Directorate of Space Situational
Awareness and Management (DSSAM)

ISRO System for Safe & Sustainable Space Operations Management

In-house system to
safeguard Indian operational space assets and limit **proliferation of space debris**

ISRO SYSTEM FOR SAFE & SUSTAINABLE SPACE OPERATIONS MANAGEMENT

Ever since the inception of Indian space programme, space-based assets have played a pivotal role in nation building by providing crucial services in the field of communication, weather and resource-monitoring, navigation, etc. However, the ever-growing space object population including that of operational satellites and orbital debris and the associated collision risks pose a serious threat to the safe and sustainable use of outer space. The increasing congestion of Earth orbits pose a looming threat of collisions among larger debris that could trigger a self-sustained cascading process of further collisions, known as the Kessler syndrome. This could result in a drastic increase in the density of space debris population, rendering outer space inaccessible for future generations.

With the announced space reforms encouraging private entities participation in space activities, India's responsibility and the contributions in the long-term sustainability of outer space activities need to be emphasized. ISRO's efforts in Space Situational Awareness (SSA) are coordinated centrally at ISRO SSA Control Centre in Bengaluru.

Given the ubiquitous applications of space technology in day-to-day life, the Long Term Sustainability (LTS) of outer space activities is of paramount importance to ensure that the outer space remains utilizable to the future generations of humankind. Effective management of safe and sustainable operations in outer space entails a holistic approach encompassing multiple areas related to observation and monitoring of space objects and space environment, processing observations for orbit determination, object characterisation and cataloguing, analysis of evolution of space environment, risk assessment and mitigation, data exchange and collaboration. ISRO System for Safe & Sustainable Operation (IS4OM) in ISRO Control Centre is conceived with such a holistic approach towards ensuring safety and sustainability while reaping the benefits of sustainable utilisation of outer space for national development.

ISRO has been taking necessary measures to safeguard all its space assets from intentional and accidental close approaches by space objects including operational spacecraft and space debris objects. The host of activities towards achieving the goals of complying with International guidelines for Long Term Sustainability of Outer space are being taken up in ISRO SSA Control Centre as Indian System for Safe & Sustainable Space Operations Management (IS4OM). The facility can support all routine operations safeguarding Indian space assets, mitigating collision threats from space objects through specific collision avoidance manoeuvres, Compliance with international guidelines such as Post Mission Disposal and Satellites End-of-Life operations together with research activities in Space Debris and Space Situational Awareness.

The importance of radars and optical telescopes as the main ground-based facilities for tracking space objects including space debris is to be highlighted. Accurate orbital information from such ground based sensors is a pre-requisite for mitigating any collision threats to an operational space asset from other objects. The backbone of SSA system is the network of observational facilities in which more efforts are required to engage with other space faring nations for data sharing aspects. It requires setup necessary Indian observational facilities for a meaningful and value added SSA system development and alerts generation.

Infrastructure for Space Weather monitoring and forecast plays a critical role in protecting space based as well as ground based infrastructure from critical solar activities. On an equal footing, detection and prevention of asteroid impacts are essential for human survival. Vision of IS4OM towards space weather services and planetary defense initiative are also to be important areas of SSA.

IS4OM will aid India achieving its SSA goals by providing comprehensive and timely information of the space environment to users. This multi-domain awareness platform will bring prompt, accurate and efficient information on on-orbit collision, fragmentation, atmospheric re-entry risk, cataloguing of observational data, hazardous asteroids and space weather forecast.

