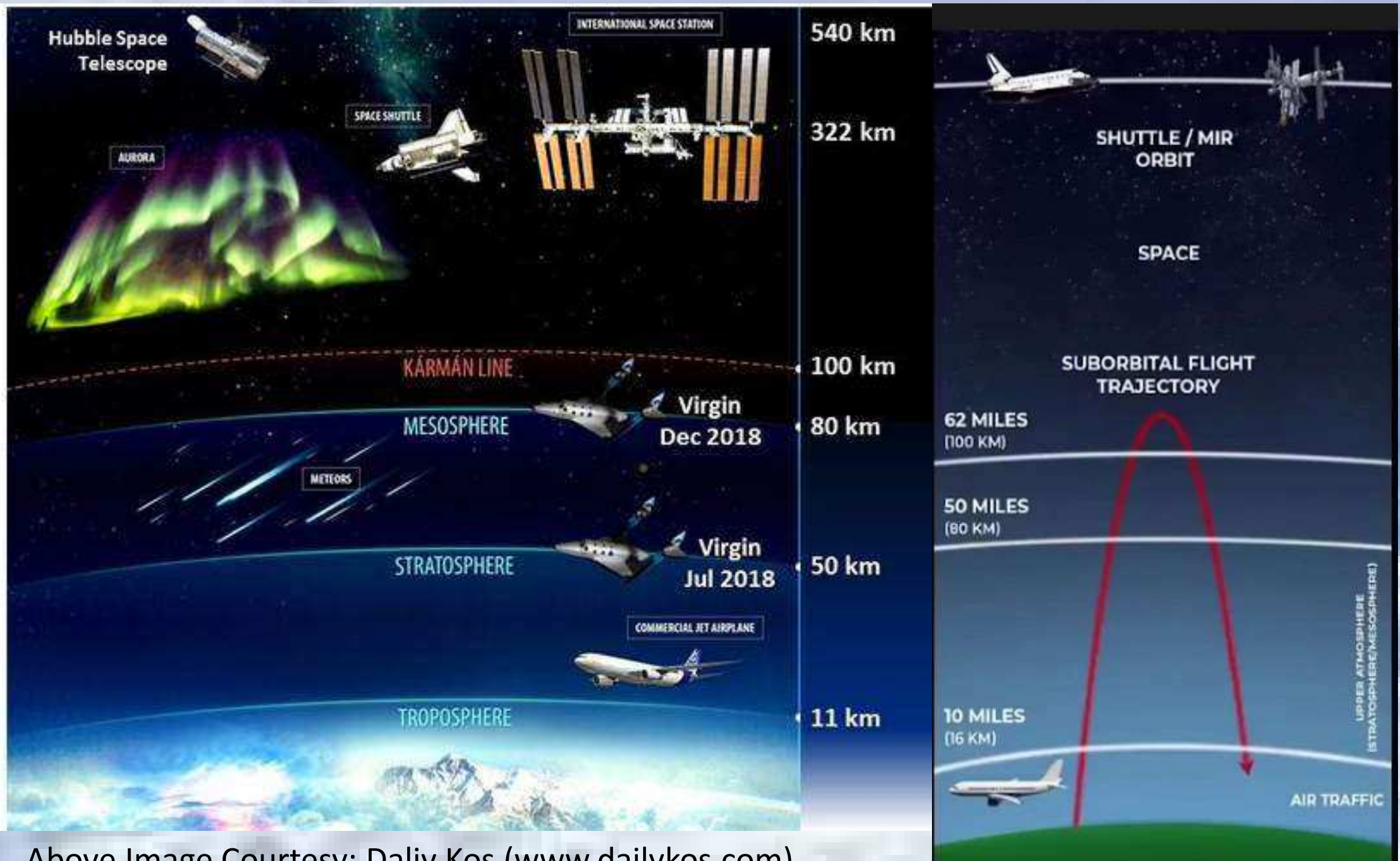


Protection of Outer Space Environmental Issues

V. Gopalakrishnan
Former Policy Analyst, ISRO

**III Semester Personal Contact Programme,
M.A. (Space & Telecommunications Laws] course
NALSAR PRO
NALSAR University of Law
August 24, 2023**

Where Outer Space Begins



Above Image Courtesy: Daliy Kos (www.dailykos.com)

Composition of Outer Space



Outer space is not completely empty—it is a hard vacuum containing a low density of particles, predominantly a plasma of hydrogen and helium, as well as electromagnetic radiation, magnetic fields, neutrinos, dust, and cosmic rays. (Van Allen Radiation belts!!)

Space Weather : Activity on the Sun's surface creates a type of weather called space weather. The Sun is really far away—about 93 million miles (150 million kilometers)—from Earth. However, space weather can affect Earth and the rest of the solar system.

Objects in Outer Space

- **Natural**
 - **Near Earth Objects**
 - Asteroids, Comets,
 - **Meteors, and meteorites**
- **Human-Made**
 - **Space Objects**
 - **Functional**
 - **Spacecraft, Space Stations**
 - **Non-functional**
 - **Space Debris**

Near Earth Objects (NEO)

- **Near-Earth Objects (NEOs) are comets and asteroids that have been nudged by the gravitational attraction of nearby planets into orbits that allow them to enter the Earth's neighbourhood - within 30 million miles of Earth's orbit.**
- **Composed mostly of water ice with embedded dust particles, comets originally formed in the cold outer planetary system while most of the rocky asteroids formed in the warmer inner solar system between the orbits of Mars and Jupiter.**
- **These raw materials could be used in developing the space structures and in generating the rocket fuel that will be required to explore and colonize our solar system in the coming decades.**

