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Awe infographics



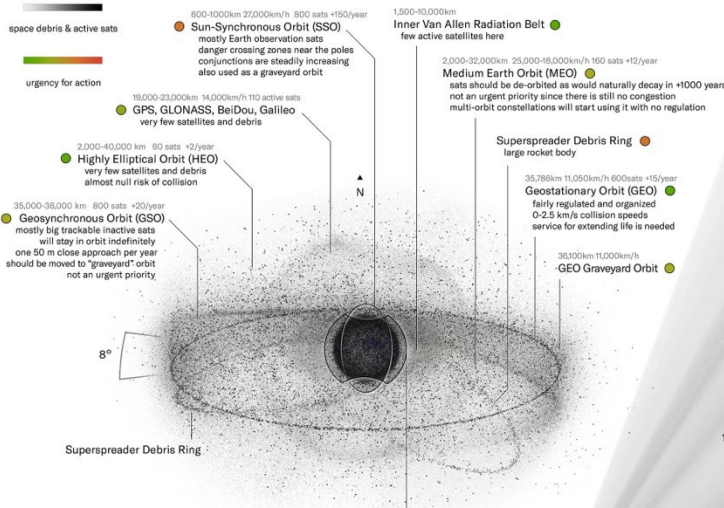
Charting Space Sustainability: A Navigational Perspective

In the grand cosmic expanse, humanity has embarked on a journey that transcends our earthly confines. Space exploration and utilization have brought us a quite interconnected everyday life at many levels, but the feeling that Earth's orbit and the universe are a part of us is not quite there yet. Space isn't just a part of us; it's also home to us, and you don't throw dangerous trash inside your home.

Similar to early historical maps, small objects in low Earth orbit (LEO) and medium-sized objects in geosynchronous Earth orbit (GEO) remain as blank uncharted areas. Naturally, there is ample space and comparatively few objects in GEO. Providing life extension services there could serve as a sustainable means to keep it this way. Most urgently, LEO, a precious and limited resource, is becoming increasingly congested and needs our full attention and urgent

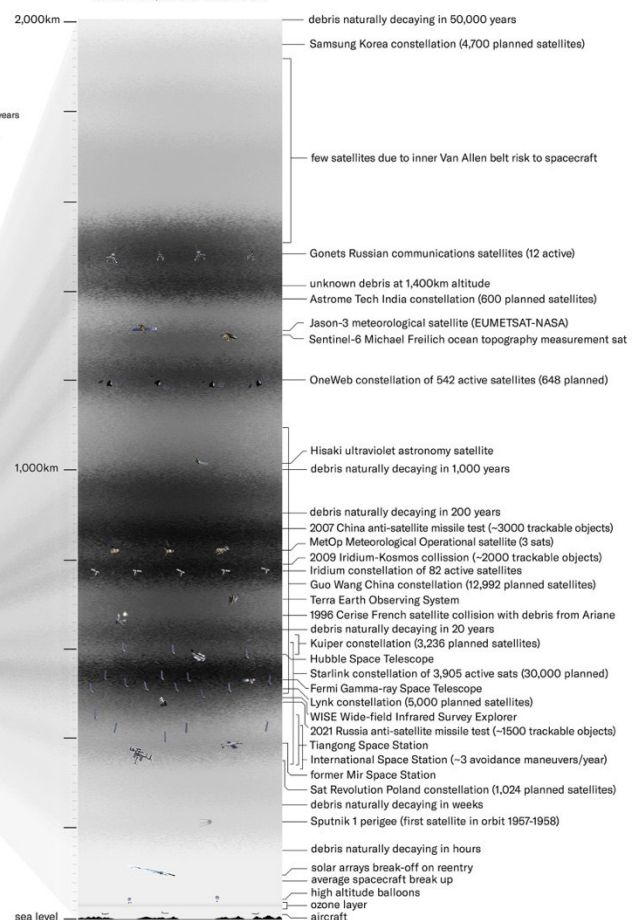
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Space Debris and Sustainability urgency in Earth's orbits



space debris density in LEO by altitude

data: 2021 NASA Space Debris Presentation to STSC



Space Sustainability challenges on Earth



Space Sustainability challenges in other celestial bodies



Moon

- Because of limited useful Lunar orbits compared to Earth orbits, exploration could soon lead to satellite congestion and space debris around the Moon
- Anticipated to increase in the upcoming decade, there are already over 200 tons of defunct spacecraft and mission-associated items on the Moon
- Moon's shadowed regions need protection to preserve potential organic molecules
- Both biological and non-biological contamination, including waste from humans and machines on limited ice deposits, have been considered
- New regulation for responsible practices on Lunar Exploration is needed



