

IN EMERGING EO NEWSPACE GLOBAL MARKETS - CHALLENGES FOR INDIAN REMOTE SENSING SYSTEMS

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Abstract

Indian Remote Sensing (IRS) satellites have been providing various types of IRS images – wide-field and high repeat multi-spectral images; moderate resolution multi-spectral data; high resolution panchromatic and multi-spectral image products; panchromatic stereo images; Synthetic Aperture Radar (SAR) data; ocean colour images, scatterometer data and many others. The data are received at Indian station and also at polar receiving stations – data is processed and disseminated from the processing centre at Hyderabad. Within India, IRS images are priced low and are widely used; across the world the use of IRS images are through cooperative arrangements. The average turn-around for moderate- or high-resolution images is 7-10 days. A Remote Sensing Data Policy (RSDP) defines the scheme for IRS data dissemination to users in India.

Globally EO business in NewSpace era have not only been commercial but have gone e-image portals –bringing high efficiency using advanced image processing and internet technologies. Spurred by US DigitalGlobe and WorldView, French SPOT, European Sentinel, other commercial systems like Rapideye, Planet etc, global EO is now focussed on high-demand geospatial markets and providing high resolution panchromatic/multi-spectral images with very high cadence/frequency of global coverage AND real-time image availability. The trend is for IMAGES ANYTIME ANYWHERE with real-time geo-rectification, seaming, organising and making available images as they stream or within 24-48 hours of image acquisition. Google offers online Landsat image archive from 1980 onwards for immediate access.

These global developments in EO imaging and dissemination can be “disrupting to IRS” even as Indian EO is making significant shifts by continued space segment deployments strengthening of ground segment and online Bhuvan geoportal - all for “easier access” by users. The characters of NewSpace EO developments have not been fully addressed in the IRS environment and fragmented nature of value generation is becoming glaringly apparent. In a highly subsidised environment and lack of competitive business models, IRS could easily slip-down to an “average national endeavour” and loose impact in the global NewSpace environment.

We assess markets of traditionally strong national programmes - like IRS that will need re-definition to be able to compete and be relevant in the NewSpace era. The paper assesses the evolutionary trends and market opportunities for IRS, maintaining “leadership” in EO, need for win-win relation between government and Indian industry, deregulation of IRS data access for energising industry and even licensing private Indian EO systems. This paper presents a strategic analysis of NewSpace implications for IRS.

Keywords: (IRS, Indian EO future, NewSpace impact, IRS Markets)

1. INTRODUCTION

There is a new scenario developing with the advances in the Earth Observation (EO) - further integrated with Precise Positioning and Geographical Information (GI) – as observed in different parts of the world and even in India. On the one hand, the power of “EO and GI” is changing the way governance, commerce, resource management, environmental protection, aviation, security and even a citizen’s life is impacted -

either in a direct or indirect manner. On the other hand, the images of the earth are now being collected from variety of easily-operable platforms – satellites, aircrafts and Unmanned Aerial Systems (UAV) or Drones owned by both government and private actors.

Ever since EO started in 1970s with Landsat-1 (then Earth Resources Technology Satellite-1) and till the mid-2000s almost all of EO systems were mainly in government domain – but now large number of private-

sector EO data businesses are a reality. The developments in past 4 decades have brought a number of EO satellites in operation, evolved in the spatial, spectral, radiometric and temporal resolutions capability.

Further, a growing number of nations are acquiring capacity for space based EO and use the data for various societal, commercial and academic applications. Just for land applications, as many as 197 individual satellites with a global land-cover observing capacity have been successfully launched - of these almost 80 were still operating. The trends demonstrate that since 1970s performance had improved in several ways. The number of these missions failing within three years of launch has dropped from around 60% to less than 20%; and the average operational life of a mission has almost tripled, increasing from 3.3 years in the 1970s to 8.6 years (and still lengthening). The average number of satellites launched annually per-decade has increased from 2 to 12. The spatial resolutions improved from around 80 meters to less than one meter multispectral and less than half a meter for panchromatic, while the synthetic aperture radar resolution has also fallen, from 25 meters in the 1970s to 1 meter post 2007. More people in a large number of countries have access to EO data at an extended range of spatial resolutions than ever before¹. We provide a compendium of recent missions, analysing the changes and showing how innovation, demand for secure supply of data, national pride, falling costs and technological advances underpin the trends which impacted the field.