ISRO System for Safe & Sustainable Space Operations Management

ISRO System for Safe and Sustainable Space Operations Management (IS^{4}OM)

Safe and Sustainable Space Operations

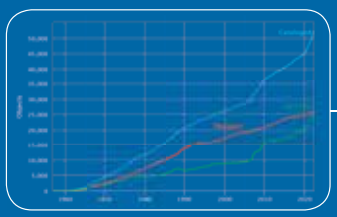
Space Debris

Sources

- New Launches, material released during space operation
- Fragmentation
- Collisions between space objects

Sinks

- Active Debris Removal
- Natural decay atmospheric re-entry



As on 06.05.2022, out of 25505 catalogued on-orbit objects only 5732 are active satellites, the rest are debris

UN/IADC recommended guidelines for space debris mitigation

Limit debris release during normal operations

Avoid on-orbit collision

Minimise on-orbit break-ups

Minimise post-mission break-up

Avoid intentional destruction with long lived debris

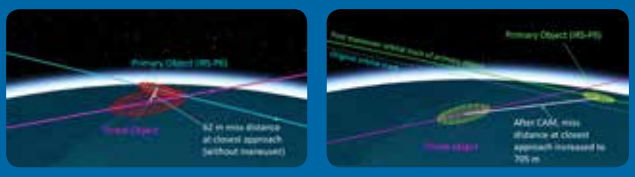
Post mission disposal of Low Earth Orbit spacecraft and LV stages

Limit ground casualty risk due to reentering objects

Post mission disposal of Geo-synchronous Earth Orbit spacecraft

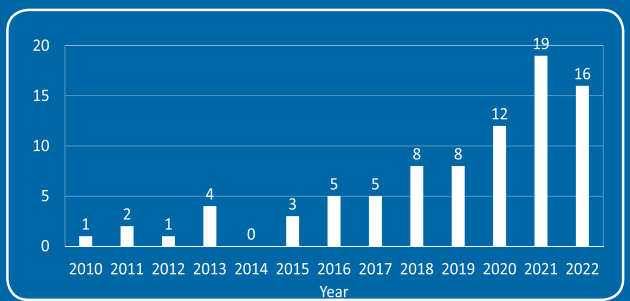
Presently ISRO follows UN/IADC guidelines to the maximum extent possible and practicable, strives to improve compliance

Conjunction Assessment and Collision Avoidance



Increase in miss distance at the time of closest approach

Number of Collision Avoidance Maneuvers



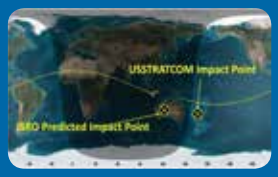
Collision Avoidance Analysis for Launch Vehicles (COLA)

Mission	Nominal Lift off Time (IST)	Delay recommended
PSLV-C18/Megatropiques	12 Oct 2011, 11:00	1 min
PSLV-C20/SARAL	25 Feb 2013, 18:00	5 min
PSLV-C21/SPOT-6	06 Sep 2012, 09.00	2 min
PSLV-C23/SPOT-7	30 Jun 2014, 09:49	3 min
PSLV-C32/IRNSS-1F	10 Mar 2016, 16:00	1 min
PSLV-C36/REsourcesat-2A	07 Dec 2016, 10:24	1 min
PSLV-C39/IRNSS-1H	31 Aug 2017, 18:59	1 min
PSLV-C40/Cartosat-2F	12 Jan 2018, 09:28	1 min
PSLV-C42/NOVASAR S1-4	16 Sep 2018, 22:07	1 min
PSLV-C43/HySIS	29 Nov 2018, 09:57	0.5 min
PSLV-C53/DS-EO	30 Jun 2022, 18:00	2 min

Liftoff time modification due to COLA (Till June 30, 2022)

Re-entry Analysis

Typical case: PSLV-C39/IRNSS Composite Body



Structural breakup upon re-entry into dense atmosphere, most of the materials ablate except a few components (gas bottles, tanks , nozzles)

In-house system to safeguard Indian operational space assets and limit proliferation of space debris

SPACE SITUATIONAL AWARENESS

Outer Space Environment

Energy and particle flux

Asteroids, Meteoroids, Comets

Man-made objects

Objectives

Observation

Assessment

Mitigation

NEtwork for space object TRacking & Analysis (NETRA)

