Isolation :> 25.00 dB
VSWR :< 1.12
Operating Temperature Range:-20°C to +70°C



3. Study on Effect of Long-term Storage on Tantalum Capacitors

Goal: To establish degradation in Tantalum capacitors and study usage life limitation (if any) with respect to application in satellite payloads

Classically shelf-life of Tantalum Capacitors has been considered to be limited due to effect of storage environment on the Tantalum oxide (various categories, typically pentoxide). With improved technology and techniques, such limitations are not spelt-out explicitly. However, no specific guidelines exist for shelf-life limitation and usage of tantalum capacitors for long mission life satellite applications after long storage.

A study on the effect of long storage on the dielectric (Tantalum) will be useful to address this aspect.

4. Usage of LCP as Alternative to Conventional Hermetic Sealing Techniques for MMIC Die

Goal: Evaluate LCP packaging for hermetic sealing of MMIC

For Space usage, hermetic sealing of active die is necessary to prevent from environmental effects, before launch. Conventional techniques employ packaging using materials like Metals, ceramics and glass. However, the parasitics introduced due to conventional packages & packaging techniques severely deteriorate the performance of high frequency components including MMICs. Various alternative techniques for packaging the die, specifically MMICs are evolved. Such packaging results in components packaged in near hermetic package which can be directly assembled on to the circuits (stripline or microstrip). One of such techniques is, Packaging of MMIC in multilayer Liquid Crystal Polymer (LCP) substrates.

Liquid crystal polymer (LCP) package made from layers of thin-film LCP is an attractive alternative to traditional metal and ceramic hermetic packages. LCP is a near-hermetic material and its lamination process is at a relatively low temperature (285 deg C versus 800 deg C for ceramics).

LCPs offer a number of advantages in advanced printed wiring board and packaging applications including, low coefficient of thermal expansion, low moisture absorption, low moisture permeability, smooth surface, low dielectric constant and low dissipation at high frequencies and high temperature capability.

A study on effectiveness of die packaging using LCP for hermeticity will help establish alternatives for hermetic sealing of active components, specifically high frequency, necessary for Space payload applications.

5. Development of EMI – RFI Gaskets

Goal: To develop EMI gasket to suppress unwanted electromagnetic, RF interface (RFI) and to provide environmental sealing.

The material of gasket shall be in the tape form. This material shall be made of expanded poly-tetra-fluoro-ethylene (ePTFE) filled with highly conductive carbon particles. Material used to manufacture EMI gasket shall be stable under atmospheric and high vacuum conditions. In order to get these gaskets indigenously made with acceptable performance, academic institutions can take-up the project as a research & development activity and once developed, technology can be transferred to any Indian industry for mass production.

Material Properties:

1.	Material Composition	:	Carbon based PTFE
2.	Operating temperature range:		-40°C to 120 °C (with adhesive) -200°C to +200 °C (without adhesive)

3.	Density	:	340 kg/m3
4.	Hardness	:	45 (Shore A)
5.	Volume resistivity	:	1.5 X 106 ohm-cm
6.	Shielding effectiveness:		more than 45 dB. (Up to 40 Ghz)
7.	Outgassing properties	:	TML ≤1.0 % & CVCM ≤0.1 %

6. Development of Microwave Absorber

Goal: To develop high loss microwave absorbers that attenuate electromagnetic interference.

Material shall be available in sheet form. It is used for reducing or eliminating cavity resonances, isolating components via insertion loss, reducing harmonics and terminating signals in waveguides.

Material Properties:

Frequency	:	1 to 18 Ghz
Base Material	:	Iron filled silicon rubber
Specific Gravity	:	2.9 to 5.1
Hardness	:	73 (Shore A)
Tensile Strength	:	9.8 kg/ cm2
Elongation	:	50 %
Reflectivity	:	-20 db at freq. between 1-8 Ghz
TML	:	≤1.0 %
CVCM	:	≤ 0.1 %
Colour	:	Gray

7. Development of Radiation Hardened Polymer Composite

Goal: To develop indigenous radiation hardened polymer composite for shielding application to replace Tantalum sheets.

Extensive applications of composites have emerged in space application in last few years. Durability issues like, long-term performance under radiation conditions needs to be studied. Polymers are generally non-conductive and transparent to radiation. So they are quite restricted for being used as shielding material in radiation environment. These drawbacks have led to the growth in the research for radiation-hardened polymers.

In this research work it is proposed to develop radiation-hardened epoxy resin by using different fillers and stabilizers to make polymer radiation-hardened shield with appropriate polymer with

appropriate fillers and stabilizers. The comparative study shall be carried out to optimize the best composition among all prepared materials.

Tests like: Total Mass Loss (TML) and Collected Volatile Condensable Material (CVCM) & Radiation exposure levels up to 1Krad or more dosage to observe radiation effects on various properties of polymer need to be under taken.