There is also shift of government- and private-ownership of EO systems which has enabled the availability of the high resolution EO images (presently 0.3m from satellites and even 0.1m from UAV platforms) in the commercial domain; the concept of EO Data Buckets in Big Data domain has now prevailed in a significant manner. The concept of small satellites in the EO domain has revolutionised the character of data availability and improved temporal resolution to almost a daily revisit anywhere on the globe.

While many (including Indian) EO data are “subsidised” or free-access with no costs, there are demands and preferences for commercial EO data whose costs are high but offer better capability. However, there is the progressive blurring of divide among (a) the “free access” societal EO and GI requirements for supporting developmental activities, (b) the “commercial access” of EO and GI for enterprise and business applications and (c) the “restricted” security requirements for human security and intelligence applications.

Globally, EO data have helped create valuable geospatial content across the world and have become mainstay for many Geographical Information Systems (GIS) applications. Easy availability of positioning information through inexpensive user devices including mobile telephones – and integration of position data with EO images into GIS has opened up new avenues of applications across the world. Through converging EO, GIS and Positioning technologies, many innovative and beneficial applications are being developed bringing benefits of timely, easily accessible and user friendly services².

We see now a new breed of EO systems incorporating developments characterized as “NewSpace”, which have been globally impacting EO field. These focus on low cost EO technology, diversification of sensing instrumentation, new forms of visualizing and representing information, extensive use of modern analytics and experimenting with disruptive concepts in technological, organizational and market services domains. Remote Sensing data sources are also greatly impacted by alternate platforms like unmanned aerial systems and revolutionary changes in technologies of access to information.

2. NEWSPACE EO DEVELOPMENTS AND TRENDS

One distinctive development has been that EO images and data have now become a part and parcel of many human activities and there are many examples of how society have benefited from use of EO data. As mentioned, EO data have helped create valuable geospatial content across the world and have spawned many Geographical Information Systems (GIS) applications. A host of young, dedicated communities have emerged that are undertaking a host of innovative and impacting activities that are centric around EO and its advancement. Yet there are continuing challenges that nations and societies face related to EO.

Gill Denis³ argues that until now, EO systems are dedicated assets owned and operated by governments or public organisations, often at national level. Even in the case of dual use missions, the governmental and commercial operations are in general fully segregated for the very high resolution satellites. Recent evolutions could affect this paradigm. Firstly, the increased performance of commercial satellites has a high degree of convergence with defence needs: 25–30 cm resolution is now the benchmark or at least a very short term target for commercial missions. The second evolution is the development of hybrid procurement schemes, combining proprietary missions and data buy framework contracts,

partly triggered by the budgetary constraints of public customers.

New space trend is more disruptive and it involves not only start-ups but also big web actors with substantial investment capacity. Both aim to transforming space into a commodity, taking benefit from the convergence between Information technology and EO. Beside the massive constellations for broadband Internet access, various initiatives have been launched for Earth observation markets, targeting high resolution and high revisit. Last but not least, more and more countries, the newcomers, invest in their own EO capacity, confirming the soft power dimension of space but also opening new opportunities for international or regional cooperation.

At a more technical level, some of the significant developments and the emerging challenges are as follows:

- **Large proliferation of Earth observation missions.**

Today, a large number of nations have built/operate EO systems and almost all nations utilise EO technology in a variety of applications. Thus, the scope of EO has expanded vastly and much focus is being placed on global missions, international cooperation, newer EO instrumentation and wide range of local/regional and global applications. US Landsat and MODIS, European Sentinel, Japan ASAR, Indian IRS, NOAA GOES, Chinese EO systems, Russian EO satellites etc are still major EO data providers globally. As of 2008, more than 150 EO satellites are in orbit, recording data with both passive and active sensors and acquiring multi-spectral data over the whole Earth and adding more than 100 Terabits of data daily⁴ - to a growing data archive of Petabytes in storage.

- **Emergence and increasing commercial EO satellites** that provides global coverage of valuable EO data and caters to many national and international requirements. Commercial EO satellites (WorldView, SPOT, RapidEye and more recently Planet and others), their operations, data distribution and civilian/business applications are major topics of discussion in EO. Many businesses (like Google, DigitalGlobe, ESRI, Microsoft and many others) support/provide value-addition to EO data and development of down-stream EO/GIS applications. Investments into the EO business and its services include not only small and medium enterprises but also large capacity players from Information Technology industry.