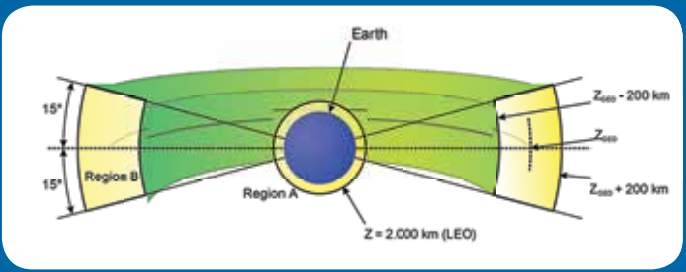
Prime Responsibilities

- Ingestion and analysis of observational data
- Space debris mitigation and compliance evaluation for long term sustainability
- Research and development related to SSA and Space Traffic Management (STM)
- Data exchanges, coordination and collaboration with ISRO centers and external entities

ISRO System for Safe & Sustainable Space Operations Management

Post Mission Disposal of GEO Satellites

GEO Protected Region



UN/IADC Recommendation on PMD of GEO Objects

"Limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit (GEO) region after the end of their mission"

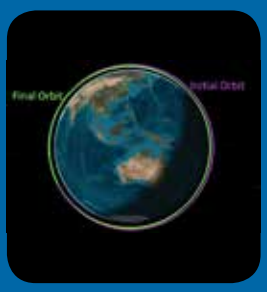
Since last two decades, ISRO's GEO satellites are re-orbited to orbits beyond GEO at end-of-life

Missions with Perfect Compliance (As on May, 2022)

Spacecraft	Date of Launch	Date of Decommissioning	Post Mission Orbit Achieved	
			Apogee Height (km) above GEO	Perigee Height (km) above GEO
INSAT-2DT	26-Feb-92	24-Aug-04	369	314
GSAT-3	20-Sep-04	01-Oct-10	289	285
KALPANA-1	12-Sep-02	01-Feb-18	570	530
INSAT-4A	22-Dec-05	23-Oct-19	296	286
INSAT-4CR	02-Sep-07	26-Nov-20	300	293
INSAT-4B	12-Mar-07	05-Nov-20	388	297

Post Mission Disposal of LEO Spacecraft and Upper Stages

Cartosat-2 Lifetime reduced from 30 years to less than 5 years by de-orbiting



First ISRO satellite de-orbited in full compliance with IADC guidelines

UN/IADC Recommendations

- Limit presence of LEO objects to avoid collision risk to operational assets
- Minimize post mission breakup risk by removing all onboard sources of energy
- Preferably by direct re-entry
- Limit post mission lifetime to < 25 years

Serves as a cemetery for re-entering satellites, space ships and space stations

NEMO POINT

Most isolated spot in the ocean, farthest from any land mass: Oceanic Pole of Inaccessibility

48.8° S, 123.4° W

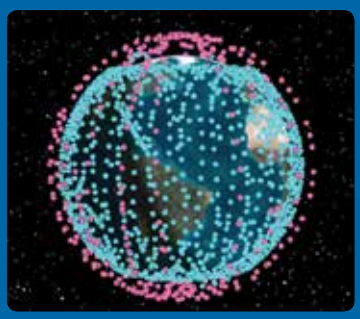
Impact of Large Constellations and Future Challenges

Typical large constellations consist of more than 500 to tens of thousands of satellites

Proposed Large Constellations

Constellation	Country	Total Satellites	Altitude (km)
Starlink (SpaceX)	U.S.A	42000	328,334-346, 360, 373, 499,540-570, 604, 641
OneWeb	U.K	6372	1200
Kuiper (Amazon)	U.S.A	3236	590, 610, 630
Telesat	Canada	1671	1015, 1325
StarNet (GuoWang/ GW)	China	12992	500 - 1150
Astra	U.S.A	13620	380 - 700
Kepler	Canada	114852	200 - 1000

Present deployment status (May 1st week, 2022)



