amazon | project kuiper

SPACE SAFETY AND SUSTAINABILITY

9 October 2024

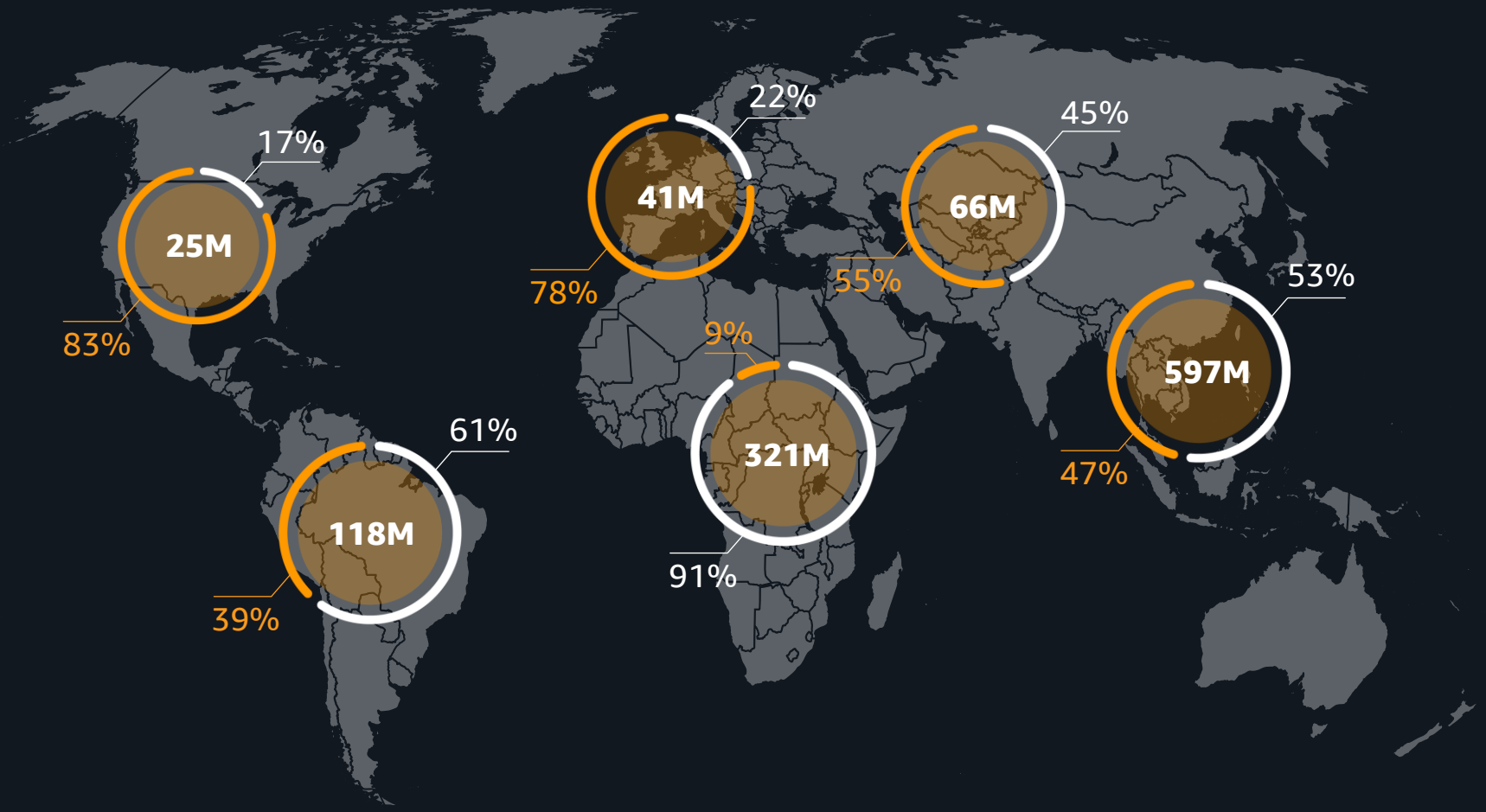
Kuiper's Mission

There are billions of people on Earth without reliable broadband access. Project Kuiper will help bridge the gap in places where service is unreliable or too expensive, or where it doesn't exist at all.

1 billion
unserved households across the globe have no fixed broadband access today (50% of the global population)

300 million
underserved households are on legacy DSL technologies

100 million
business, enterprise, and public sector endpoints lack reliable connectivity



Source: S&P Market Intelligence

amazon | project kuiper

WHAT IS PROJECT KUIPER?