A list of private EO missions is listed below (list not exhaustive; illustrative)

No	Private Missions	EO	Observations
1	Planet (US)		300 dove constellation; <20kgs each – 3m and 90 cms; Daily Earth coverage
2	UrtheCast (US)		ISS based payloads; Deimos OptiSar (670/1400kg) combination; 1m SAR and optical data; Spot-scan coverage
3	Jilin (China)		60 satellites (~100-200kgs); 72cm imaging and UHD video; aims for all-weather data
4	Satellogic (Argentina)		~300 (when complete) smallsats (~35kgs); 1m XS and 2-hourly revisit
5	AstroDigital (US)		25+ smallsats (~10-20 kgs); 2.5m GSD; Daily coverage of Earth
6	NOVASAR (UK)		SAR satellites (~400kgs); SAR strip; 6m S-Band SAR small strips

- **Advanced development in sensor and instrumentation technologies**, expanding capabilities to optical, IR, Microwave regions of the electromagnetic spectrum with extensively improved geometric resolution, spectral resolution and radiometric sensitivity – apart from temporal coverage. Technology advances and new practices in the commercial sector have enabled considerable enhancement in the performance of smaller and less expensive spacecraft systems and more importantly in diminishing the gap between capabilities of government owned dedicated military systems and commercial satellites operated by private sector. Advances in sensors offer wide range of data through high and medium resolution optical imagers, thermal imaging sensors, hyper spectral imaging instruments, multi band passive microwave radiometers, Altimeters, Polari meters, active sensors like Synthetic Aperture Radars in different bands of microwave spectrum, scatterometer and LiDAR (mounted on aircraft). For commercial operators leading in the provision of high resolution optical imagery, a resolution capability of 25-30 cm has virtually become a norm.
- **Improved data communication technologies**, including the revolution of the internet, have made it very easy to deliver large volumes of EO data to users on a near-real-time basis – so that instant use of EO data can be made for many mission-critical

applications and brought EO data to the desk of citizens across the world.

- **EO as Big Data** is becoming pervasive – with rapidly growing volumes daily; fast and quick daily updates and variety of EO data that is getting archived from the large number of EO satellites. The focus is on providing EO data as per user demand – when user wants, where user wants and as user wants. This has proliferated one-stop EO Data Portals that provide large amount of data on immediate basis – either by access-to-download or pay-to-download. The major aspect is that data is made available instantly as it is acquired – almost within few hours on huge, easy-to-use, Data Portals. Globally, EO is now focussed on high-demand geospatial *markets* and providing high resolution panchromatic/multi-spectral images with very high cadence/frequency of global coverage AND real-time image availability. The trend is for IMAGES ANYTIME ANYWHERE with real-time geo-rectification, seaming, organising and *making* available images as they stream or within few hours of image acquisition. The concept of Analysis Ready Data” (ARD) is fast emerging - EO data that have been processed to a minimum set of requirements and organized into a form that allows immediate value-adding and analysis without additional user efforts⁵. Landsat and Sentinel of Europe have developed ARD Platforms for dissemination of global data within 24 hours of acquisition. SPOT provides a Portal for immediate ordering and access of SPOT/Pleiades images across the globe within 24-48 hours of acquisition. Planet, through its large constellation acquires and delivers images of about 3m resolution on a daily basis cadence for any part of the globe and makes it available immediately on its Data Portal⁶. Google Earth Engine offers online real-time Landsat (from 1980s onwards), Sentinel and variety of EO images for immediate access and processing⁷.
- **Advances in digital data analysis and geo-spatial data fusion** – with data mining and data analytics have enabled quick and rapid information extraction from EO data and enabled the emergence of a vibrant geospatial industry. At same time, large scale hardware implementations (e.g. Cloud Computing) and capable software that process EO data and ingest critical geo-spatial information into GIS applications. The leverage created by these technological advances in large scale data storage, superfast processing of large data volumes, the quantum leaps in the fields of analytics, AI, machine learning and visualisation of information as well as its delivery had unfolded possibilities of ubiquitous mass market applications. For instance, ubiquitous use of maps in cellular phones for a variety of location based services is already a common place. The spin-in effect of technologies from other fields like information storage, data processing, or software could draw large actors from those sectors to commoditise EO data or consolidate commercial EO systems into their businesses.
- **EO applications have opened up in many new areas** – which impact citizens, societies, enterprises and governments in a major way - enabling the sustainable development plans for our Earth. Today, most nations use EO data for inventory/mapping, improved statistics, improved decision making and managing disasters and many other national development and global collaboration activities.
- **EO has spawned the growth and usage of geo-spatial technologies and applications.** EO images/data and GIS have become so “coupled” in the user domain that without EO images/data GIS decision-solutions are almost impossible and, in inverse, wide GIS usage is creating newer and innovative demand on EO technology.
- **New models of public funding** – innovative approaches are being adopted for public funding of private EO satellite systems through policy interventions. Advance funding for future EO data Buy-back (as has been adopted in US since 2003) will become new cornerstones for future EO system – thereby, not only achieving national technological growth but also growth of private sector EO industry. Such Framework Partnerships between national programmes and private sector will substantially change the EO data procurement process - instead of owning dedicated EO systems by governments, they would trigger Private Public Partnership (PPP) in EO. These models will pose challenges to traditional EO actors from publicly funded systems or change the competitive landscape across the globe. There are other consequences of the trends - commercially less attractive segments but still relevant for national needs, such as systems generating medium resolution data, weather, environmental and ocean data, low resolution wide-field data and dedicated systems generating military or security intelligence will mostly continue to be owned and operated by the governments. Open access data policies and data sharing principles adopted by key government players in US, Europe and Asia will probably draw a global appeal, thus polarising commercial investments into certain attractive segments of value chain and for institutional services.
- **A number of inter-governmental programmes** around EO/GIS have emerged and are coordinated through UN-OOSA, GEO, ISPRS, GSDI etc and these efforts have made phenomenal advances in regional and global applications development of EO and GIS.