8. Development of a Tool Setup to Evaluate the Effects of Single-Event-Upsets that Occur due to Radiation on Xilinx Devices

Goal: Development of a setup for evaluating Single Event Upset (SEU) effects in Xilinx FPGAs. SRAM based FPGAs are prone to temporary bit flipping due to high energy radiation particles in space (Single Event Upset). Depending on the design, SEU may affect functionality. Hence, identification of critical bits, which affect functionality, is required for effective mitigation. SEU mitigation techniques are then applied only on these identified critical bits.

Testing methods need to be devised that can allow the introduction of SEUs in the design and observation of their behaviour. Fault injection can be achieved either by intentionally programming an FPGA with an incorrect bit stream or partial dynamic reconfiguration. A combination of fault injection and gate-level simulation can prove very efficient for identifying SEU effects and mitigation techniques.

A setup is to be developed for fault injection in different FGPAs of Xilinx Virtex family, using test/gold vectors from QuestaSim. It is desired that the setup enables testing different designs, frequencies; injection of single bit/multiple bit upsets and the number of test signals.

The typical setup may comprise of three main parts:

a) Flexible FPGA-based Control Board, that can rule the fault injection procedure
b) DUT board, that should contain the FPGA to be tested, e.g. Virtex 4 device; &
c) Workstation.

9. Estimating Software Reliability

Goal: To predict/ estimate reliability of any software under development or under operations/ maintenance.

Software reliability estimates are used during development, to make the release decision; and after the software has been operationalised, as part of system reliability estimation, as a basis of

maintenance recommendations and further improvement. It is required to study existing reliability estimation models and come out with workable solutions for adoptionat SAC.

10. Relating Human Psychology to Software Quality

Goal: Towards prioritizing the QA efforts in a general perspective, it is required to understand human psychological perspectivesof various stakeholders, including end-users & developers.

Human psychology relates to the software life cycle processes& end-user experience of the software. A research relatinghuman psychological processes to the software development & quality assurance processes from the perspectives of various stake-holders, will provide useful knowledge for addressing software quality throughout software life-cycle.

11. Mining Software Repositories for Software Process Improvement

Goal: To improve the overall efficiency of the process and people involved in different phases of software development.

The field of mining software archives, such as version archives like code repositories, bug reports, documents, mailing lists, etc., is concerned with the automated extraction, collection, abstractionand interpretation of events and artifacts created and recorded during software development. Based on mining these software repositories propose and develop empirical techniques to validate/ improve software development and quality assurance approaches.

8. Projects and Programme Management

As SAC carries out many advanced R&D activities and executes many time bound projects with huge budget, a management support group is established for resource planning and monitoring. In addition, the functions related to Technology transfer and Industrial interface, RESPOND and Research coordination, Interface with academic Institutes, Human Resources development, Management Information System and Networks planning and operations as well as managing the IT facilities are the other tasks carried out by this group.

» Research Areas:

1. Work flow design/ management
2. Benefits and Challenges for outsourcing Space projects
3. Monitoring & Evaluating Projects: Contemporary Methods
4. Projects Management and Monitoring: Measuring Performance : Earned Value Analysis
5. Studies of Budgeting Methods for Indian Space Program
6. Cost Management approach for Science, technology & Engineering Projects
7. Cost Benefit Analysis of Communication payload projects
8. Technology valuation and management
9. Technology R&D and Knowledge management
10. Technology Forecasting with respect to State of the Art Technologies
11. Mentoring & Incubating Space Industry for creating the sustainable supply chain
12. Demand assessment for future communication services
13. Demand assessment for future earth observation requirements
14. Organizational behavior – Case study of SAC/ISRO
15. Organisational communication
16. Information dissemination methods
17. HR Studies and Human Capital Management
18. Innovative Organisation - building culture of Innovation – SAC case study
19. Impact analysis of SAC/ISRO's space programs (RS,SATCOM, SATNAV) in Rural and Urban India
20. Space Technology – Need and expectation of society and present scenario study
21. Need of ground and space based sensors to meet India's requirements
22. Research on Planning and development strategies
23. Enterprise Resource Planning in Govt R & D organization
24. Exploring Techno-management areas of association between Govt – Academic institutions and Industry – Market research

9. Development and Educational Communication Unit (DECU)

To harness space technology for social benefits, Experimental as well as operational applications of satcom infrastructure are actively pursued for such social benefits as distance education, rural development, tele-medicine, satellite navigation and communication support for disaster management as well as fleet monitoring system.