Satellites & technology

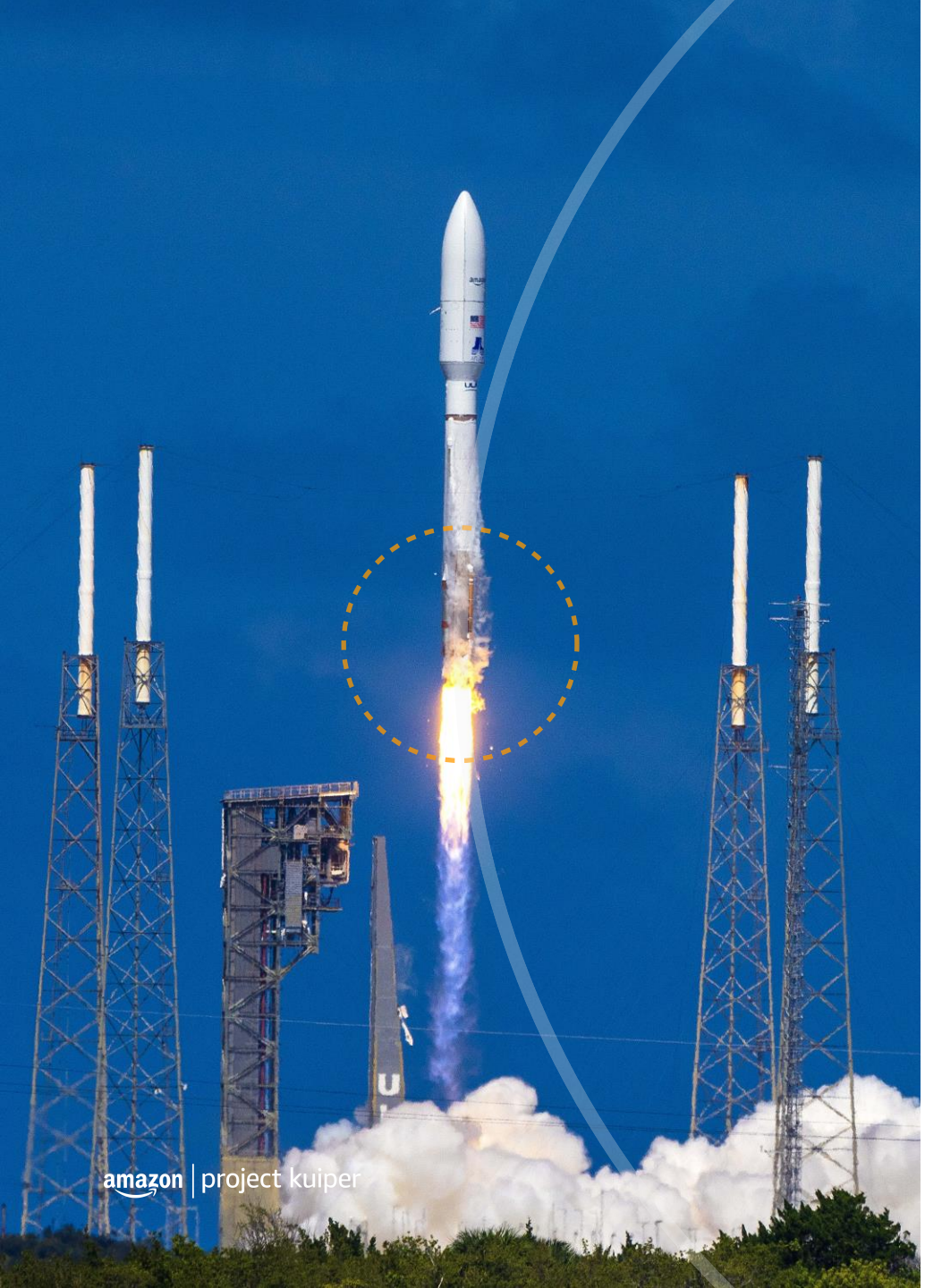
We are deploying 3232 satellites at several altitudes and multiple orbital inclinations (590 km/33.0º , 610 km/42.0º, 630 km/51.9º), allowing us to deliver our high-speed service to a majority of the world's population with the flexibility and capacity they demand.
The Kuiper System combines these satellites with hundreds of ground gateways and global networking and infrastructure to reliably connect tens of millions of customer terminals.

Facilities & infrastructure

Project Kuiper is headquartered in Washington state with a 219,00-sq-ft research and development facility in Redmond and a 172,000-sq-ft satellite manufacturing facility Kirkland. We're opening a 100,000-sq-ft satellite processing facility at Kennedy Space Center in Florida, and investing in additional launch infrastructure at ULA's facilities at Cape Canaveral, Florida, to support a higher launch cadence.

People & talent

More than 2,000 people around the world work on Project Kuiper, representing a wide variety of disciplines.



PRODUCTION DEPLOYMENT

Amazon has secured at least 80 launches to support its deployment plan for Project Kuiper. Manufacturing of our production satellites is underway, and launches will begin in the next few months.

PROJECT KUIPER LAUNCH LINEUP

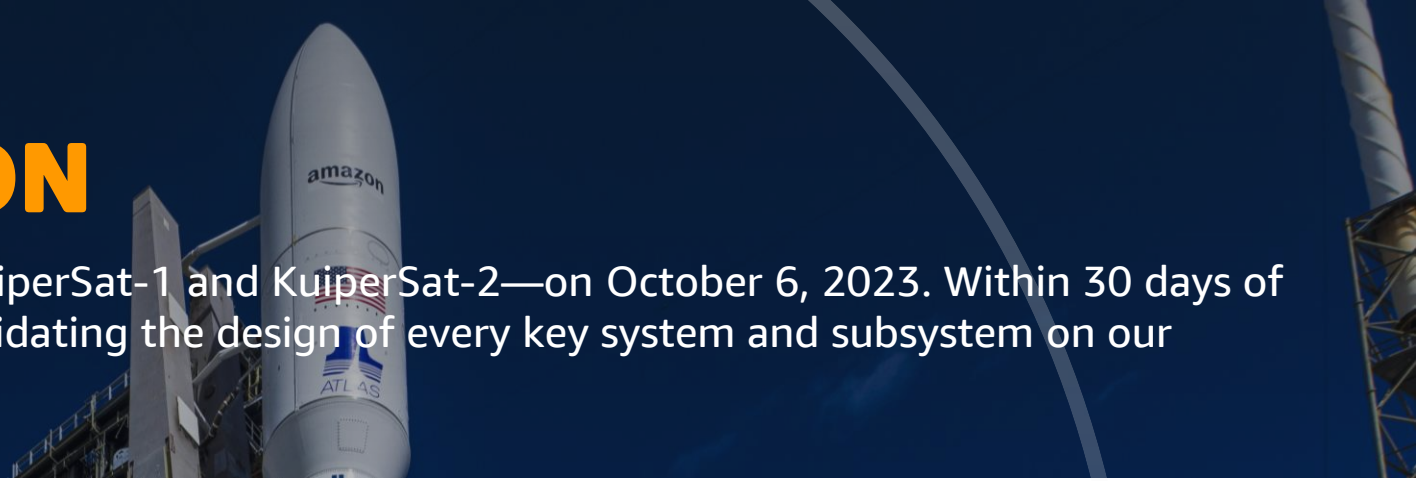
- Launches with Arianespace, Blue Origin, SpaceX, and United Launch Alliance (ULA) provide enough capacity to deploy vast majority of our 3,236-satellite constellation
- Amazon invested billions of dollars across three agreements, making it the single largest commercial procurement of launch vehicles in history