Starlink = 2300 | OneWeb = 388

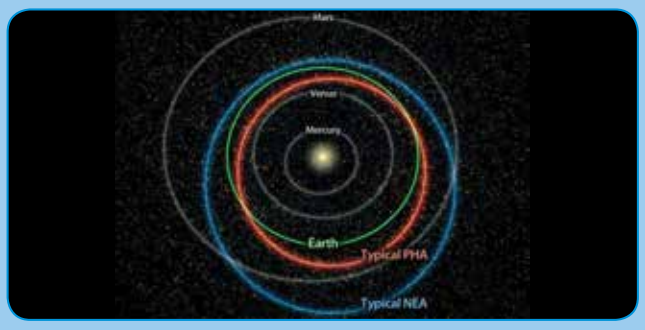
As on Date

- Several conjunctions for Indian spacecraft near 550 km orbit
- Satellites originally slated for 550 km relocated to 574 km.

Near Earth Objects and Planetary Defence

Near Earth Asteroid (NEA)

Asteroids in vicinity of the Earth (with perihelion distance less than 1.3 au, 1 au = 1.5 million km)



Diameter of Impacting Asteroid	Type of Event
5 m	Bolide
10 m	Superbolide
25 m	Major Airburst
50 m	Local Scale Devastation
140 m	Regional Scale Devastation
300 m	Continent Scale Devastation
600 m	Below Global Catastrophe Threshold
1 km	Possible Global Catastrophe
5 km	Above Global Catastrophe Threshold

Potentially Hazardous Asteroid (PHA)

- Bigger NEAs (size > 140 m) with orbits within 7.5 million km of Earth's orbit
- Impact can wreak havoc like extinction of several species
- Postulated to have caused dinosaur extinction

Asteroid Apophis

- 340 m sized Asteroid 99942 identified as the most hazardous asteroid
- Possibility of impact ruled out within next 100 years based on subsequent monitoring and analysis

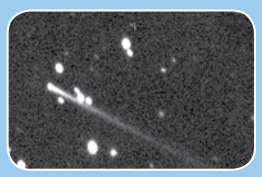
Notable impacts

Date	Impacting Object	Place of impact	Consequence
05/02/2013	Chelyabinsk meteor 20 m asteroid	Chelyabinsk Oblast, Russia	~1500 injured ~7200 buildings damaged
30/06/1908	30 m Asteroid	Tunguska, Russia	Destroyed 8 crores Trees
6.5 crore years ago	10-15 km asteroid	Mexico	Killed 70% of all species

Artist's impression of a PHA impact on a planet

Lonar lake impact crater in Maharashtra, India

Aim Detect any asteroid or comet potentially impacting Earth, either prevent or mitigate the risk



Detection

Tracking and Monitoring

Characterization

Risk assessment

Mitigation

Impulsive Deflection

Deflection achieved by high velocity projectiles

Kinetic Impactors

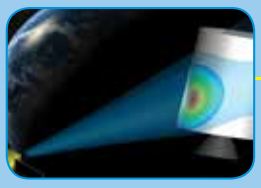
Deflection caused by impulsive transfer of momentum

Nuclear Impactors

Nuclear explosives to mitigate impact when warning time is short

Low Thrust Deflection

Deflection achieved by a low but continuous thrust



Ion Beam Shepherd

Push asteroid by continuous hitting of high speed beam of ions.

Gravity tractor

Contact-less deflection method: spacecraft used to create gravitational attraction and change the trajectory

Evolution of Space Object Population

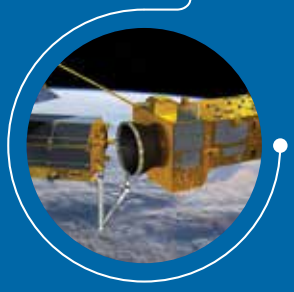
Active Debris Removal

Solar Sail
Solar radiation pressure to lower the orbit

Drag augmentation device
Deployed balloon increase the area-to-mass ratio and subsequently the atmospheric drag

Laser
Space based laser debris removal system has advantage of more access to the targets but comes at much higher cost.