On the other hand, demand is increasing – mainly due to variety of resolutions meeting user needs; availability of EO data as NEEDED and on DEMAND; improved quality of EO data combined with their high cadence. In the very high resolution data segment, government policies would act as a grid that would control the level of access and dissemination of data, in other words influencing the market dynamics across various geographies.

We feel that NewSpace is the alignment of EO system with the IT systems and driven by hard entrepreneurial drive to meet market needs and also create aggressive new markets. With a strong business drive, NewSpace EO would cater to the growing demand for niche EO data and services with full private investment and ownership. There will be large number of initial entrants in NewSpace business – but slowly the robust will remain and drive the market and national needs together.

So the future NewSpace EO seems to be – driven by private sector; ultra-high resolutions of imaging – spatial/spectral/temporal; daily (or even 3-4 times a day) coverages of any area on Earth; instant EO data delivery to users – within hrs of acquisition; Portal-based EO data ordering and delivery as an EO-data marketplace; small and efficient satellites with low weights/power specifications; long-term sustainability; intelligent cloud-based image processing and services; direct GIS ingest and fusion; intelligent image analytics using AI and Machine Learning - all at commercial considerations - meeting a variety of user application needs.

3. DEVELOPMENTS OF INDIAN REMOTE SENSING SATELLITE PROGRAM

Indian Remote sensing Satellite (IRS) programme was conceptualised in early 1980s and was initiated with IRS-1A launched in 1988. Since then, IRS constellation of satellites have been catering to observational needs for land, ocean and atmosphere and supported a wide range of applications in India. Through the developments that spanned over three decades, there has been considerable enhancement in IRS capabilities – spatial resolutions have reached sub-metre levels; panchromatic fore-aft stereo has been flown; spectral resolutions have been mainly in optical and near/middle IR with few active SAR and microwave missions; the temporal resolution has been enhanced to 5-day visit by tilting cameras and even hourly-basis by geo-synchronous imaging; data acquisition and dissemination has been enhanced with advanced data processing systems and many other enhancements.

Over the years, 38 EO missions have been launched by India (out of a total of 97 satellite missions that have been undertaken). Currently 12 satellites are in operations and can be broadly categorised as (i) resources information satellites, (ii) cartographic series, and (iii) ocean and atmospheric observation satellites. They provide a wide range of images and observational data such as wide-field and high repeat multi-spectral images; moderate resolution multi-spectral data; high resolution panchromatic and multi-spectral; panchromatic stereo images; Synthetic Aperture Radar (SAR) data; ocean colour images, scatterometer data and many others.