Mars

- Both the orbit and surface of Mars should remain as free as possible from debris and litter to preserve its pristine environment for scientific exploration and potential future habitation
- Spacecraft and habitats should be designed with minimal emissions of gases that could contribute to the pollution of Mars' thin atmosphere
- Before we rule out the life-containing status of Mars, spacecraft, rovers, and equipment should be sterilized to avoid introducing Earth's microorganisms to Mars and vice versa



Asteroids

- Asteroid mining, if done sustainably, offers potential benefits, such as access to rare minerals and reducing the environmental impact of traditional mining on Earth
- Altering the trajectory of an asteroid, even for scientific research, could potentially lead to unintended consequences including a new path that intersects with Earth or other celestial bodies



Solar System

- Large populations of living organisms may already be thriving on ocean worlds like Europa, Enceladus, Ganymede, Callisto or Titan
- Forward contamination should be prevented by sterilizing space probes sent to sensitive areas of the Solar System
- The Committee on Space Research (COSPAR) presents recommendations for avoiding interplanetary contamination depending on the type of space mission and the celestial body explored
- For both landers and orbiters, spacecraft trajectories should be designed so that if communications are lost, they will miss the target to prevent unintended impacts

Other Systems

Figure 1: Overview of key space sustainability issues under consideration in 2023. Solar System objects images credit: NASA/ESA/UAESA

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action. Megaconstellations are suddenly altering the night sky, impacting scientific research, cultural heritage, and more importantly: climate and ecology. De-orbiting satellites bring pollutants like aluminum into the atmosphere, affecting Earth's circulation in ways we cannot quite predict. Rocket launches introduce greenhouse gases and pollutants into the upper atmosphere, potentially influencing the ozone layer and other climate patterns.

Mapping Our Cosmic Priorities

Some argue that our current environmental challenges on Earth should take precedence over space sustainability efforts. They suggest that focusing on issues like climate change and biodiversity loss should be our primary concern. This is true, but we should not underestimate the interconnectedness of these spaces. Space sustainability isn't just about protecting outer space; it is about recognizing how our actions in space can exacerbate problems on Earth. Addressing these problems can lead to innovative solutions that benefit both our planet and our cosmic endeavors.

The blueprint for space sustainability is not a static diagram. As we incorporate more data and integrate machine learning into our situational awareness, and as space exploration continues to advance, new issues will undoubtedly emerge. Ideally, we should be prepared to address them. Setting a goal to make this map reasonably navigable within the next decade would be a worthwhile objective. Achieving relatively clean and organized LEO orbits may only be possible if we start taking deliberate action today.

Celestial Guardianship Through Every Step of the Course

As we venture beyond Earth's orbit and set our sights on celestial neighbors, responsible exploration becomes the only acceptable modus operandi. Lunar exploration must be conducted in a collaborative and respectful manner to prevent the creation of another landscape spoiled by orbital congestion and debris.

While sustainable space mining may be theoretically achievable, we should refrain from altering the trajectories of asteroids for any purpose to ensure the safety of Earth and other celestial bodies from unintended anthropogenic-caused impacts. Exploring other worlds that we believe could potentially harbor extraterrestrial life also necessitates the utmost caution on our part.

A Shared Responsibility as One with the Universe

Shared human existence can be conceived as a cosmic symphony. We must not lose sight of our interconnectedness with the universe. Our actions resonate far beyond our planet. While for the moment all decisions are being made from Earth's surface, our ethical footprint is boundless.

Yes, we will strive to address pressing environmental and social issues on Earth in the next decade, as well as environmental and social issues in the heavens. Yes, it is challenging to agree and work together in a competition-driven model of a world. We should begin by acknowledging that our choices today have ripple effects across time and space, impacting many generations yet to come.