INDUSTRY IMPACT

- Contracts support thousands of suppliers and highly skilled jobs in 49 states in the U.S. and 13 countries across Europe

PROTOFLIGHT MISSION

Project Kuiper launched two prototype satellites—KuiperSat-1 and KuiperSat-2—on October 6, 2023. Within 30 days of launch, we achieved a 100% mission success rate, validating the design of every key system and subsystem on our satellites and across our network



Satellite Technology

- Prototypes include production-ready technology and sub-systems, including phased array and parabolic antennas, power and propulsion systems, and custom-designed modems

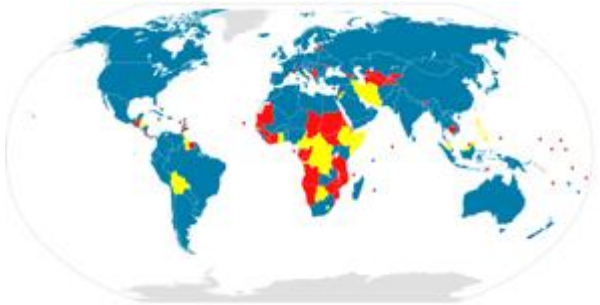
Network performance & optical links

- The mission validated our network technology connecting satellites, customer terminals, ground gateways, and links to the internet and AWS, and allowed us to demonstrate 4K video streaming, two-way video calls, and online shopping
- We demonstrated 100 Gbps optical links between our prototype satellites

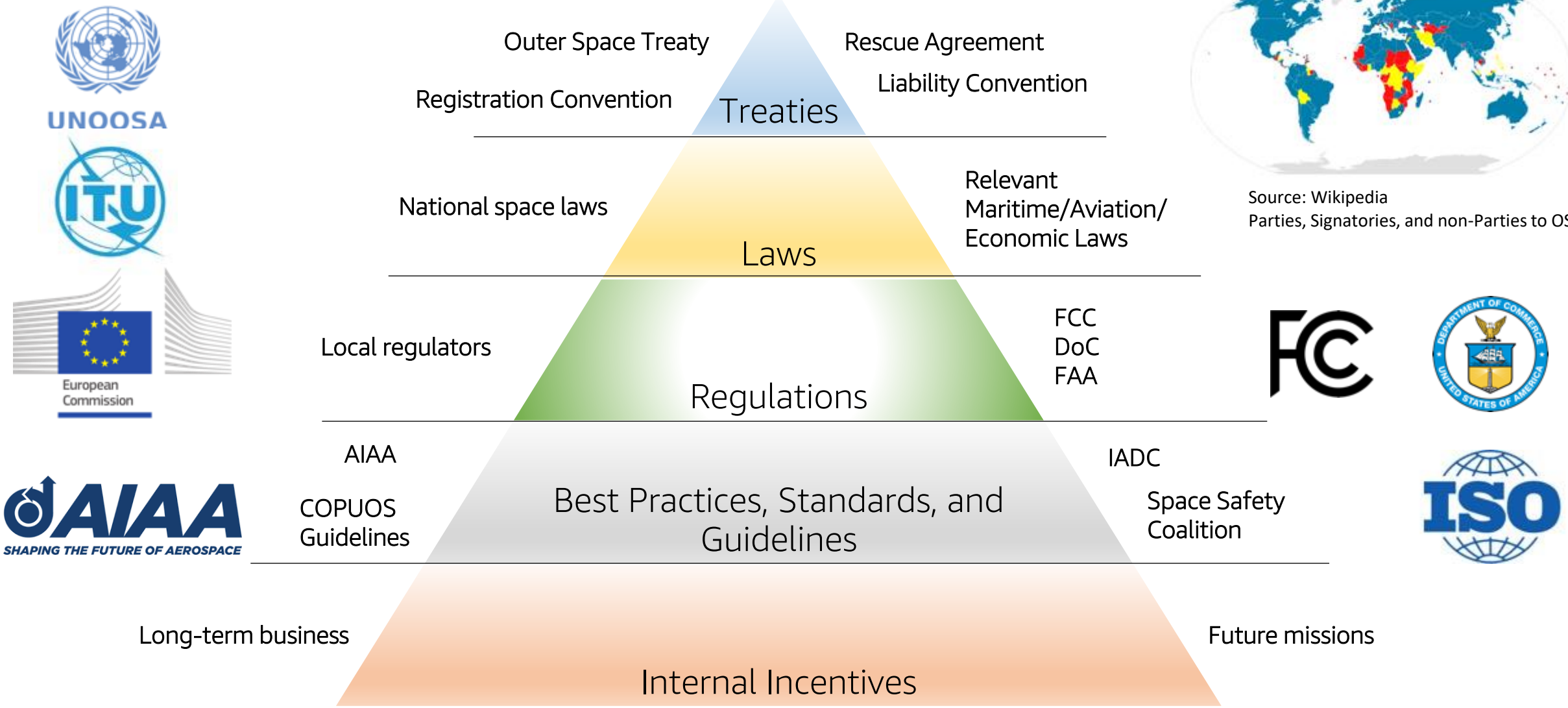
Safety & sustainability

- On-orbit testing demonstrated our custom electric propulsion system can safely maneuver the satellites to maintain their assigned orbits, avoid debris and other spacecraft, and actively deorbit at the end of their missions
- One of the satellites includes reflectivity mitigation technology to evaluate ways to reduce impact on optical astronomy