Broadly, Indian EO systems can be categorised into 4 major phases:

- The experimental phase (in very early 1980s) which included the early Bhaskara and Rohini series satellites. The sensor technology was initiated with TV cameras and experiments also started with CCD cameras for digital imaging. The satellites were spin-stabilised systems and data rates handling were in the kb levels. These early systems helped establish the end-to-end systems capability in EO.
- The semi-operational stage with the IRS-1 systems which came into being from 1987 onwards when line CCD cameras were developed by ISRO and provided medium resolution of 36/72m multispectral capability. These IRS-1 systems matched the levels of capability that was available with Landsat/SPOT in that era and helped India transition into initiating an operational global capability. By early 1990s, IRS systems were received in global stations and data disseminated through commercial arrangements.
- The operational phase started with IRS-1C – which provided, for the first time, 5.8m resolution in civilian domain. The series of satellites that followed upto early 2000s upped the spatial resolution capability to 2.5m with stereo capability and even ~1m resolution with ingenious step-and-stare technology. This also set into stage the then next-generation Cartosat and Resourcesat series of satellites with a complement of 2.5m stereo imaging AND complement of high-resolution multi-spectral at 5.8m; 23m moderate resolution multi-spectral and 55m wide-field sensor – bringing in the concept of “high-repeat” of every 5 days large-swath coverage. The IRS capability also entered into SAR based EO with RISAT providing spectral diversity for all weather and day & night observation capability.
- Ocean, Atmospheric and climate observations were addressed by INSAT series meteorological segment which came into being from 1980s onwards providing meteorological imaging capability. Oceansat series was initiated around 2000s to observe ocean phytoplankton and ocean physical parameters. Megha

Tropiques (Indo-French joint mission), SARAL and SCATSAT-1 were also taken up to add to the data collection for oceans and climate. Multiple sensors like Ocean Colour Monitor, Multi Frequency Scanning Microwave Radiometers and Scatterometers, Very High Resolution Radiometers and sounders (operating in 19 channels) were developed – thus providing unique capability in EO systems design and development.

In 2001, ISRO conducted a unique exercise to define a long-term strategy for EO and outline a 2025 strategy for Indian EO. Rao et al⁸ noted that future Earth Observation Systems will have to take into consideration the aspects related to the commercialisation and standardisation of programmes world-over; transitioning into a business environment; data continuity and the need to monitor processes rather than events. Technological changes were seen to re-define many of the concepts of observation from space and issues like spatial resolution, spectral resolution and temporal resolution may no more be a concern for observation systems. A strategy was outlined for the Indian EO Programme with a vision for the next 25 years. Based on a thorough analysis, the observation needs of the future were planned and systems design outlined. An exhaustive Need Analysis was undertaken keeping in mind the Global change applications; Mapping and Cartographic applications; Natural Resources and Environmental management applications etc. Issues related to defining the space and data acquisition as a national “public good”, costing of data products and services and evolving a commercial remote sensing policy have been addressed for providing the overall thrust of the Indian EO program. The strategy had identified transition to support a two-pronged strategy of supporting national development and, at the same time, developing a commercial business EO enterprise in the country. The need to generate newer user segments and develop newer services and products was recognised from the utilisation point of view and the impact accruing from these proposed strategy was defined⁹.

Over the years various elements of the EO-2025 strategy have been implemented in the various missions of Resourcesat, Oceansat, Cartosat etc and many evolutionary improvements in capability were incorporated including better spatial and radiometric resolutions, enhanced data transmission speeds, higher onboard storage (up to 200 Giga Bits), , addition of SWIR band, and a flexible wider swath (in mono band). The spacecraft capabilities compare well with those of leading space agency programs for systematic imaging, with further advantage of cost effectiveness.