» *Research Areas:*

1. Mapping Information and Communication Practices in the Tribal Areas specially focus to Rajasthan, Madhya Pradesh, Gujarat and Maharashtra states
2. A comparative study on Media Habits between Rural and Urban India
3. Community's Felt and perceived information needs in the agriculture sector
4. Community's Felt and perceived information needs in the health sector of Rural India
5. Impact Assessment of Edusat Network as supportive role in the field of formal education & teachers' training

Acronyms

AIS - Automatic Information System

AOT- Aerosol optical thickness

ASAR- Airborne Synthetic Aperture Radar

ASIC - Application Specific Integrated Circuit

BOC- Binary Offset Carrier

CAD- Computer Aided Design

CAMP- Channel Amplifiers

CARTOSAT - Cartographic Satellite

CCD - Charge Coupled Device

CFRP- Carbon Fiber Reinforced Plastic

CR- Cognitive Radio

DECU- Development and Educational Communication Unit

DEM- Digital Elevation Model

DMSAR - Disaster Management Synthetic Aperture Radar

DOE- Diffractive Optical Element

DQE- Data Quality Evaluation

DSDB- Digital Sound & Data Broadcast

DSP- Digital Signal Processing

EMC- Electro Magnetic Compatibility

EMI- Electro Magnetic Interference

EO- Electro Optical

EPC-Electronic Power Conditioner

FBAR- Film Bulk Acoustic Resonator

FM - Flight Model

FSI- Full Spectrum Inversion

GAGAN - GPS Aided Geo Augmented Navigation

GCP- Ground Control Point

GEO- Geostationary Earth Orbit

GIS- Geographical Information System

GNSS- Global Navigation Satellite System

GSO- Geo Synchronous Orbit

HTS- High Temperature Super Conductivity

HySI- Hyper Spectral Imager

IMS- Indian Mini Satellite

IMUX & OMUX- Input and Output Multiplexing filters

INSAT- Indian National Satellite

IRNSS- Indian Regional Navigation Satellite System

IRS- Indian Remote Sensing Satellite

LIDAR- Light Detection and Ranging

LNA- Low Noise Amplifier

LTCC- Low Temperature Co-fired Ceramics

MADRAS- Microwave Analysis and Detection of Rain and Atmospheric Structures

MEMS- Micro Electro Mechanical Systems

MIC- Microwave Integrated Circuit

MMIC- Monolithic Microwave Integrated Circuit

MoM- Method of Moments

MPM- Microwave Power Modules

MSMR- Multi-frequency Scanning Microwave Radiometer

MSS- Mobile Satellite Services

NIR - Near Infrared Region

NPP- Net Primary Production

OCM- Ocean Colour Monitor

OD- Optical Density

OISL- Optical Inter-satellite Link

PFF- Payload Fabrication facility

POL- Point of Load

RISAT - Radar Imaging Satellite

ROIC- Read Out Integrated Circuits

ROSA- Radio Occultation Sounder for Atmospheric Studies

RS- Restricted Service

SAMIR- Satellite Microwave Radiometers

SAPHIR- Sounder for Atmospheric Profiling of Humidity in the Inter-tropics by Radiometry

SAR- Synthetic Aperture Radar

SATNAV- Satellite Navigation

SAW- Surface Acoustic Wave

SiP- System in Package

SLAR- Side Looking Airborne Radar

SMA- Shape Memory Alloy

SMR- Satellite Mobile Radio

SoC- System on Chip

SSPA- Solid State Power Amplifier

SST- Sea Surface Temperature

SWIR- Short Wave InfraRed

TMC- Terrain Mapping stereo Camera

TWTA- Travelling Wave Tube Amplifier

UHF- Ultra High Frequency

VHF- Very High Frequency

VHRR- Very High Resolution Radiometer

VNIR- Visible and Near Infrared Region

Annexure 1

Details and Formats on Research Sponsored (RESPOND)

(For further details and latest information particularly on salaries etc refer to Respond page on www.sac.gov.in)

The Indian Space Research Organisation (ISRO) has a programme through which financial support is provided for conducting research and development activities related to Space Science, Space Technology and Space Application in Universities and academic Institutions in India. This programme of Research Sponsored by ISRO is called RESPOND. In special cases research and development projects proposed by non-academic R & D laboratories can also be supported through this programme. The aim of RESPOND is to encourage quality research in areas of relevance to the Indian space programme.

The primary objective of the Indian Space programme is to harness the advanced areas of space science and technology for national development and to derive the maximum benefit for the people of India. The Indian Space Programme includes the following major elements:

- Demonstration of the feasibility of deriving from space science and technology, applications in space communications, long distance education, earth resources survey, meterology and geodesy.
- Development of indigenous capability for design and development of orbiting satellites for scientific research and space applications, sounding rockets and satellite launch vehicles.
- The main objectives of the RESPOND Programme is to establish strong links with academic Institutions to carryout quality Research and developmental projects of relevance to space and derive useful outputs to support ISRO programmes. RESPOND programme will enhance academic base, generate human resources and infrastructure at the academic Institution to support the space programme.