Source: <https://solarsystem.nasa.gov/asteroids-comets-and-meteors/asteroids/in-depth/>

Asteroids

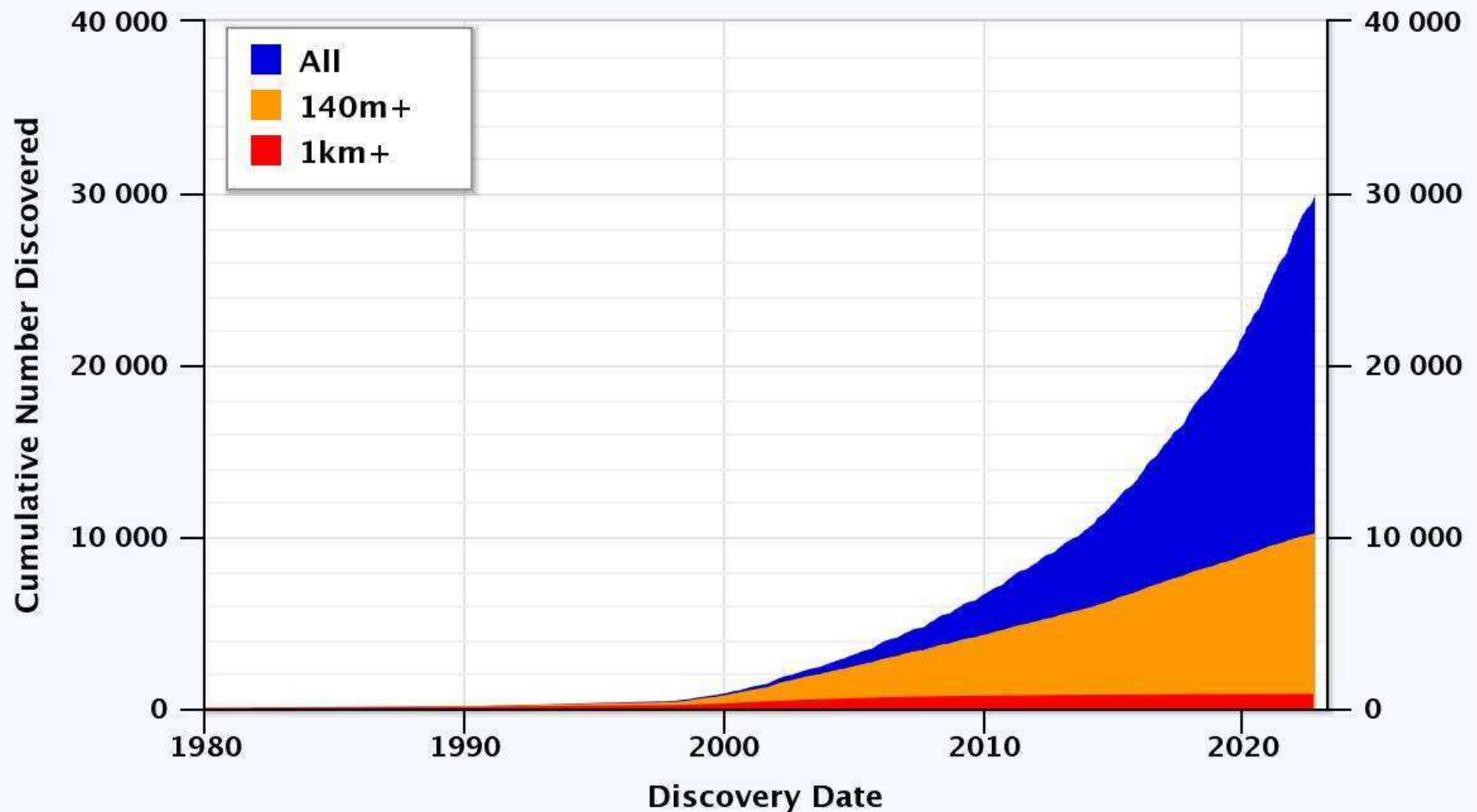
- Asteroids, sometimes called minor planets, are rocky remnants left over from the early formation of our solar system about 4.6 billion years ago.
- The three broad composition classes of asteroids are C-, S-, and M-types.
 - The C-type (chondrite) asteroids are most common. They probably consist of clay and silicate rocks, and are dark in appearance
 - The S-types ("stony") are made up of silicate materials and nickel-iron
 - The M-types are metallic (nickel-iron).
- Space Shuttle Columbia was killed in 2003 by an asteroid only.

Source: <https://solarsystem.nasa.gov/asteroids-comets-and-meteors/asteroids/in-depth/>