SPACE SUSTAINABILITY PYRAMID

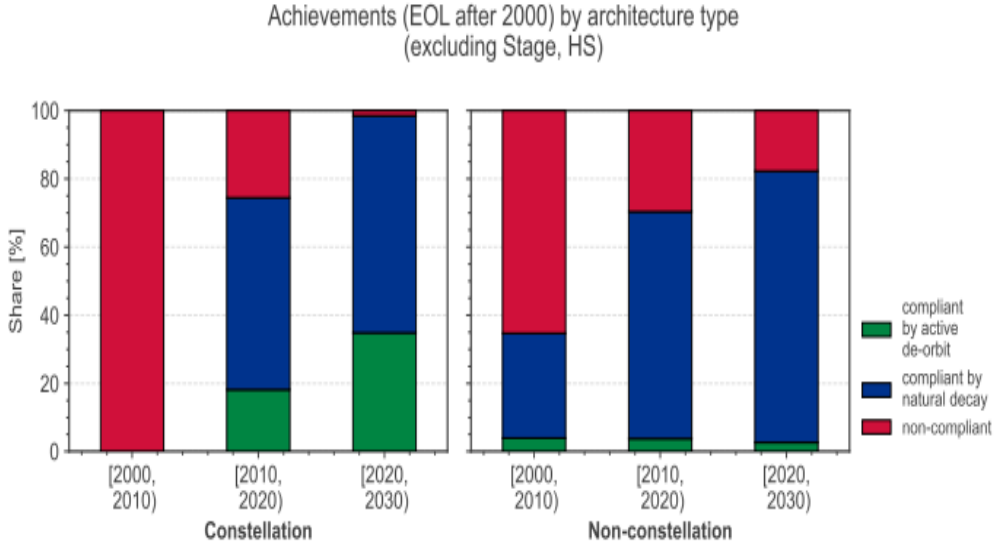


Source: Wikipedia
Parties, Signatories, and non-Parties to OST



WHY DOES KUIPER WANT TO BEHAVE SUSTAINABLY?

- Amazon is highly committed to sustainability as a core tenet.
- Lead by example to protect our orbital environment.
- Kuiper has an intrinsic incentive to behave sustainably.
  - Need for inter-operator collaboration -> Share satellite ephemeris publicl
  - Financial consequences of a sudden failure-> Invest in redundancy and shielding to protect from MMOD.
  - Less tolerant of a failed satellite in operational shells -> Deorbit failing satellites earlier.



Source: ESA Space Environment Report 2024

SPACE SAFETY GUIDING PRINCIPLES

Sustainability

Amazon is committed to building a sustainable business for our customers and the planet, and we are inventing new ways to protect the space around Earth.

Excellence

Project Kuiper strives to be the world's most sustainable constellation operator.

Speed

Project Kuiper is launching in the near term, not the far off future. We need sustainable solutions now, driven by leveraging the "bottom of the pyramid" - best practices, standards, and internal incentives.

Data-Driven Solutions

Project Kuiper is committed to implementing solutions that are backed by research and actual operational data.

Continued Growth

Project Kuiper's system is designed for continued improvement. As new space safety solutions and advances emerge Kuiper will continue to improve and iterate on key space safety capabilities.

Collaboration

Project Kuiper will continue to collaborate and exchange ideas with the broader operator and research community.

SPACE SUSTAINABILITY: 4 KEY TOPIC AREAS

Four different physical regimes with sustainability needs, different solutions, and different outcomes.