Supported Areas of Research

Research proposals are Supported by ISRO in any area of relevance to the space programme of which the following are few examples:

- Space Science: Physics of the ionosphere and magnetosphere; meteorology, dynamics of the atmosphere; geophysics, geology; astronomy; cosmology; astrophysics; planetary and interplanetary space physics and climatology.

- Space technology: Rocket and satellite technology; propulsion systems design and optimization; aerodynamics and heat transfer problems related to space vehicles; guidance and control systems for launch vehicles and spacecraft; polymer chemistry, propellant technology; ultra-light- weight structure; satellite energy systems; space electronics, Space communication systems; orbital mechanics and computer sciences.

- Space Applications: Remote sensing of the earth's resources: space communication; satellite geodesy image processing, satellite meteorology including weather forecasting, Space Education and Ecology.

Some illustrative examples of specific problems in the above-mentioned areas can be made available by ISRO from time to time. Proposers need not feel to restricted, however, in the selection of subjects for the proposals intrinsic scientific merit can be demonstrated.

Proposal Submission

Individual or group(s) of scientists, engineers, members of the teaching staff, research workers belonging to recognised academic institutions, universities and research organizations may submit proposals. The proposer(s) should be full-time employee(s) of the concerned institution. Proposals with applications for research grants must be forwarded by the institution. Proposals from persons not attached to a recognized institution cannot be considered.

The proposals should preferably be submitted in response to announcements made by ISRO for such purpose from time to time. There is no last date for submitting proposals. ecisions on support are generally taken twice in a year, during February-March and August-September. Each proposal must name a Principal Investigator from the institution forwarding the application. There may also be co-investigator(s) from different institutions working on the project. But satisfactory completion of a project will be the responsibility of the Principal Investigator and his institution. Each proposal should provide such information as:

- Bio-data of all the investigators. (Age may be indicated).

- Brief description of the research proposed including the objectives and the scientific/application merits of the work.

- Description of the method or technique to be used for the proposed investigation.

- The extent of financial support needed for executing the work within the shortest possible time.

- A list of research projects related to the proposal undertaken or carried out through funding by other Agencies.
- Seven copies of the proposal on standard A4 size paper (297mmX210mm) should be prepared in the format given in Forms & Procedure.

Five copies of the proposal in the Space Applications, Space communications, Remote sensing and meteorology areas should be sent to following address :

Director
Space Applications Centre, ISRO
Ambavadi Vistar P.O.
Ahmedabad - 380 015
e-mail : director@sac.isro.gov.in

Two copies of the proposal must be sent to:

Scientific Secretary
Indian Space Research Organisation HQ
Department of Space
Government of India
Antariksh Bhavan
New BEL Road
Bangalore - 560 231
e-mail : scientificsecretary@isro.gov.in

Along with the declaration in the format, Proposals are processed and evaluated through procedures laid down by ISRO for this purpose. Proposers are normally informed about the outcome of the evaluation in April or October.

Research Grants

The institutions proposing a project for support are expected to commit the use of the existing infrastructure available with them. ISRO supports the purchase of necessary equipment and consumables required for the projects, and grant research Fellowships, research associateships and research Scientists for working on these projects. There is no provision for payment to the Principal Investigator (or other academic staff) belonging to the Institution.

Guidelines governing the allocation of funds by ISRO are set out below. These may change from time to time.

- Grants for the purchase of equipment may be provided for the investigation of the equipment is of a specialized nature, required exclusively for the project and is either not available at, or cannot be spared from, parent Institution for the project.
- Appointment of a limited number of research assistants and technical supporting staff such as technicians, instrumentation mechanics, etc. can be made for an approved project. However, at the close of project ISRO cannot assume any responsibility for the project staff who will have no claim whatsoever to recruitment in ISRO on any basis.
- The selection and appointment of the above project staff is the responsibility of the Principal Investigator. These should be made according to the normal selection procedures of the university or institution submitting the research proposal. The qualification / experience required and the salary offered for such staff should have the approval of the head of the institution according to the rules followed in the Institution.
- The research personnel who are associated with the project may be awarded ISRO's research Fellowships, Research Associateships and Research Scientists according to guidelines laid down by ISRO for this purpose. Details on the award of Research personnel are given in following sections.
- Amount may be granted, in addition, under the following heads:
  - » Purchase of books and scientific literature necessary for the investigation and not available in the parent university or institution (for Journals, ISRO approves only the purchase of single copy of issues or Photostat copies of the papers relevant to the project). Subscription to journals on a regular basis cannot be covered by these funds.
  - » Special consumable materials essential to the project.
  - » Computer time and other services.
  - » Travel in connection with the project or for attending seminars and symposia of relevance to the subject of the investigation.
  - » Miscellaneous expenses (contingency) such as typing charges, stationery, postage, etc.
- All requirements of foreign exchange for the purchase of equipment and/or consumables should clearly identified and mentioned in the budget. It is expected that the foreign exchange will normally be arranged by the concerned Institution and ISRO will provide

equivalent money only in Rupees. Only under exceptional circumstances can ISRO consider proposals for limited foreign exchange allocations.