Total Number of Asteroids

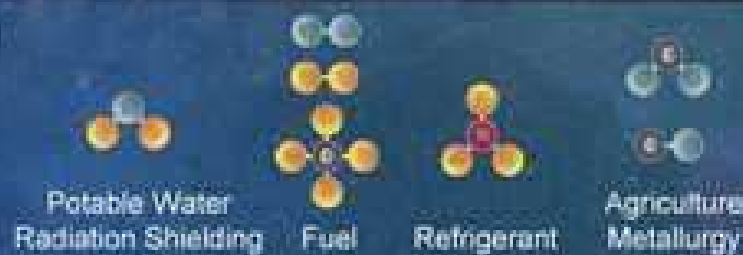
Near-Earth Asteroids Discovered

Most recent discovery: *2022-Sep-29*



High Value Asteroid Materials

ASTEROID ELEMENTAL ABUNDANCE RELATIVE TO EARTH'S CRUST



VOLATILES AND H₂O
to fuel the growth of
humanity into new frontiers



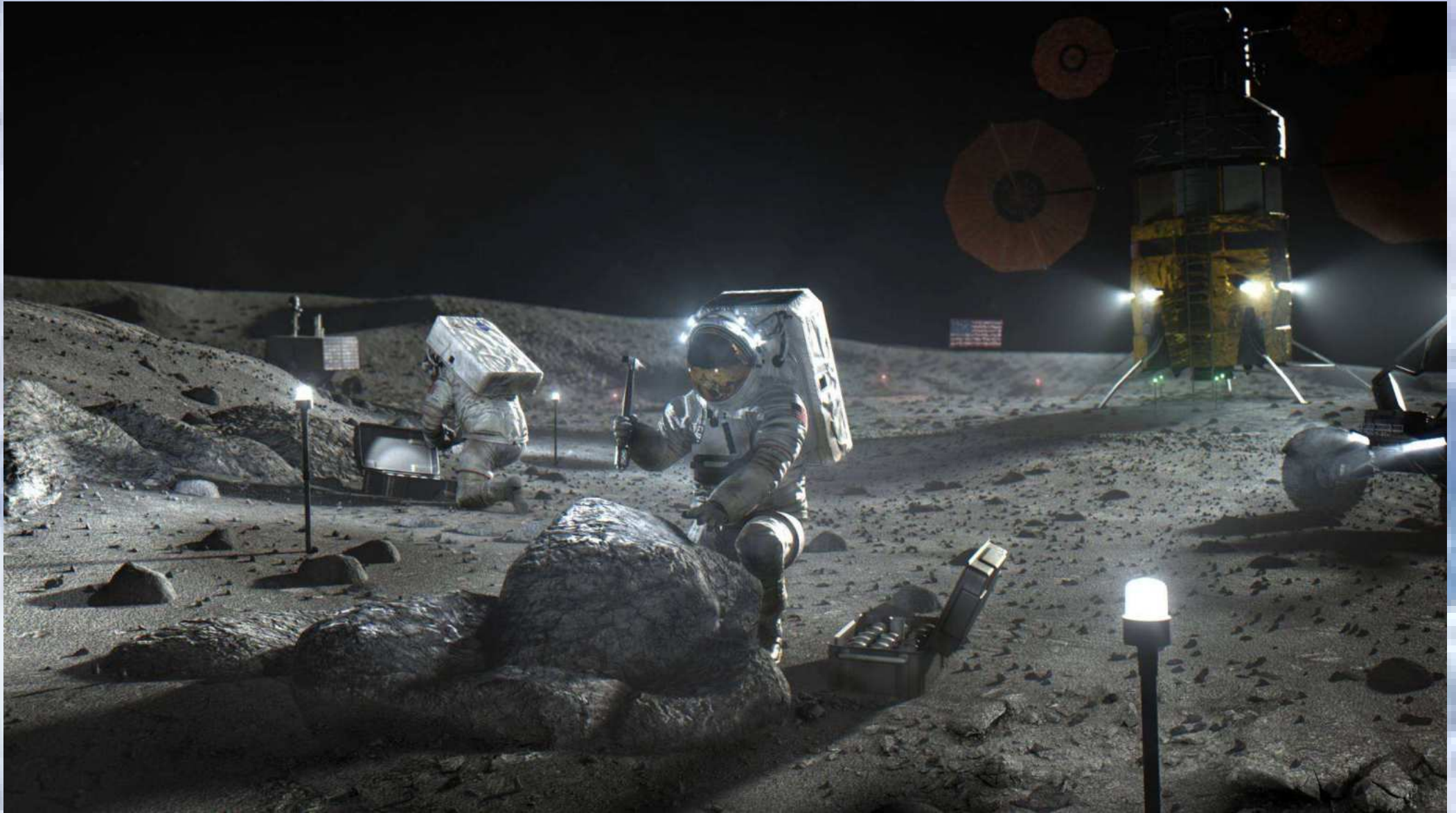
INDUSTRIAL METALS
to construct and
sustainably service space
platforms



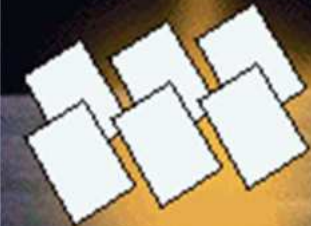
PLATINUM GROUP METALS
to support demand growth on
Earth



Artemis Program



A computer graphic image shows astronauts landing on the Moon under the U.S. Artemis program. | NASA / VIA KYODO©



US Lunar Gateway Program

- Lunar Gateway program, an advanced planned mini-space station to orbit the moon and intended to serve as a home base for missions to the moon's surface, including the Artemis 3 mission to land the first woman and next man on the moon by 2024, using innovative technologies.
- From facilitating short-term missions, the station will evolve and pioneer what will become the first sustainable human presence on the moon.
- The learning through Artemis programme, to take the next giant leap of sending astronauts to Mars.

Topic of Asteroid Warning In UNCOPUOS

- **The U. N. General Assembly and the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) have sought to address the issue of cosmic hazards and planetary defence against asteroid strikes.**
- **As a result of United Nations-endorsed recommendations, two entities, namely, the International Asteroid Warning Network (IAWN) and the Space Mission Planning Advisory Group (SMPAG) were established in 2014, to represent important mechanisms at the global level for strengthening coordination in the area of planetary defence.**
- **The IAWN is tasked with developing a strategy using well-defined communication plans and protocols to assist Governments in the analysis of asteroid impact consequences and in the planning of mitigation responses.**
- **Space Mission Planning Advisory Group (SMPAG), is to exchange information and develop options in the event a concerted planetary defence might be necessary against a threatening asteroid or comet strike.**