In India, the demand for EO data is varying from year to year, although long term trend shows upward movement over a decade. The number of data products disseminated by NRSC¹⁰ during fiscal years 2011-12 to 2015-16 were in the range of about 200,000 to 490,000. The average annual demand during this period was 250,000 products, of which commercial sales ranged between 40,000 - 80,000 products, while the rest were shared on open access basis on Bhuvan Portal¹¹. It is seen that, like in the global trend, in India too the major data sale pertains to high resolution data - such as panchromatic data of 1 and 2 meter resolution (Cartosat 1&2); followed by that for 23 meter multi-spectral data and wide field sensor data (from Resourcesat). Further, the demand and sale of data from DigitalGlobe and others are also high - to the extent of a million square kilometer (area) annually procured from these foreign satellites operated over India. India’s Data demand in terms of commercial volume could only give a partial picture due to aforementioned policies, but yet an estimate of commercial data demand from domestic as well as overseas could be in the range of 20 to 30 million USD and most of this value resides in the available highest spatial resolution¹².

In summary, Indian EO is at levels of wide capability – missions for land, ocean, atmospheric observations; continuity mostly maintained; capability of spatial resolutions of upto 1m/2.5m/5.8m; panchromatic-stereo/multi-spectral and microwave sensors; 26 days repeats with revisit of 5-days capability; IRS satellite class of ~700-1500 kgs; cadence based data access not yet available but traditional ordering and delivery systems; global data archives on Portal accessibility yet to be achieved, and, high level competition to IRS from commercial Highres imaging systems of 0.3m and instant delivery systems of Landsat/Sentinel/Planet and others.

3.1 Indian EO – Way Ahead

A peek into future plans over the next 10-12 years have been analysed and assimilated from information from different sources – through discussion with Indian experts, newspaper reports, parliamentary proceedings¹³, annual reports etc and a construct of Indian EO future has been made and given below.

Future Indian EO will follow the global trends as well be tuned to national priorities. Continuous watch over the region will be enabled by imaging from geostationary orbit at a resolution of 50 m through a new fleet of satellites. A shift to third generation Resourcesat systems - vastly improving coverage at 10m and 20m resolutions by repetitive revisit of once in two days by –increase in fleet size as well as by widening the swath, and, enriching

spectral content to 5 Multispectral Bands would be realised. Thermal imaging and hyper-spectral imaging will be a new additional dimension. The microwave imaging capability in C band will get further diversified through collaborative approach into deployment of radars in L & S bands and even in P-bands.

In high resolution arena, new capabilities beyond the present 0.8m -1m data, with considerable improvement in spatial resolutions are planned - small satellites may be the mode of mission realisation. It will be capable of more frequent revisits (better than a day) and delivery of the products within a few hours. A significant enhancement in capability would be the possibility of 1.25m stereo mission – thereby improving the DEM coverage possibility.

Future Ocean and atmospheric observational satellites should ensure continuity of user services. Secondly, the sensor data in 8 bands at 360m resolution along with information on sea surface height (for ocean state observation) has to be ensured. Two identical missions for ocean data on daily basis is envisaged.

For meeting the challenges of tropical weather forecasting, densification of wind vector data (at 25km resolution) at 6 hourly intervals is a goal. To measure the temperature and humidity profiles of atmosphere, a millimetre wave sounder is also possible. EO Missions with LIDAR based wind profiler and a precipitation Radar, instruments for reflectometry involving Global Navigation Satellite Systems and Radio Occultation (RO) measurements would be envisaged.

4. CHALLENGES FOR INDIAN EO

The markets of traditionally strong national programmes like Indian Remote Sensing Programme would have to face the challenge of NewSpace EO systems and developments. Two major characteristics of NewSpace that would be disrupting Indian EO environment (but be positively favourable to Indian EO markets) are the ultra- high resolution data (of upto 0.3m) availability; daily coverage/cadence and instant user access on a ARD or e-market place that synchronises various EO data instantly to meet Indian user needs.

A large number of Indian users access the no-cost Landsat and Sentinel portals to obtain data without delay. Within 24 hours of Landsat data acquisition, Indian users access <https://earthexplorer.usgs.gov/> and obtain various Landsat-8 (and even past Landsat) images. Sentinel 1 and Sentinel-2 images are accessed at <https://scihub.copernicus.eu/> on open access basis within 2-3 days of their acquisition. Similarly, Google Earth Engine also provides all Landsat and Sentinel data

holdings in ARD format for easy usability to global users – including Indian users. The key point to note here is that these public EO systems are providing no-cost, open access to global images and instant image access across the globe, which is a major resource available to global EO users, including from India.

Similarly, many Indian users are ready and willing to pay commercial costs and accessing specific-area daily cadence images within hours of acquisitions or weekly/monthly cadence images from Planet – which offers ARD platform for global users.