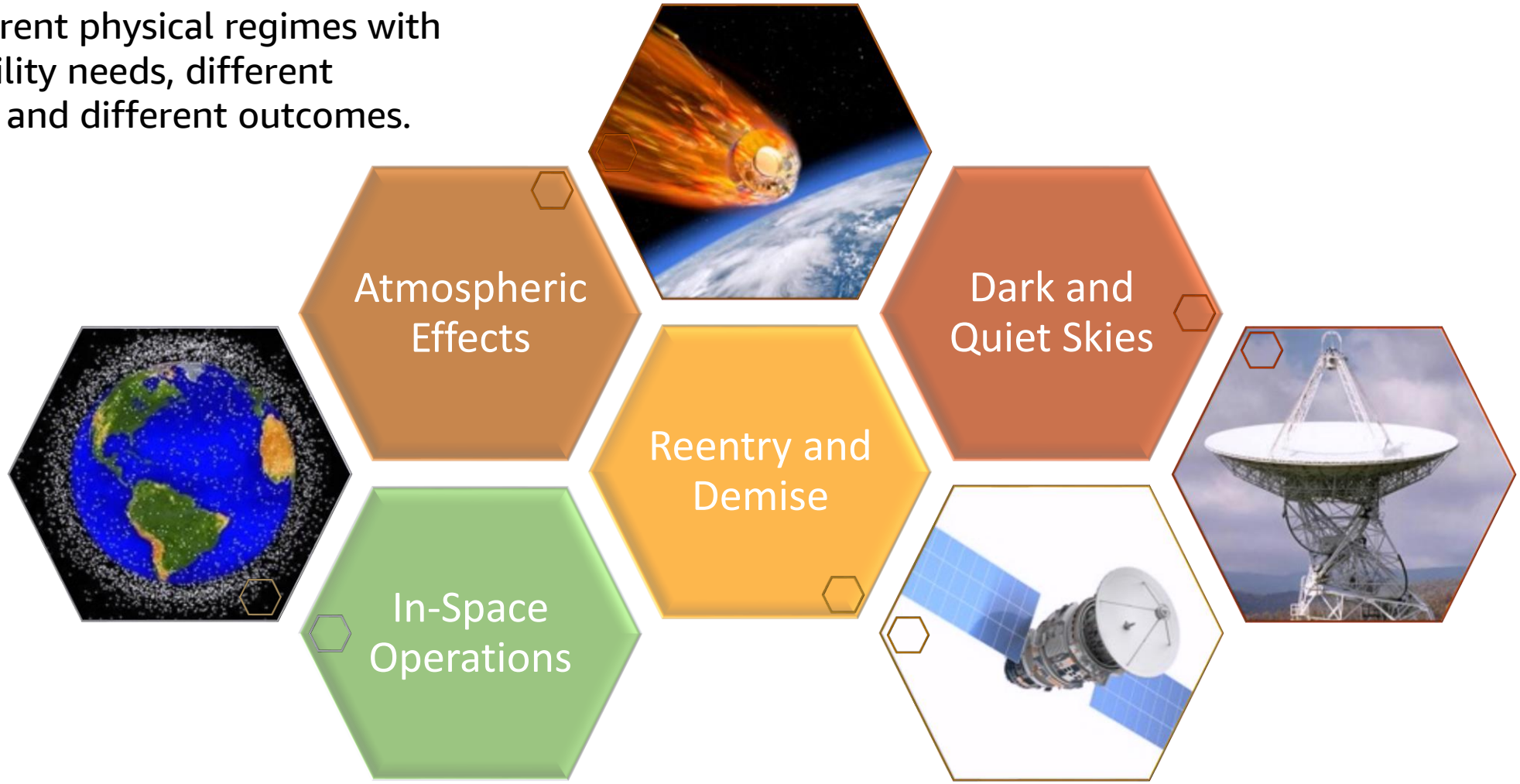


Image Sources: NASA, ESA, NRAO, Adobe Stock

SPACE SUSTAINABILITY: IN-SPACE OPERATIONS

Four different physical regimes with sustainability needs, different solutions, and different outcomes.

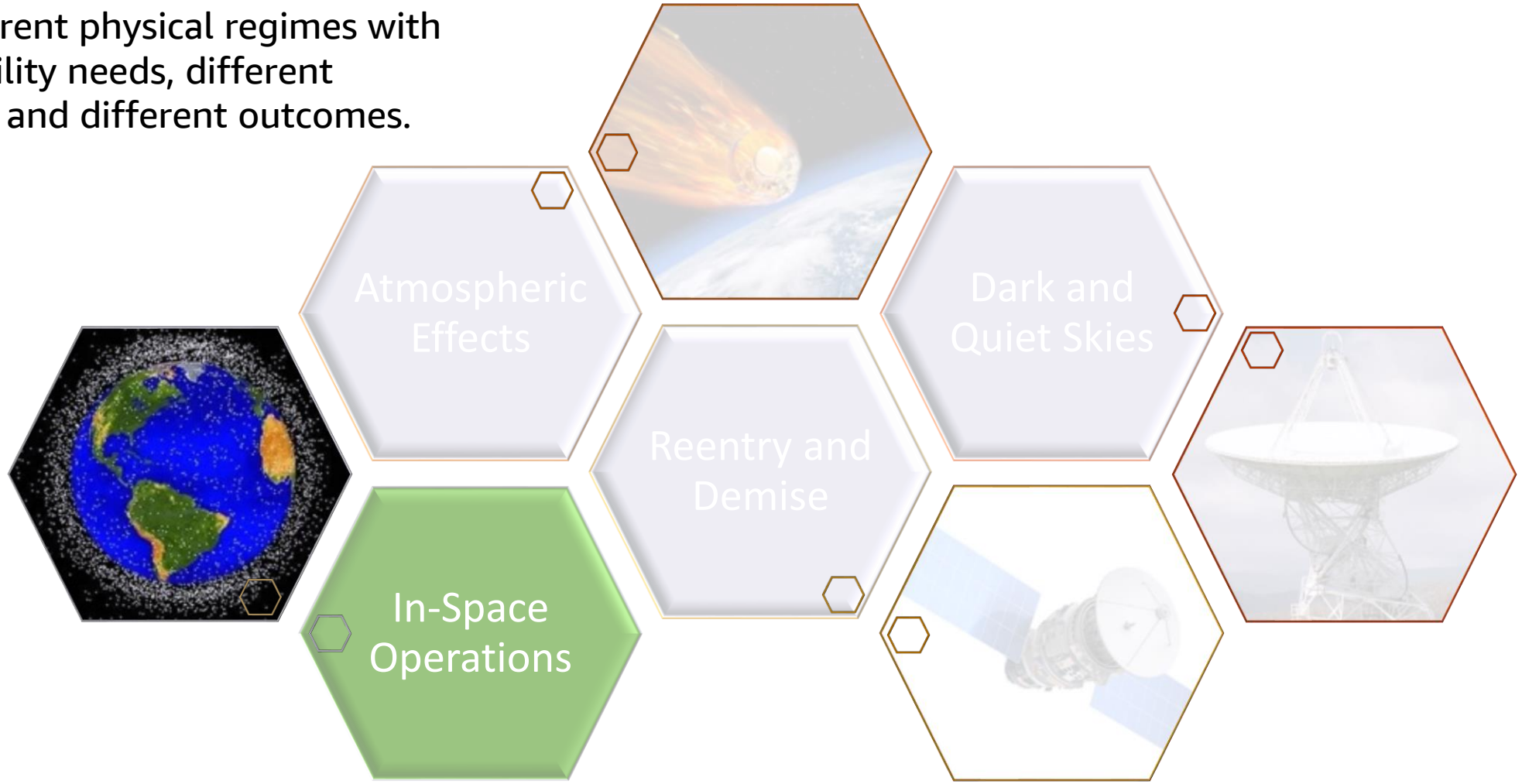


Image Sources: NASA, ESA, NRAO, Adobe Stock

SPACE SUSTAINABILITY: IN-SPACE OPERATIONS

How does it normally work today?

- Space Situational Awareness (SSA) services share data between operators and compute conjunctions.
- Operators coordinate and conduct maneuvers to reduce the probability of collision (Pc) below a reasonable threshold (1E-4 is standard).
    - Largely human-in-the-loop, but for large constellations it is becoming more commonplace to have automated systems.
- For Debris < 10 cm, conjunction predictions are inconsistent.