Electrodynamic tether
Capture the debris using an extensible folder arm while an electro-dynamic tether fixed at the root of the arm.



Capture Vehicle
Approach and capture a non-operational object and tow it into a lower orbit or parking or graveyard orbit

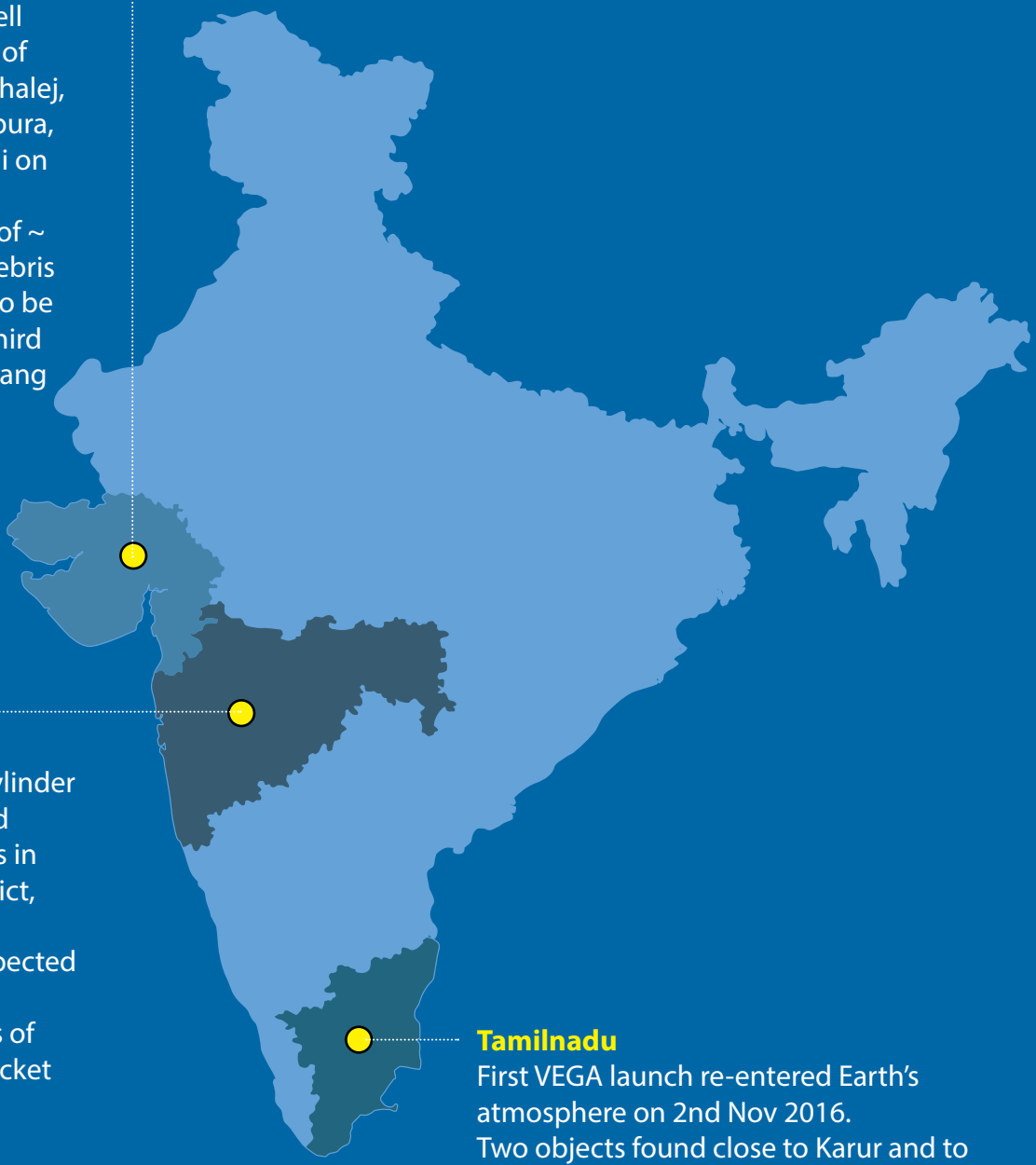
12th May, 2022: Space debris impacts in Gujarat