What is Planetary Defense

- Planetary defense is the term used to encompass all the capabilities needed to detect the possibility and warn of potential asteroid or comet impacts with Earth, and then either prevent them or mitigate their possible effects.
- Planetary defense involves:
 - Finding and tracking near-Earth objects that pose of hazard of impacting Earth;
 - Characterizing those objects to determine their orbit trajectory, size, shape, mass, composition, rotational dynamics and other parameters, so that experts can determine the severity of the potential impact event, warn of its timing and potential effects, and determine the means to mitigate the impact; and
 - Planning and implementation of measures to deflect or disrupt an object on an impact course with Earth, or to mitigate the effects of an impact that cannot be prevented. Mitigation measures that can be taken on Earth to protect lives and property include evacuation of the impact area and movement of critical infrastructure.
- A Brochure of UN Office for Outer Space Affairs (UNOOSA)'s on Near-Earth Objects and Planetary Defence is available at :
 - https://www.unoosa.org/documents/pdf/smpag/st_space_073E.pdf

Space Environmental Issues

Caused by Human Endeavour

- **Alterations of the outer space environment, including deep space, planetary orbits, and planetary surfaces and sub surfaces.**
- **These environmental issues include biological, electromagnetic spectrum, radiological, chemical, and material contamination that may be produced through humankind's exploration and use of outer space.**

Space Environmental Issues

Space Environmental Issues

- **Natural**
 - NEO attacks on Earth
 - Comets
 - Meteors
- **Human- made**
 - Asteroid Redirect Missions
 - Asteroid Sample Recovery missions
 - Space Debris
 - Light Pollution disturbing Astronomical Observations

OSIRIS-Rex Sample recovery from Bennu Asteroid

(Origins, Spectral Interpretation, Resource Identification, Security-
Regolith Explorer)



<https://youtu.be/LJBv4reH9IU>

Double Asteroid Redirection Test (DART)

- The DART mission is NASA's demonstration of kinetic impactor technology, impacting an asteroid to adjust its speed and path.
- DART was aimed at testing a method of planetary defense against near-Earth objects (NEOs).
- DART is the first-ever space mission to demonstrate asteroid deflection by kinetic impactor.
- DART's target was the binary asteroid system Didymos, which means "twin" in Greek (and explains the word "double" in the mission's name).
- Date of launch:
 - The spacecraft launched on a SpaceX Falcon 9 rocket on November 23, 2021
- Date of DART Impact:
 - September 26, 2022, 7:14 p.m. EDT

NASA's Asteroid Redirect Mission

- NASA is developing a first-ever robotic mission to visit a large near-Earth asteroid, collect a multi-ton boulder from its surface, and redirect it into a stable orbit around the moon.
- This Asteroid Redirect Mission (ARM) is part of NASA's plan to advance the new technologies and spaceflight experience needed for a human mission to the Martian system in the 2030s.

<https://www.nasa.gov/content/what-is-nasa-s-asteroid-redirect-mission>



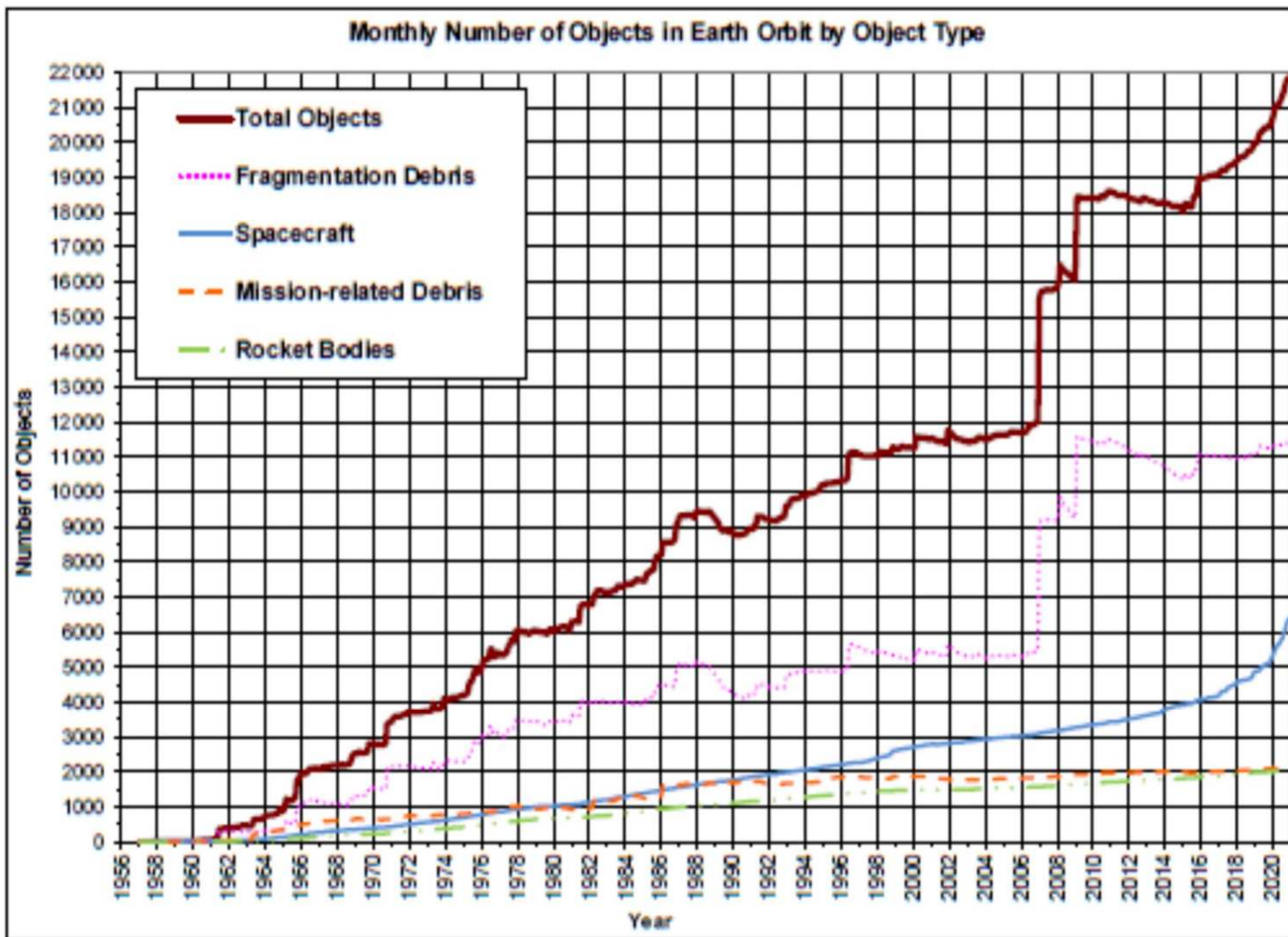
Space Debris Issues to Outer Space Environment