What is Kuiper doing?

- Building satellites to the highest industry standards to avoid unintentional breakups or detaching material.
- Using a 1E-5 threshold for collision risk.
- Sharing ephemerides and maneuver plans publicly.
- Engaging in bilateral agreements to establish maneuvering norms.
- Automated collision avoidance.
- Shielding, redundancy, and specific design configurations to minimize MMOD consequences.

Sources: Youtube, AARP

11

SPACE SUSTAINABILITY: REENTRY AND DEMISE

Four different physical regimes with sustainability needs, different solutions, and different outcomes.

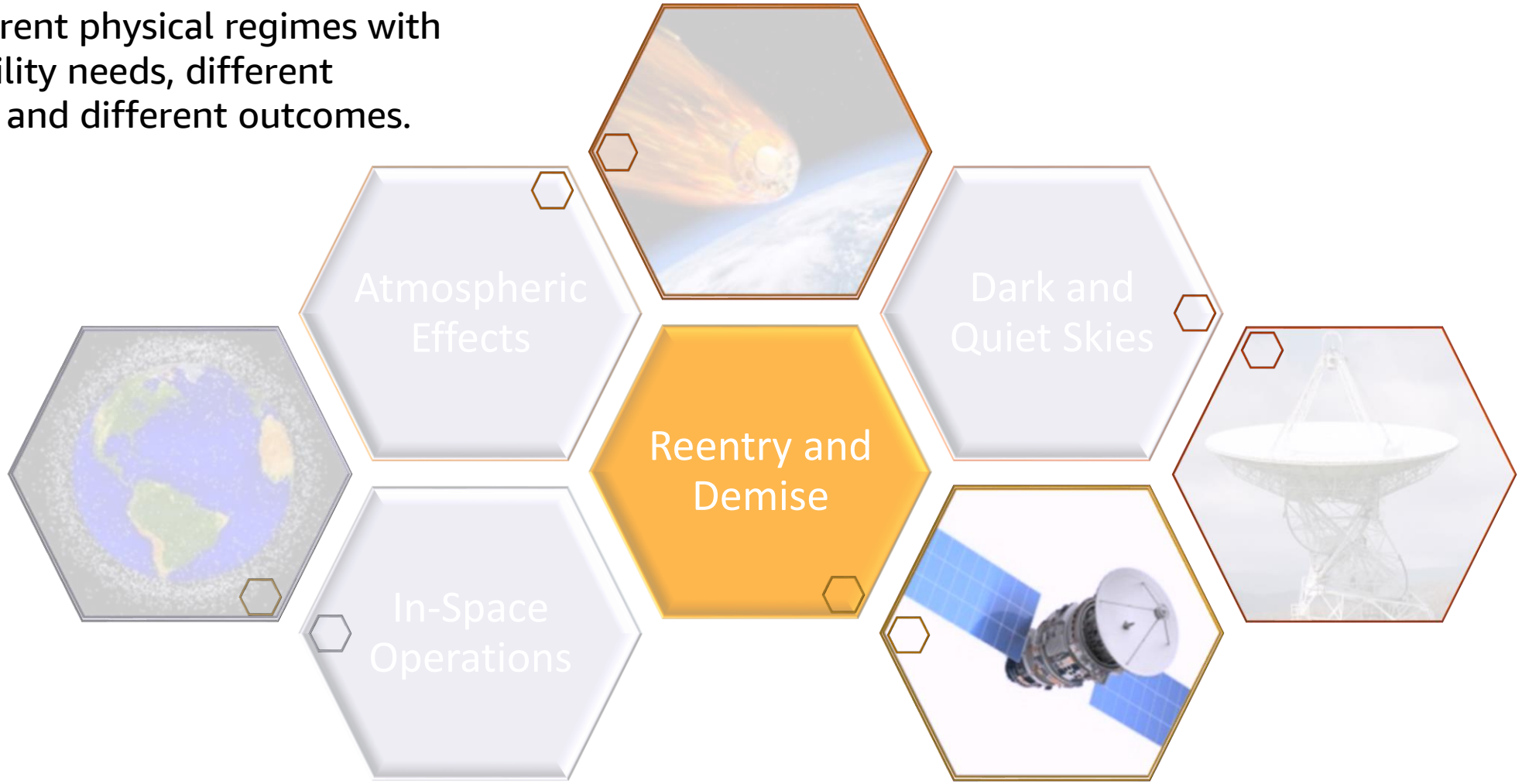


Image Sources: NASA, ESA, NRAO, Adobe Stock

SPACE SUSTAINABILITY: REENTRY AND DEMISE

How does it normally work today?

- When satellites deorbit, the high aerodynamic friction causes them to burn up.
- Satellites designed so any components that do not burn up pose no danger to infrastructure or human lives.
  - Controlled spacecraft are maneuvered into safe areas (e.g., South Pacific Ocean).
  - Uncontrolled spacecraft must have no surviving items with >15 J energy and casualty risk of > 1 in 10,000.
- Satellites typically deorbit within 5 years (FCC) or 25 years (standard elsewhere).

What is Kuiper doing?

- Passivating before atmospheric reentry at 350 km.
- Satellites designed to demise without energetic material reaching surface.
- Baseline ops: active deorbit within 1 year.
- Passively deorbit in 5 years.
- Removing satellites before they become non-maneuverable via active satellite health monitoring.

SPACE SUSTAINABILITY: ATMOSPHERIC EFFECTS

Four different physical regimes with sustainability needs, different solutions, and different outcomes.