2nd April, 2022: Space debris impacts in Maharashtra

2nd Nov, 2016: Space debris impacts in Tamilnadu

Objects Impacted in Indian regions

Gujarat
Five metal balls fell in different areas of Gujarat such as Bhalej, Khambolaj, Rampura, Chaklasi and Savli on 12th May 2022.
Having a weight of ~ 5 kg, the space debris were suspected to be the re-mains of third stage from he Chang Zheng 3B rocket.



Maharashtra
Metal ring and cylinder like objects found at multiple places in Chandrapur district, Maharashtra.
The debris is suspected to be a fuel tank and upper stages of Chinese CZ-3B rocket bodies.

Tamilnadu
First VEGA launch re-entered Earth's atmosphere on 2nd Nov 2016.
Two objects found close to Karur and to Dindigul in Tamilnadu.
The objects were identified to be propellant tank of the AVUM stage.

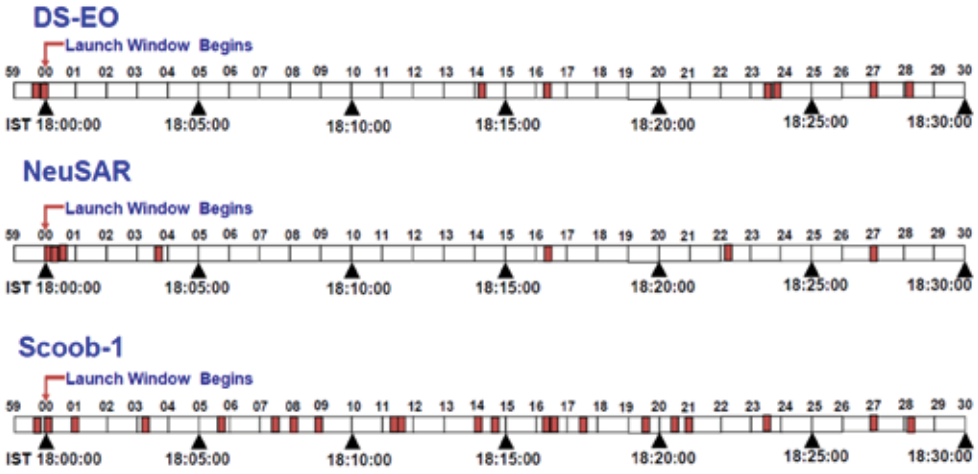
Lift-off delayed by 2 minutes for PSLV-C53

COLlision Avoidance Analysis (COLA) for launch vehicle PSLV-C53 revealed the risk of collision between onboard payloads with space objects at the intended time of lift-off on 29th June, 2022 at IST 18:00 hrs.

For nominal lift-off of 18:00 IST, the most concerning conjunctions were with Starlink and Fengyun 1C debris, in particular with Starlink 2701 as the closest approach was found to be within 100 m during ascent phase.

Even with 18:01 IST lift-off, a close conjunction between he PSLV-C5 passenger satellite Scoob-I with Starlink-1705 and Iceye-X6 was detected in its orbital phase.

Safe lift-off time proposed was IST 18:02 hrs for a collision free ascent phase as well as orbital phase.



SATELLITE BOX SCORE

Country/ Organization	Active and defunct Spacecraft*	Spent Rocket Bodies & Other Cataloged Debris	Total
CHINA	529	3833	4362
CIS (RUSSIA)	1556	6707	8263
ESA	96	60	156
FRANCE	80	520	600
INDIA	107	115	222
JAPAN	207	111	318
UK	480	1	481
USA	4433	5209	9642
OTHER	1068	97	1165
TO TAL	8556	16653	25209

Source: ODQN, June-2022

NETRA Building
ISTRAC Campus, Bengaluru

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For Further Information

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