Space Debris in motion



Sources of Space Debris

- **Mission related - Satellites, Rocket bodies**
- **Accidental – Satellite break-ups, On-Orbit Collisions, Drop-outs from astronaut's extra-vehicular activities**
- **Intentional or Avoidable – ASAT tests, Intentional Destructions, Abandonment of space objects in LEO, launching of Space Objects non-compliant to UN debris mitigation measures, micro and small satellites**





UNITED NATIONS
Office for Outer Space Affairs



#SpaceCare

SATELLITES VS DEBRIS

2700 working satellites share their orbits with **8800 tonnes** of **space debris**



≈ 1950
discarded rocket stages



≈ 2850
defunct satellites



Debris objects travel many kilometres per second. In case of impact, they may destroy working satellites



≈ 128 million
debris fragments
1 mm–1 cm in size



≈ 900 000
fragments
1–10 cm in size



≈ 21 000
unidentified debris
objects and fragments



≈ 34 000
fragments larger
than 10 cm



About 26 000 debris objects are **monitored from Earth**

Smaller objects that cannot be monitored **estimated by statistical models**



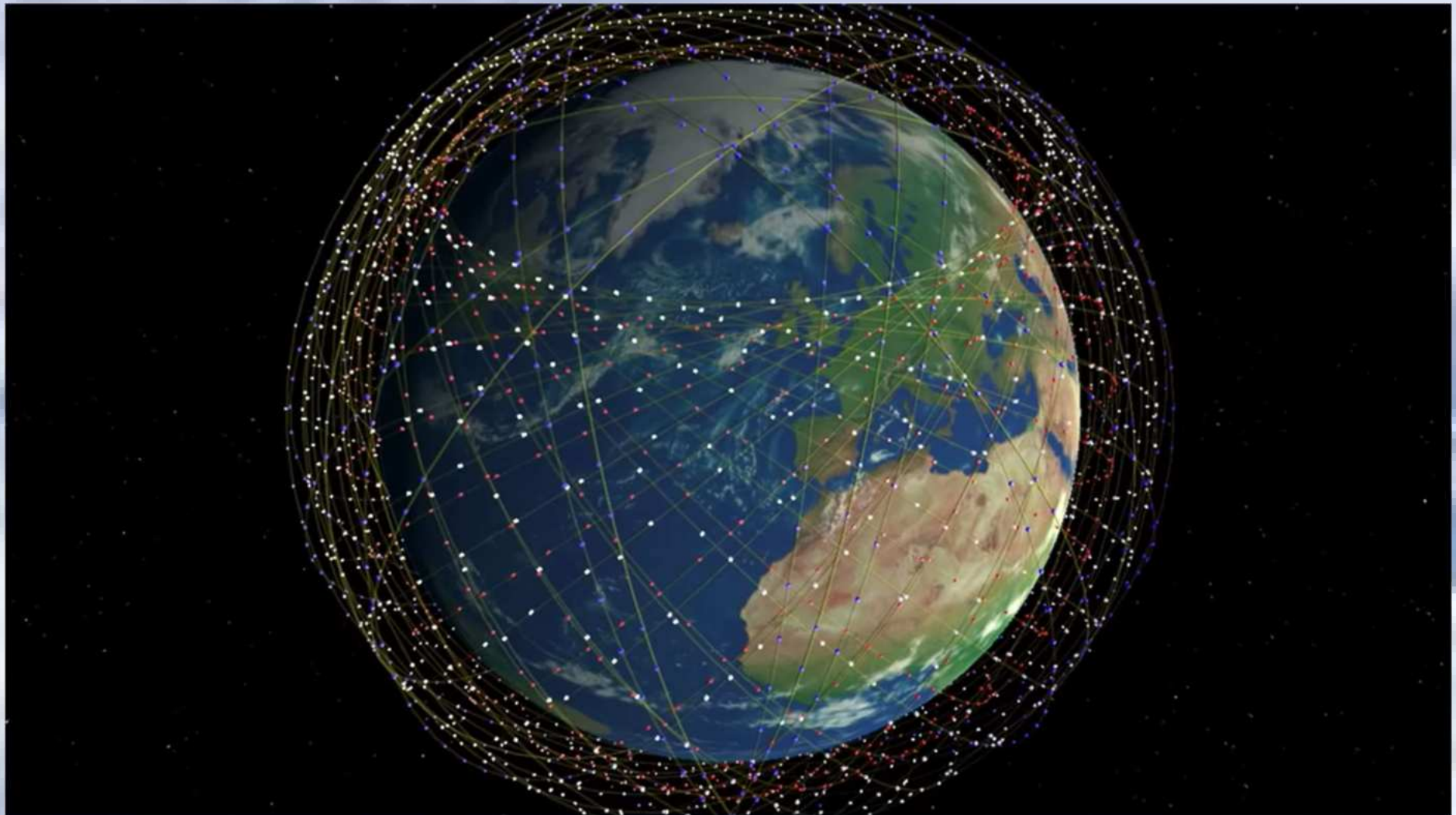
#SpaceSustainability

Up-to-date as of December 2020

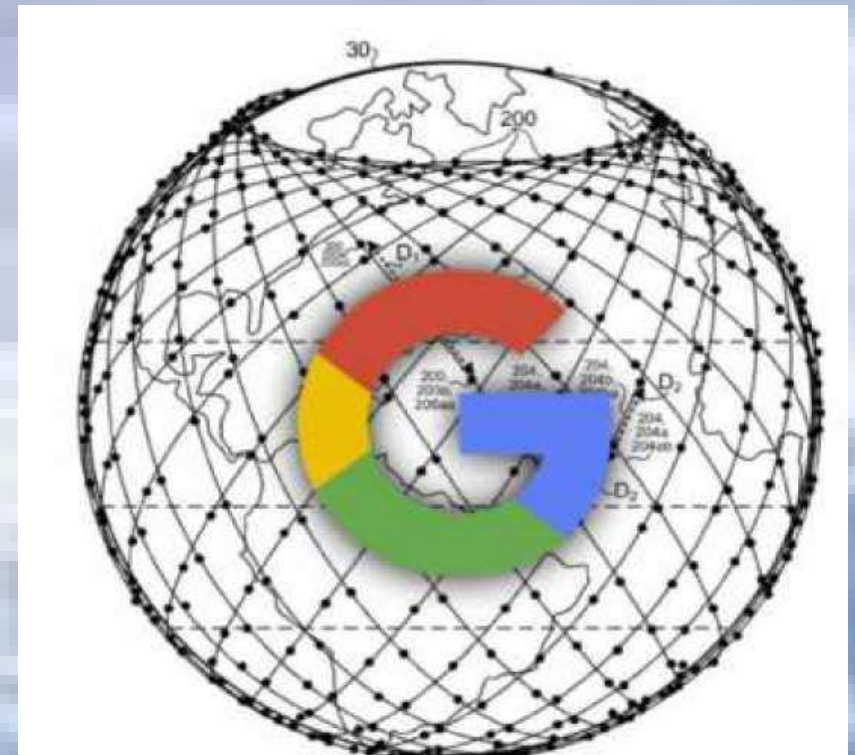
Space Debris Mitigation Guidelines

- United Nations Space Debris Mitigation Measures Guidelines – 7 Guidelines (UNGA Endorsed in 2007)
 - Limit Debris released during normal operations
 - Minimize the potential for break-ups
 - Limit probability of accidental collisions in orbit
 - Avoidance of intentional destructions
 - Minimize potential for post-mission break-ups
 - Limit long term presence of space objects after EOL
 - Limit long-term interference of space objects with GEO region at EOL
- Effectiveness of Mitigation Guidelines
 - Soft Law - For voluntary implementation -Legally Non -Binding
 - Offers neither incentives for compliance nor penalty for non-compliance
 - Not effective to control the existing debris population – *Kessler Effect*

Proposed Starlink Satellite Constellation



One Web and Google Constellations