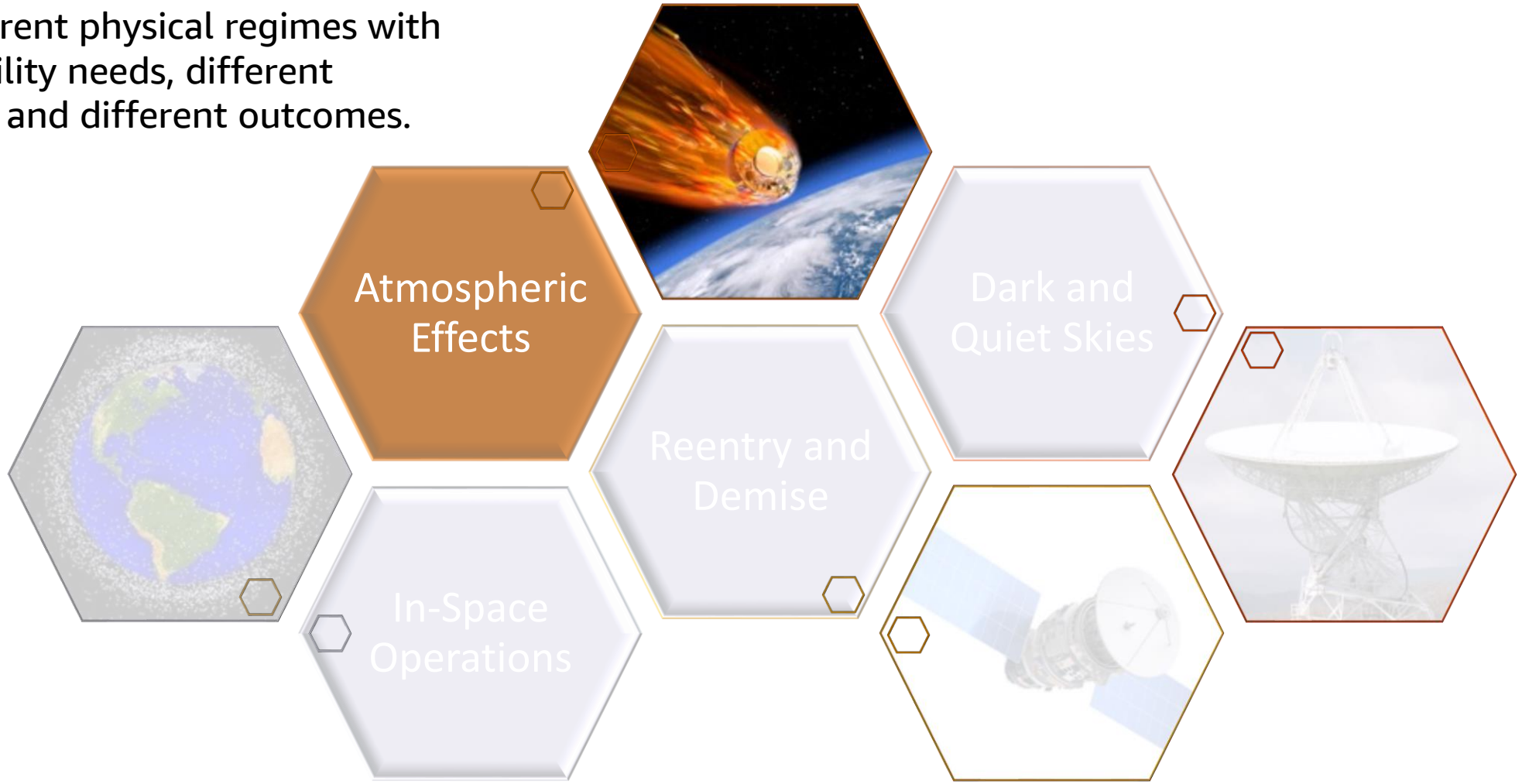
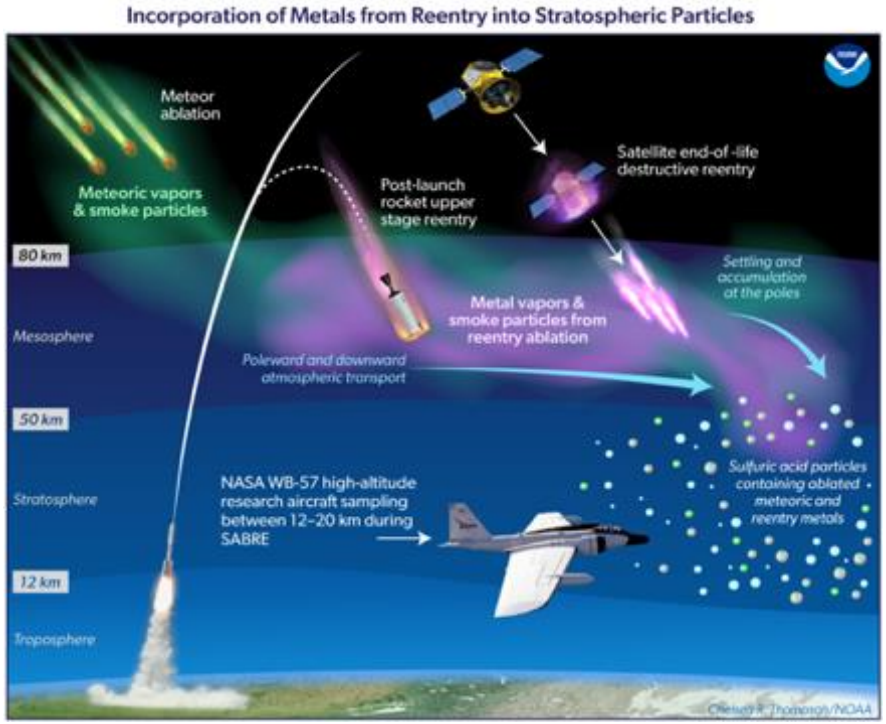


Image Sources: NASA, ESA, NRAO, Adobe Stock

SPACE SUSTAINABILITY: ATMOSPHERIC EFFECTS

- NOAA measured copper, aluminum, lithium, and rare metals in higher numbers (2023) linked to reentry of space debris.
- Current research is conflicting and uncertain about the impact of these particles.
  - Potential for ozone impact if atmospheric particles enter the stratosphere.
  - Global cooling effects from aluminum oxides.
- Call for additional research into transport mechanisms, chemistry, and impact of these particles.
- Conflicting with other space safety measures:
  - Less orbital debris → More satellites entering atmosphere → More space debris ablation → More particles in atmosphere.