- No funds are normally available for international travel in connection with the project.
- ISRO does not normally provide funds in the project for printing any material in connection with the project.
- ISRO does not grant any funds for buildings and civil works for housing any equipment or personnel. However, charges for equipment installation can be provided.
- All travel in connection with the project should be approved by the Principal Investigator according to the TA / DA rules of the concerned Institution. The mode of Journey including air-travel may also be approved by him so that the implementation of the project takes place in time subject to the condition that the institution has no objection to such an arrangement and that the travel expenses are contained within the budgetary provisions for the project approved by ISRO
- The funds will be sanctioned under different specific heads and will normally be released by ISRO once every year. Reappropriation of funds among different heads is permissible only in special cases with the approval of ISRO.
- If the amount sanctioned during a particular period is not spent, the spill-over will be taken into account while sanctioning further funds.

Terms and Conditions of ISRO Research grants

- ISRO reserves The Right To revoke In Whole Or In Part The Funds Approved for a project at any time without assigning any reason.
- Approved funds must be utilized solely for the purpose for which they have been granted unless ISRO agrees other wise. A certificate that the funds have been so used must be produced by the grantee Institution at the end of each year of support.
- Acknowledgement of ISRO support must be made in all reports and publications arising out of an approved project / investigation. The Institution will take prior permission of ISRO before publishing any work based on an ISRO supported project. Such permission will not be unreasonably withheld.

- Two copies of all publications resulting from the research conducted with the aid of the grants should be submitted to ISRO.

- No investigator receiving a grant from ISRO may make commercial use of the results of the work through patents or otherwise. ISRO reserves the exclusive right to determine whether any patent shall be taken out and for which commercial use, if any, shall be made of any result of the investigations. All patents shall be in the name of ISRO and ISRO shall retain exclusive rights to commercially exploit them. The share, if any, for the royalty to the Investigator, the parent Institution and ISRO will be determined by ISRO.

- The Principal Investigator is required to submit two copies of yearly reports indicating the progress of the work accomplished. He is also required to submit two copies of a detailed scientific/technical report on the results of the research and development work after the completion of the project. One copy of these reports should be sent to the address to which the proposal was sent and other to the scientific Secretary, ISRO Headquarters. Annual reports should preferably be sent to the release of funds for the subsequent year. The reports will become the property of ISRO.

  ISRO may designate scientists/specialists to visit the Institution periodically, for reviewing the progress of work on an ISRO-funded project.

- An inventory of items purchased from ISRO funds should be sent to ISRO giving the description of the equipment, cost in rupees, date of purchase and name of supplier along with a purchase certificate from the Head of the Institution. All items of equipment and non-consumable items costing more than Rs. 5,000 remain the property of ISRO and ISRO reserves and right to recall, transfer or dispose them off on the termination of the project.

- The accounts of the expenses incurred out of ISRO funds should be properly maintained and should be authenticated by an approved auditor. The final statement of accounts in duplicate, duly audited, should be sent to ISRO at the end of each financial year of support. A statement of accounts of his Institution should be sent to ISRO for every operational year of the project sufficiently in advance to enable the release of funds for the subsequent year.

- If the total amount sanctioned is not spent during the whole period of support, the remainder amount must be surrendered to the Pay and Accounts Officer, Department of Space, within one month after completion of the project.

- The assets acquired wholly or substantially out of an ISRO grant should not, without prior sanction, be disposed off or utilized for purposes other than that for which the grant is sanctioned.
- A register of assets, permanent and semi-permanent, should be maintained by the Institution and this should be available for ISRO audit scrutiny.
- The Institution cannot divert the grants for a project to another institution if it is not in a position to execute or complete the assignment. In such a case the entire amount of the grant must be immediately refunded to ISRO.
- The terms and conditions of ISRO research grants are subject to change from time to time, but the funding of any project till its completion will be governed by the terms and conditions exiting on the date of starting of the project with ISRO funds, unless mutually agreed to otherwise.