OneWeb intends to cover the Earth with a nominal constellation of 648 LEO mini satellites built by Airbus Defence and Space (image credit: Airbus DS)

Of the constellation, 648 of them will be placed in 18 orbital planes with an altitude of about 1200 km. ..(Source : eoPortal Directory- <https://directory.eoportal.org/web/eoportal/satellite-missions/content/-/article/oneweb>)

Google plans to launch a constellation of 1000 satellites orbiting around Earth, covering 75 % of its surface ... to spread the reach of internet across the world (source: USPTO)

Starlink Satellites in orbit



A train of SpaceX Starlink satellites are visible in the night sky in this still from [a video captured by satellite tracker Marco Langbroek in Leiden](#), the Netherlands on May 24, 2019, just one day after SpaceX launched 60 of the Starlink internet communications satellites into orbit. (Source: Space.com; Image: © [Marco Langbroek via SatTrackBlog](#))

The background of the slide is a high-resolution aerial photograph of a vast, flat, arid landscape. The terrain is a mix of light brown and tan colors, with subtle variations in texture suggesting different soil types or sparse vegetation. The horizon is visible in the distance under a clear, pale blue sky. The overall scene conveys a sense of isolation and environmental fragility.

Environmental Protection Clauses in International Treaties

ENMOD Convention

Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD)

- **Entry into force: 5 October 1978, in accordance with its article IX (3).**
- **Pursuant to its article VII, the Convention is of unlimited duration.**
- **Status: The Convention is signed by 48 States, of which 16 have not ratified it. Today it has 78 States parties**

ENMOD Convention (*..contd.,*)

- States parties undertake not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to another State party (article I).
- The Convention defines environmental modification techniques as changing -- through the deliberate manipulation of natural processes -- the dynamics, composition or structure of the earth, including its biota, lithosphere, hydro-sphere, and atmosphere, or of outer space.