SPACE SUSTAINABILITY: DARK AND QUIET SKIES

Four different physical regimes with sustainability needs, different solutions, and different outcomes.

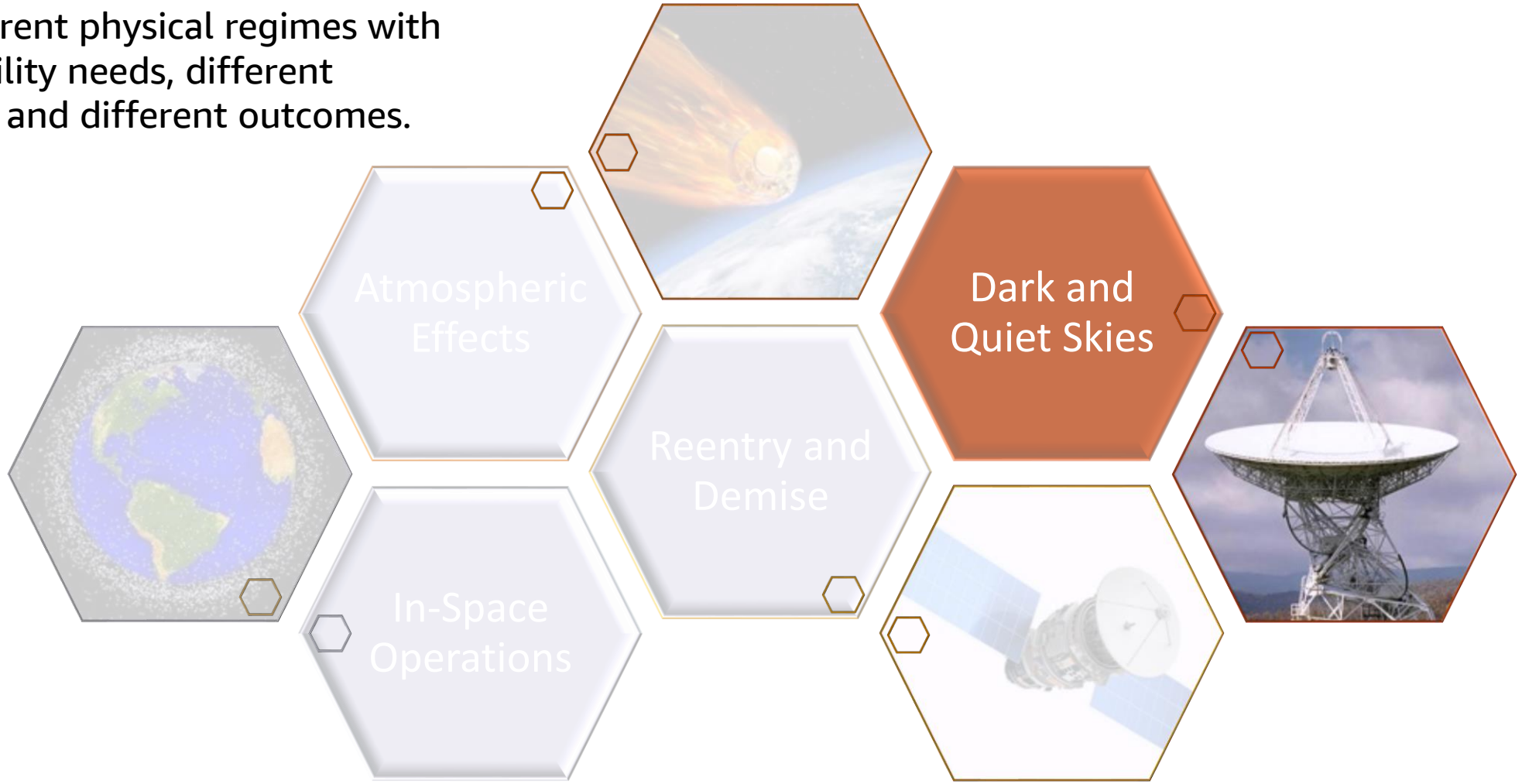


Image Sources: NASA, ESA, NRAO, Adobe Stock

SPACE SUSTAINABILITY: DARK AND QUIET SKIES

We are taking steps to minimize our impact on astronomical observation.

System design

- Project Kuiper operates at lower altitudes, helping reduce duration of illumination compared to higher altitudes (consistent with IAU CPS recommendation).
- Prototype mission to evaluate reflectivity and test mitigation measures including di-electric films, paint, and panel orientation.
- Work is still in early R&D stage without commercially available solutions.

Deployment & operations

- Maneuvering capabilities reduce earthward reflectivity during propulsive operations (orbit raise and lower).
- Steering capabilities allow us to minimize reflections during mission operations.
- Kuiper does not operate in any spectrum allocated for radio astronomy.
- We are coordinating with U.S. National Science Foundation.

Collaboration

- Working with the astronomical community to find shared solutions.
- Sharing ephemeris data throughout operations to help protect and preserve scientific research.
- Kuiper has supported IAU's Centre since its inception and co-chaired the Industry & Technology Hub.
- Amazon is working with IAU CPS SatHub to monitor visibility of proto satellites prior to deorbit.

CONTINUED ADVOCACY

- International Standards Organization (ISO) – Working Groups
- ESA Clean Space: EU Zero Debris Charter.
- Paris Peace Forum: Net Zero Space Initiative.
- Inter-operator discussions and agreements
- Contributing to research and SSA forums

amazon | project kuiper

Thank you!