General rules

- ISRO Research Fellowships, Research Associateships and Research Scientists hereinafter referred to as Fellowships/ Associateships/ Scientists are awarded for specific projects or Education/Research Schemes approved by ISRO.
- The recipients of these Fellowships/ Associateships /Scientists are expected to conduct research work whole-time under the Principal Investigator of the ISRO sponsored project. In special cases of individual Research Fellows/Associates, the candidates could be governed by the conditions of Research work as specified by the projects/ programmes/ schemes for which the Fellowships have been offered by ISRO.
- ISRO shall be invited to nominate and ISRO may nominate a member for the committee appointed by the institution.
- The Fellows/ Associates/ Scientists shall not transfer from one institution to another, except with the prior approval of ISRO. The award of ISRO Fellowships/Associateships/ Scientists does not imply any assurance or guarantee by or from ISRO or any kind of employment to the beneficiaries.
- Generally the upper limit for the period of Fellowships/ Associateships/ Scientists will be the same as that of the project. However, in exceptional cases, mainly to enable the Fellow to

complete his Ph.D., ISRO may extend the period of the concerned fellowship but not beyond the limit of five years.

- Leave for a maximum period of 30 days in a year, in addition to general holidays, may be allowed to the Fellows/ Associates/ Scientists during the tenure of Fellowships/ Associateships/ Scientists by the appropriate authority in the university/institution. The general holidays, however, do not include the vacation period e.g., summer, winter and pooja vacations.
- Monthly emoluments of the Fellowships/ Associateships/ Scientists will be paid to the concerned institution for disbursement to the Fellows/Associates/Scientist.
- Note: The scales of pay, service benefits, terms and conditions, etc for appointment are subject to revision from time to time by the Department of Space/Government of India.

Research Fellowships

Designation and Qualification	Revised Emoluments Per month w.e.f. 1/10/2014
A : Junior Research Fellow (JRF) (I) Post Graduate (PG) Degree in Basic Science with NET or Equivalent Qualification OR (II) Graduate Degree in Professional Course with NET or equivalent qualification OR (III) Post Graduate Degree in Professional Course	25, 000
B : Senior Research Fellow (SRF) Qualification prescribed for JRF with two years of research experience	28, 000

Note: The performance of the junior Research Fellows (JRF) shall be reviewed, on completion of two years, by an appropriate Review Committee duly constituted by the Directors of Centre/Units. Based on the recommendations of the review committee and approval of Director of the Centre/Unit, Junior Research Fellow may be awarded the position of Senior Research Fellow (SRF)

Research Associates (RA)

The fellowship for Research Associated may be fixed as consolidated amount at any of the three pay levels given below depending upon the qualifications and experience

Educational Qualification : Doctorate or equivalent degree in Science / Engineering / Technology or having 3 years of research, teaching and design development experience after ME / M. Tech with at least on research paper in Science Citation Indexed (SCI) journal.

SI. No.	Category	Revised Emoluments Per month (₹)
1	Research Associate I (RA-I)	36, 000
2	Research Associate II (RA-I)	38, 000
3	Research Associate III (RA-I)	40, 000

The stipend of research fellow/associate is exempt from the payment of Income tax as per the provision under 10 (16) of the IT Act, 1961.

The fellowship amount for JRF and SRFs as shown above are lump sum amount and no other allowances or contingent grant would be payable to them.

The fixation of the Research Associateship in any of the three categories will be based on individual's performance at the selection, his qualification and experience.

Research Scientists

Depending upon the need of individual project, Research Scientists could be appointed in such projects in any of following three grades:

Sl No.	Scales (as per VI CPC)
1	(PB-3) ₹ 15600 – 39100 + GP of ₹ 5400
2	(PB-3) ₹ 15600 – 39100 + GP of ₹ 6600
3	(PB-3) ₹ 15600 – 39100 + GP of ₹ 7600

Other scales below 15600-39100 + GP of ₹ 5400 as recommended by VI CPC and approved by Govt. of IndiaThe qualifications and experience of Research Scientists conform to those followed for filling up posts in these grades of Lecturers, Readers and Professors in the UGC system of scales of pay.

Service Conditions:

Dearness Allowance (D.A.):

JRFs, SRFs and Research Associates will not be entitled to this allowance. The Research Scientists will be eligible to draw DA as per rates of Central Government as per rules of local institutions where they are working.

House Rent Allowance:

House Rent Allowances will be allowed to all research fellows viz. Junior Research Fellows (JRF), Senior Research Fellows (SRF), Research Associates (RA) and Research Scientists (RS). If they are not provide with hoste accommodation as per rules of the institutions where they are working, For this purpose, the fellowship amount for JRF/SRF/Research Associates and Research Scientist will be taken as Basic Pay.

Medical Benefits: The JRF, SRF, Research Associates and Research Scientist will be allowed medical benefits, as per rule of the institution where they are working.

Leave and other services benefits:

JRFs/SRFs are eligible only for casual leave while Research Associates/Scientists are eligible for leave as per rules of the institutions. Maternity Leave as per Govt. of India Instructions would be available to all female JRFs/SRFs/RAs/RSs.