The **first challenge** to Indian EO – to compete with the real-time ARD data offered by Landsat/Sentinel and Planet/DigitalGlobe in a e-marketplace environment. With large number of Indian user accessing public domain free Landsat/Sentinel data, this will certainly impact the demand on IRS EO data – especially in the multispectral and SAR category. Thus, Indian EO capability would greatly be enhanced if it gets onto an Indian EO ARD platform and makes available past IRS archives AND current IRS data acquisitions instantly – say within 4-6 hrs of data acquisition. Major shift of paradigm is required to move away from traditional Data Processing systems which take about a week at best to average of 15-20 days to provide users access to data. India needs to develop an Intelligent Data Processing Systems; process them using high-speed algorithms quickly and within 6 hrs make them available to Indian users on Indian EO Portal – serviced on a good e-access Big Data platform.

The **second challenge** that Indian EO would face is the ability to cater and meet the high resolution market demand of various government and non-government users in the country. Today, considerable demand and sales of DigitalGlobe, Planet and other high resolution images are happening every year – especially in infrastructure, urban development, disaster management and even in plot-level crop assessments in contract farming etc. With the larger availability of high resolution images from a variety of foreign commercial EO satellites, the demand would be more and more met by such image availability. In a review of Space Applications by the Prime Minister of India on September 7, 2015, a common thread of challenge identified by 5 major ministries/department Secretaries was two-fold – the need for high-resolution images (even upto 0.25m were mentioned) and policy for addressing access difficulty for EO images¹⁴. This clear messaging coming from Indian users is that high-resolution EO images are critical need and gap has to be filled. As explained earlier, Indian is planning ahead in new capabilities beyond the present 0.8m -1m data, with considerable improvement in spatial resolutions BUT its

challenge is immediate because commercial Planet/DigitalGlobe etc already have 0.3m and 1m global instant image services in position. Thus, if it takes another few years for Indian EO to accomplish high resolutions of around 0.3m and instant imaging capability, large market segments would have been serviced and developed already by commercial players in global EO. Thus, quickening and hastening this high resolution 0.3m imaging capability and matching global levels of EO is essential.

One point to note here is that IRS systems had been one of the flagship segments of Indian Space endeavours. With IRS-1C in 1995 and ahead, Indian EO was the best and led the global EO technology scenario with availability of 5.6m and 2.5m imaging capability – this was supremacy built over decades of IRS systems. For nearly two decades from advent of the operational program beginning with IRS-1A, the systems kept pace with the global state of the art, and, even leading it at times. However, in the 2000s, the progress in the world on EO technology has been quite rapid and Indian EO has to catch up in that scenario.

For example, the goals are to be set taking cognisance of (i) the high spatial resolution capability available from commercial systems, (ii) ability to image and deliver with turn- arounds matching with commercial systems, including automatic processing and delivery (iii) adoption of innovative trends in small/micro/nano satellite mainframes and miniaturisation of sensors to maintain cost leadership, and, (iv) developing world class industrial capability across the value chain.

The **third challenge** that Indian EO faces is the ability to involve Indian industry into EO systems – with the final ability to build, own and operate Indian EO by private sector. It is to be noted that globally, EO industry growth has been quite expansive and large players are making technology and market push of innovative EO systems – with advanced design and development. Public agencies (like NRSC or ISRO) would always have a handicap to compete and match the global technology push of global EO industry – this can have a serious impact on Indian EO user demand and market access (signatures of this are already seen in the high increasing level of foreign data sales for Indian applications by Indian users). The Remote Sensing Data Policy (RSDP)¹⁵ of India allows for licensing of operations of EO satellites from India – thus, it is time that Indian industry could be licensed to build/own/operate EO satellites and thereby compete with global industry on equal basis. We have earlier recommended a game-changer approach whereby Indian EO industry can be developed in next 5-10 years with national commitment to procure or “buy-back” EO images from industry¹⁶ – if such or similar approaches

are taken up then the Indian EO can play a major role in global level for next 20-30 years.

A different but yet closely connected challenge is to reduce the lead times for deploying higher capability spacecraft in larger numbers, addressing enhanced data throughputs and higher cadence of visits demanded. The turnaround to make and deploy satellites have to be reduced multi-fold. A strategic approach to meet this challenge through technology solutions and industry participation will be the key to gain user commitment.