Partial Test Ban Treaty (PTBT)

- Treaty Banning Nuclear Weapon Tests In The Atmosphere, In Outer Space And Under Water (shortly known as -Partial Test Ban Treaty – PTBT)
- Signed: Moscow, August 5, 1963
- Entered into force: October 10, 1963.
- Article 1: Each of the Parties to this Treaty undertakes to prohibit, to prevent, and not to carry out any nuclear weapon test explosion, or any other nuclear explosion, at any place under its jurisdiction or control:
 - (a) in the atmosphere; beyond its limits, **including outer space**; or under water, including territorial waters or high seas

Outer Space Treaty, 1967

Article-III:

- States Parties to the Treaty shall carry on activities in the exploration and use of outer space, including the moon and other celestial bodies, in accordance with international law, including the Charter of the United Nations, in the interest of maintaining international peace and security and promoting international co-operation and understanding

Outer Space Treaty, 1967

- Article IX:
- In the exploration and use of outer space, including the moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of co-operation and mutual assistance and shall conduct all their activities in outer space, including the moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty. States Parties to the Treaty shall pursue studies of outer space, including the moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extra-terrestrial matter and, where necessary, shall adopt appropriate measures for this purpose.

... Carried forwrd

Outer Space Treaty, 1967

- **Article IX: (..contd)**
- **If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space, including the moon and other celestial bodies, it shall undertake appropriate international consultations before proceeding with any such activity or experiment. A State Party to the Treaty which has reason to believe that an activity or experiment planned by another State Party in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities in the peaceful exploration and use of outer space, including the moon and other celestial bodies, may request consultation concerning the activity or experiment.**

Moon Agreement, 1979

- Article 2: Similar to Article III of OST
- Article- 4: ... to preserve for future generations..
- Article 7:1. In exploring and using the moon, States Parties shall take measures to prevent the disruption of the existing balance of its environment, whether by introducing adverse changes in that environment, by its harmful contamination through the introduction of extra-environmental matter or otherwise. States Parties shall also take measures to avoid harmfully affecting the environment of the earth through the introduction of extraterrestrial matter or otherwise.

Moon Agreement, 1979

Article 7 Contd:

- **7.2. States Parties shall inform the Secretary-General of the United Nations of the measures being adopted by them in accordance with paragraph 1 of this article and shall also, to the maximum extent feasible, notify him in advance of all placements by them of radioactive materials on the moon and of the purposes of such placements.**
- **7.3. States Parties shall report to other States Parties and to the Secretary-General concerning areas of the moon having special scientific interest in order that, without prejudice to the rights of other States Parties, consideration may be given to the designation of such areas as international scientific preserves for which special protective arrangements are to be agreed upon in consultation with the competent bodies of the United Nations.**



COSPAR planetary protection policy

The policy must be based upon the most current, peer-reviewed scientific knowledge, and is there to enable the exploration of the solar system, not prohibit it.

The COSPAR Panel on Planetary Protection is to develop, maintain, and promote the COSPAR policy and associated requirements that must be achieved to protect against the harmful effects of forward and backward contamination and to guide compliance with the Outer Space Treaty ratified today by 110 nations, i.e.

The conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants must not be jeopardized.

In addition, the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from an interplanetary mission.



Current Policy: COSPAR Planetary Protection Policy - Prepared by the COSPAR Panel on Planetary Protection and approved by the COSPAR Bureau on 17 June 2020.

Available at: <https://doi.org/10.1016/j.srt.2020.07.009>

COSPAR Panel on the Planetary Protection

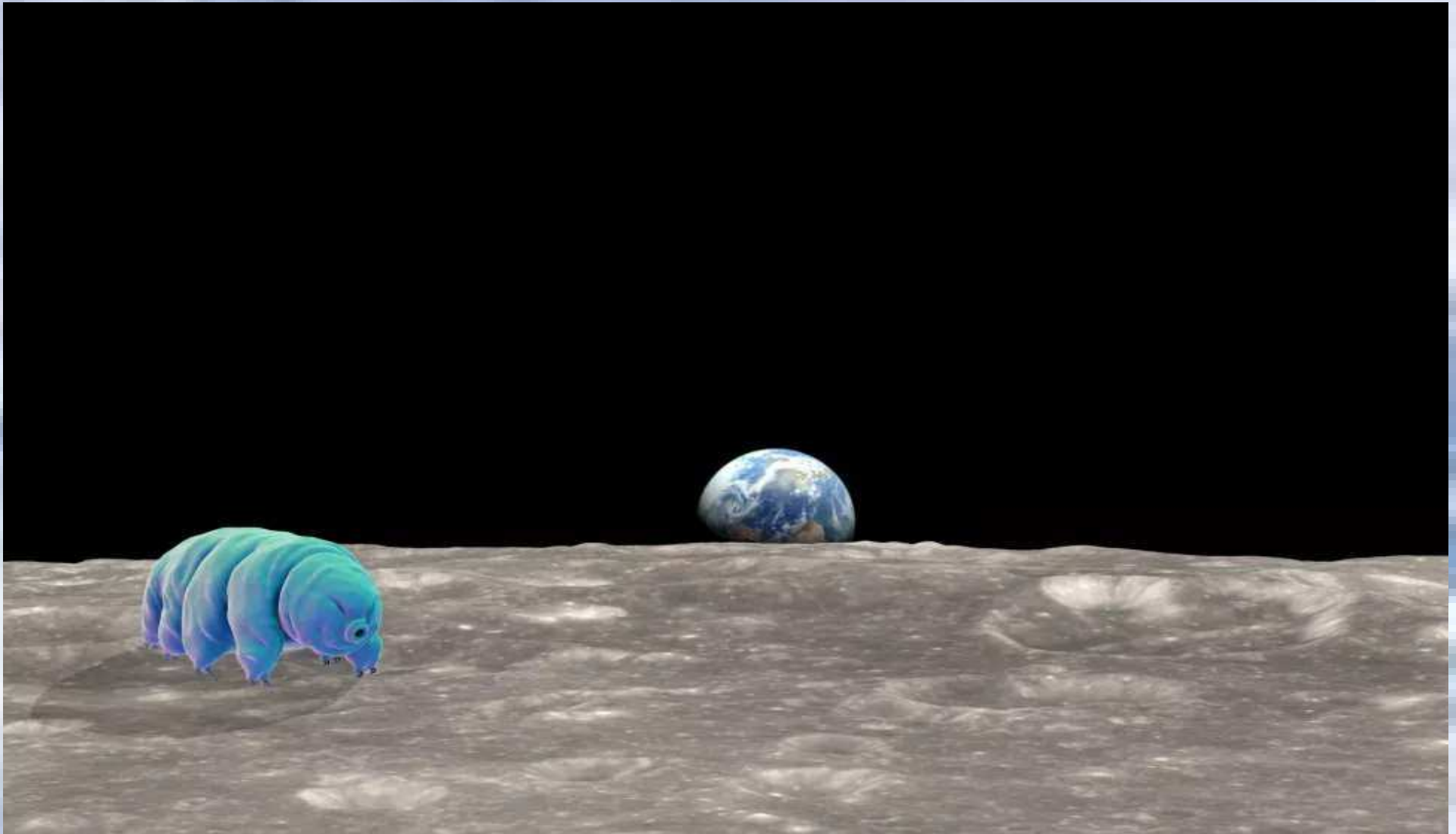
Scope and Objectives of the Panel:

- The Panel on Planetary Protection (PPP) is concerned with biological interchange in the conduct of solar system exploration and use, including:
 - (1) possible effects of contamination of planets other than the Earth, and of planetary satellites within the solar system by terrestrial organisms; and
 - (2) contamination of the Earth by materials returned from outer space carrying potential extra-terrestrial organisms.
- The primary objective of the Panel within COSPAR is to develop, maintain, and promulgate clearly delineated policies that provide specific requirements as to the standards that must be achieved to protect against the harmful effects of such contamination.

Categories with Target Bodies

- Category I: Flyby, Orbiter, Lander: **Undifferentiated, metamorphosed asteroids; others TBD**
- Category II: Flyby, Orbiter, Lander: **Venus; Moon (with organic inventory); Comets; Carbonaceous Chondrite Asteroids; Jupiter; Saturn; Uranus; Neptune; Ganymede†; Titan†; Triton†; Pluto/Charon†; Ceres; Kuiper-Belt Objects > 1/2 the size of Pluto†; Kuiper-Belt Objects < 1/2 the size of Pluto; others TBD**
- Category III: Flyby, Orbiters: **Mars; Europa; Enceladus; others TBD**
- Category IV: Lander Missions: **Mars; Europa; Enceladus; others TBD**
- Category V: Any Earth-return mission.
 - “Restricted Earth return”: **Mars; Europa; Enceladus; others TBD**
 - “Unrestricted Earth return”: **Venus, Moon; others TBD**

Israeli spacecraft Beresheet Lander crashed into the Moon, 2019



Tardigrades - often called water bears - are creatures under a millimetre long that can survive 150C temperature and almost absolute zero.

An aerial photograph of a vast, flat, arid landscape. The terrain is covered with sparse, low-lying vegetation in shades of green and brown. In the distance, a range of mountains is visible under a clear blue sky. The overall scene is desolate and expansive.

Other International Initiatives

Other International Initiatives

- **Long Term Sustainability (LTS) of Outer Space Activities**
- **International Code of Conduct for Outer Space Activities (ICOC)**
- **Treaty on Prevention of Placement of Weapons in Outer Space (PPWT)**

Long Term Sustainability (LTS) of Outer Space Activities

- In June 2019, the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) adopted a set of 21 voluntary consensus guidelines on LTS of Outer Space activities
- The guidelines are grouped into four categories:
 - Policy and regulatory framework for space activities
 - Safety of space operations
 - International cooperation, capacity-building, and awareness
 - Scientific and technical research and development
- In 2021 further and new guidelines have been taken on a multi year work plan mode. India is chairing this Committee.

LTS Guidelines (*.... Contd.,*)

D. Scientific and technical research and development

D.1.4: States and international intergovernmental organizations should consider appropriate safety measures to protect the Earth and the space environment from harmful contamination, taking advantage of existing measures, practices and guidelines that may apply to those activities, and developing new measures as appropriate.

Conclusion

- Addressing the environmental issues involves not only standards, policies, regulation, and treaty law, but also involves ethics and moral issues
- Current issues like Space security, and Emerging space activities such as, Space resources mining, solar power satellites, space tourism, space colonization, etc., would also pose serious space environmental issues in the coming years.
- Regardless of activities, Protection of Outer Space including Planets, Space Objects and Space Weather are to be complied by all states.

Conclusion (*.... Contd.,*)

- If these are neglected, protection to Earth in terms of space based services from space objects would become unavailable to the humanity.
- Fair and Responsible use of outer space by every stakeholder is the key
- An international organisation, besides monitoring, for regulating and fixing the responsibility with penal awards is warranted.
- International Cooperation of all States including space faring and space active states is required to protect Outer Space Environment.

‘Protect the Space Environment to Protect Ourselves’

The background of the slide is a high-resolution aerial photograph of a vast, flat, arid landscape. The terrain is a mix of light brown and tan colors, with subtle variations in texture and tone suggesting different soil compositions or perhaps a dry lake bed. The horizon is visible in the upper third of the image, where the land meets a clear, pale blue sky. The overall impression is one of extreme isolation and natural beauty.

- ***Thank you for your kind attention!***

(gopal.isro@gmail.com)