Participation of JRF/SRF/RA/RS in any scientific event in India or abroad will be treated as "on duty". The travel entitlement for JRF/SRF/RA/RS for participation in scientific events / workshop in India will continue to be the same as earlier i.e, II AC by rail.

Bonus & Leave Travel Concession:

Not admissible to any category.

Retirement Benefits:

JRFs/ SRFs/ Research Associates and Research Scientist will not be entitled to these benefits. However, Research Scientists who are appointed for the duration of the project may be allowed to be members of the New Pension Scheme (NPS) of the Institution.

Encouragement for pursuing higher studies:

JRFs/ SRFs/ may be encouragement to register for higher studies and the tuition fees to undertaken these studies may be reimbursed from the contingency, grant Sanctioned under the project grant, it required.

Obligations of JRF/SRF/RA/RS:

a. JRF/SRF/RA/RS shall be governed by the disciplinary regulations of the host institute

b. The JRF/SRF/RA/RS must send a detailed consolidated report of the research work done during the entire period of Fellowship on completion of the tenure / resignation at the earliest.

The periodic Enhancement of research Fellowship:

the Research Fellows, Research Associates and Research Scientist are not entitled for annual increment.

The revised emoluments will take effect from 01/10/2014 for all categories of JRF/ SRF/ Research Associates.

Frequently Asked Questions (FAQ)
(relevant to DOS)

1 What categories of research personnel do the OM on revision of fellowship cover?

The OM is applicable to junior Research Fellows, Senior Research Fellows and Research Associated only. Revision of Fellowship for other research positions like Research Scientists etc. are not covered in the OM.

2 Is the OM is applicable to the Humanities and Social Sciences?

The OM is applicable only to Science and Professional degree holders in Engineering/Technology and other disciplines like humanities, Social Sciences, Commerce and Management are not covered under the OM.

3 What are NET examinations and its equivalent for coverage under the OM?

Any national level examination conducted by the Central Government departments /agencies for admission to Ph.D programme are considered equivalent to NET. The following are the list of examinations, which can be equated to NET:

i. CSIR-UGC National Eligibility Test including NET-Lectureship

ii. Graduate Aptitude Test in Engineering (GATE) conducted by MHRD.

iii. Joint Admission Test (JAM) conducted by MHRD.

iv. Graduate Pharmacy Aptitude Test (GPAT) conducted by MHRD.

v. Biotechnology Eligibility Test & Test conducted in Bio-informatics by Bio-Informatics National Consortium

vi. Joint Entrance Screening Test (JEST), Joint Graduate Entrance Examination for Biology & Interdisciplinary Life Sclences (JGEEBILS) conducted by the Department of Atomic Energy

vii. JRF Entrance Examination conducted by the Indian Council of Medical Research.

viii. All India Competitive Examination (AICE) conducted by the Indian Council of agricultural Research.

4 Will the revision of fellowship be applicable to candidates who have passed any one of the above mentioned NET equivalent examinations?

Yes. The revised fellowship will be provided to candidates who have qualified in any of the above mentioned NET or NET equivalent examinations and are selected through institutional mechanism.

5 Does the non- NET research covered under the OM?

No. DST would announce the fellowship revision for non-NET separately later, which will be endorsed by DOS for implementation.

6 Whether the OM covers research fellowship under INSPIRE scheme?

No. DTS is taking the cases INSPIRE scheme separately.

7 Which are the Central Government Departments / agencies that will implement the OM?

The OM will be implemented by the Ministries / Departments under Government of India like MHRD, CSIR, DST, DBT, DSIR, DOS, DAE, DRDO, MoES, etc., which are operating Research Fellows scheme of DST.

8 Will the revised fellowship be paid only to researchers working in IITs?

The OM is applicable to all researchers working in all types of institutor's like academic, R & D laboratories, NGOs etc. subject to the condition that they have qualified in any of the NET or NET equivalent examinations.

9 How will the revision in fellowship be implemented in projects?

Subject to fulfillment of the conditions stipulated in the OM. The concerned Departments /

Ministries can authorize the revision through respective Principal Investigators / Head of the academic institutions, undertaking that extra mural research of Government of India.

10 Whether an existing research fellow, who is not a NET qualified person, will be eligible for revised fellowship rate, if he/she acquires the prescribed qualification while serving?

Yes. The revision of fellowship will be applicable prospe3ctively only on notification of the results by the individual the Office.

11 In there no distinction in emoluments between graduate degree holders and post graduate degree holders in professional courses?

The OM does not distinguish between Post Graduate degree in Science and professional degree holders.

12 Is there any notification about increase in fellowship for ME / M. Tech students?

No. The OM does not cover the fellowship payable to M. Tech students and Ministry of Human Resources Development / All India Council of Technical Education is the appropriate body to decide and decide and issue separate orders about the fellowship.