The **fourth challenge** to Indian EO would be in the area of image-based value-added services – a capability that will centre around what the world is witnessing in Big Data, AI, Machine Learning etc and rapidly generating new and innovative image products that can benefit individual citizens, societies, government and the nation as a whole. Private sector is providing innovative Image and GI services across land, ocean, meteorology, atmosphere, disaster support, environment etc in unique ways. Indian citizens also savour Google Maps and Google Earth; Weather.com; ArcGIS Online, Planet.com, Landsat, Sentinel thru Copernicus, SPOT, OpenGIS and many other citizen and market centric applications. Today, even in India the state and central government offices widely use these products and services, in ways that are changing the face of EO data usage in quiet and silent manner. This is an important challenge for India – centring on the core technological capability in EO and GIS in the country. Taking Indian EO to the Front-ranks would very much depend on building upon this capability for service innovations in a quick and speedy manner.

If the challenges are addressed in the context of global developments in EO, the IRS programme can continue to emerge as leading programme and not be “disrupted” further into a routine programme that diminishes impact nationally and globally. Even as Indian EO is making significant shifts, the characters of NewSpace EO developments have to be fully addressed in the IRS environment and value generation process is to be revitalised. In a highly subsidised environment and lack of competitive business models, IRS could easily slip-down to an “average national endeavour” and lose impact in the global NewSpace environment if timely interventions are not made.

The question then is - how traditionally strong national programmes like IRS will be able to compete and be relevant in the NewSpace era?

First and foremost, the national needs and user’s expectations, which are the *raison d’etre* for IRS system needs to be given high focus. In the growing economy of

India, there are burgeoning needs for information for decision makers and public alike. An example is infrastructure development, where the government has been making huge investments and endeavouring to enhance public services. On the other hand, the private sector which operates in various economic and social sectors, is also hungry for more and more timely and relevant information. Rapid access to high quality satellite data is thus the key to growth. A few examples of applications where highest quality data with rapid turnaround is of quintessential value are the initiatives like Smart Cities, real estate developments, agricultural insurance, road infrastructure development, urban development and taxation planning, rural development, and disaster management. Improvements demanded in even traditional applications for natural resources management such as water management, soils, forestry, and agriculture and so on will need substantial quantum of data with greater spectral and spatial diversity and faster turnaround time than experienced in the past.

5. CONCLUSIONS

We see a new breed of EO systems characterised as “NewSpace” signposts that focus on low cost EO technology, diversification of sensing instrumentation, new forms of visualizing and representing information, extensive use of modern analytics and experimenting with disruptive concepts in technological, organizational and market services domains.

NewSpace EO seems to be driven by private sector; ultra-high resolutions of imaging in spatial/spectral/temporal domains; daily coverages of any area on Earth (or even 3-4 times a day); instant EO data delivery to users – within hours of acquisition; Portal-based EO data ordering and delivery as an EO-data marketplace; small and efficient satellites with low weights/power specifications; long-term sustainability; intelligent cloud-based image processing and services; direct GIS ingest and fusion; intelligent image analytics using AI and Machine Learning – all of these are laser-focused to meeting a variety of user application needs.

Even as Indian EO is making significant developments, we have shown that it can make considerable paradigm shifts to be flagship programme in NewSpace era through tuning of its system capabilities to the ‘best of breed’ level globally and vastly transforming its access and delivery systems, and, enabling global data archives on portal accessibility. In a highly subsidised environment and lack of competitive business models, IRS could easily slip-down to an

“average national endeavour” and loose impact in the global NewSpace environment, unless the strategy is renewed and revitalised.

We have identified 4 major challenges for Indian EO:

- Matching and surpassing state-of-art EO technological trends and positioning competing EO systems of satellites/sensing/data availability/data analysis – second to none in the world.
- Positioning EO data policies on par with present day needs and standards/practices and tuned to national needs and global market systems.
- Developing an Indian EO industry and promote Indian private entrepreneurship and innovation to build/own/operate EO systems for India and global market. Areas to explore could include value chain elements such as data acquisition, processing and dissemination systems (within a few hours to within a day).
- A strategic approach for Indian EO that brings to the fore a long-term vision and strategy for developing EO, say, for next 20 to 25 years.

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