Formats for submitting research proposals under RESPOND

Application for Grant of Funds

1	Application Institution (Full Address)	
2	Title of the Research Proposal	
3	Name of the Principal Investigator (Address/Phone/E-mail)	
4	Name(s) of other investigator(s) with the name(s) of their Institution	
5	Proposed duration of Research Project	
6	Amount of grant requested (in Rs.)1st Year, 2nd Year, 3rd Year Total	
	Staff	
	Equipment and Supplies	
	Others	
	Total	
7	a) Bio-data of all the Investigators (Format-A). b) Brief description of the Research Proposal with details of budget (Format-B). c) Declaration (Format-C).	
8	I/ We have carefully read the terms and conditions for ISRO Research Grants and agree to abide by them. It is certified that if the research proposal is approved for financial is approved for financial support by ISRO, all basic facilities including administrative support available at our Institution and needed to execute the project will be extended to the Principal Investigator and other Investigators.	

Name	Institution	Designation
Principal Investigator		
Co-Investigator(s)		
Head of the Department/Area		
Head of the Institution		

Format A
Bio-data of the Investigator(s)*

1. Name :
2. Date of Birth : DD/MM/YY
3. Designation :
4. Degrees conferred (begin with Bachelor's degree) :
   1) Degree 2) Institution conferring the degree 3) Field(s) 4) year
5. Research/training experience (in chronological order) :
   1) Duration 2) Institution 3)Name of work done
6. Major scientific fields of Interest :
7. List of publications :
8. Co investigators :
   Name (1):
   Name (2):
9. Contact Details:
   Address
   Phone No.
   Fax No.
   Mobile No.
   E-mail

* Bio-data for all the investigators should be given, each on a separate sheet.

Format B
Proposal Preparation Format

1. **Title of the research proposal:**

2. **Summary of the proposed research:** A Simple concise statement about the investigation, its conduct and the anticipated results in no more than 200 words :

3. **Objectives:** A brief definition of the objectives and their scientific, technical and techno-economic importance. :

4. **Major Scientific fields of Interest:** A brief history and basis for the proposal and a demonstration of the need for such an investigation preferably with reference to the possible application of the

results to ISRO's activities. A reference should also be made to the latest work being carried out in the field and the present state-of-art of the subject.

5. **Approach:** A clear description of the concepts to be used in the investigation should be given. Details of the method and procedures for carrying out the investigation with necessary instrumentation and expected time schedules should be included. All supporting studies necessary for the investigation should be identified. The necessary information of any collaborative arrangement, if existing with other investigators for such studies, should be furnished. The principal Investigator is expected to have worked out his collaborative arrangement himself. For the development of balloon, rocket and satellite-borne payloads it will be necessary to provide relevant details of their design. ISRO should also be informed whether the Institution has adequate facilities for such payload development or will be dependent on ISRO or some other Institution for this purpose.

6. **Data reduction and analysis:** A brief description of the data reduction and analysis plan should be included. If any assistance is required form ISRO for data reduction purposes, it should be indicated clearly.

7. **Available Institutional facilities:** Facilities such as equipments, etc, available at the parent Institution for the proposed investigation should be listed.

8. **Fund Requirement** Detailed year wise break-up for the Project budget should be given under following heads: Salaries, Equipment, Consumables and Supplies, Travel, Contingency, Institutional Overhead

Format C

Declaration

I/We hereby agree to abide by the rules and regulations of ISRO research grants and accept to be governed by all the terms and conditions laid down for this purpose. I/We certify that I/We have not received any grant-in-aid for the some purpose from any other department of the central government/state government/public sector enterprise during the period to which the grant relates.

Name & Signature	Designation	Phone & E-mail ID
Principal Investigator		
Head of the Department/Area		
Head of the Institution		
Head of the Institution		


Sponsored Research (RESPOND) at SAC
SAC
Welcome to RESPOND at Space Applications Centre.
Sponsored Research (RESPOND) at SAC
Indian Space Research Organization (ISRO) is India's lead agency for the development of satellites, launch vehicles and applications of space technology. Space Applications Centre (SAC) is a major centre of ISRO. The spectrum of SAC activities extends from communication and broadcasting to national resource management and environmental monitoring. Following are the areas of SAC activities.
Satcom payloads
Satcom Applications
Sensor payloads
RS data and applications
Technical facilities
Annual Report 2013-14
Evaluation of Completed Respond Projects
Research Area Document
Proposal Submission
Research Grants
Terms and Conditions
Ongoing Activities
Forms & Procedure
Highlights
Annual Report 2013-14 of Respond at SAC
Annual Review of RESPOND Projects-2014
Satellite
Antenna

RESPOND & Research Coordination Division
Planning Projects Group
Space Applications Centre, ISRO
Ambawadi Vistar P.O.
Ahmedabad-380 015.
Website : www.sac.gov.in/respond