DIPLO SPACE · FIELD NOTE 03

# The Crowded Orbit

## How much is circling overhead, how little of it we can actually see, and why keeping orbit usable is a problem no one country can solve alone

Applied-research field note · Edition 1.0 · Diplo Space, Inc. (Virginia 501(c)(3), EIN 99-1402470) · Every claim traced to a public primary source · The lab takes no policy position

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Start here — the plain-English version. Everything humanity has ever launched that is still up there and no longer working — dead satellites, spent rocket stages, and the shrapnel from things that have exploded or collided — is space debris. It matters because low Earth orbit is not empty and it does not clean itself quickly: a fleck of paint moving at 25,000 km/h hits like a rifle bullet, and a lost bolt can end a billion-dollar satellite. We can only individually track the larger pieces — roughly the softball-sized and up — and even that list runs to tens of thousands of objects. Below that size, models estimate over a hundred million fragments too small to see but plenty large enough to kill a spacecraft. The worrying part is a feedback loop scientists named the Kessler syndrome: enough collisions create enough debris to cause more collisions, until an orbit becomes too dangerous to use. This note lays out how crowded orbit actually is, who can see the danger, and why keeping orbit usable is a governance problem no single country owns — every figure traced to a public source, no policy position taken.

ABSTRACT Low Earth orbit is a finite, shared resource that is filling rapidly. As of mid-2026, surveillance networks track roughly 45,670 objects in orbit, of which only about a third are working satellites; the rest are debris and spent hardware. Statistical models put the true population far higher — on the order of 54,000 objects larger than 10 cm, 1.2 million between 1 and 10 cm, and 140 million from 1 mm to 1 cm, each fragment fast enough to disable or destroy a spacecraft. This field note translates the debris problem for non-specialist officials: it quantifies what is on orbit and how little of it is trackable, explains the collision-cascade risk (the Kessler syndrome), and shows why post-mission-disposal rules, liability, and cleanup are governed by a patchwork of national regulators and voluntary international guidelines with no single binding authority. It advocates no remedy; it makes the shared risk legible to the officials who must weigh it.

How to read this note. Section 1 explains what debris is and why speed makes small objects lethal. Section 2 sets out the numbers — what we track versus what is really there. Section 3 explains the Kessler cascade and why the problem outlives any single launch. Section 4 covers who can see the danger (space situational awareness). Section 5 surveys the governance patchwork; Section 6 explains why this is a space-governance question; Section 7 poses questions for policymakers. A glossary precedes the references. Every headline figure is sourced to a public primary document; figures marked illustrative depict structure, not measured values.

| 45,670 | 140M | 44% | >200 yr |
|---|---|---|---|
| objects tracked in orbit | modeled fragments >1 mm | of tracked catalog is junk | debris grows even if launches stop |

## 1 Why a fleck of paint is a weapon

Orbital debris is counter-intuitive because the danger is not mass but speed. In low Earth orbit an object travels at roughly 7–8 kilometers per second — about 28,000 km/h. Two objects on crossing orbits can close at ten kilometers per second or more. At those speeds kinetic energy, not size, governs the damage: a one-centimeter aluminum fragment carries roughly the energy of a small car at highway speed, and a fleck of paint has cracked the window of a crewed spacecraft. This is why a population of small, untrackable fragments — not just the large dead satellites — is the core of the problem.

The second counter-intuitive fact is that orbit does not clear itself on any useful timescale. Below a few hundred kilometers, atmospheric drag pulls objects down within years. But the orbits most prized for imaging, communications, and the new mega-constellations sit high enough that debris can linger for decades to centuries. What goes up in a congested orbit largely stays there — long enough that today's launches and today's fragments are tomorrow's hazard.

## 2 The numbers: what we track versus what is there

The tracked catalog is only the visible surface of the problem. Surveillance networks regularly track and catalog about 45,670 objects in orbit.[1] But most debris is too small to track individually. ESA's statistical model of the environment estimates roughly 54,000 objects larger than 10 centimeters, about 1.2 million between 1 and 10 centimeters, and some 140 million from 1 millimeter to 1 centimeter.[1] The middle band is the quiet menace: 1.2 million objects large enough to end a mission but too small to see coming.

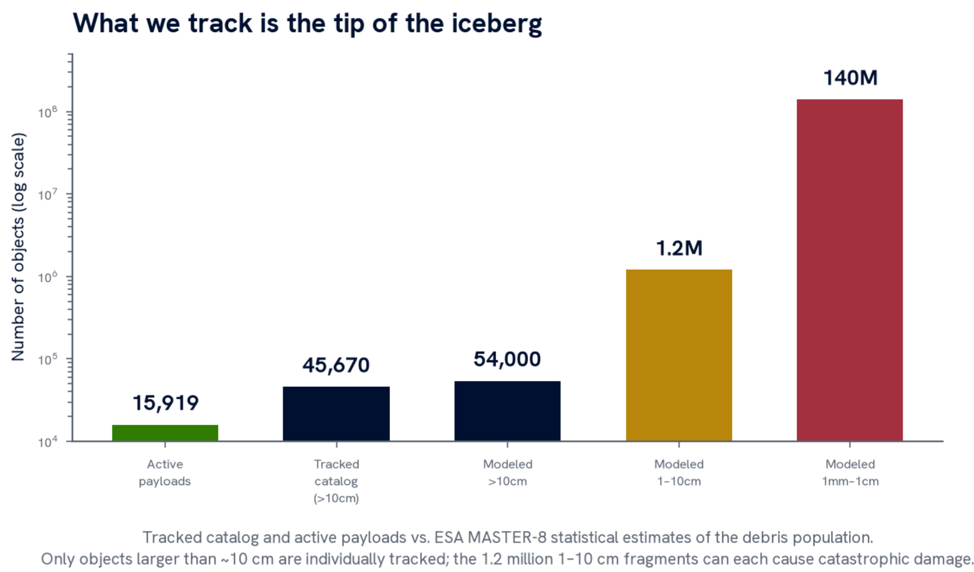


Figure 1. The tracked catalog and active-satellite counts against ESA's MASTER-8 statistical estimates of the debris population (log scale). Only objects larger than roughly 10 cm are individually tracked; the millions of smaller fragments are modeled, not seen.

Of what we can see, a striking share is not working. CelesTrak's catalog shows about 34,360 objects on orbit, of which roughly 19,410 are payloads, 12,488 are tracked debris fragments, and 2,410 are spent rocket bodies — so about 44% of the tracked population is non-functional mass that cannot be commanded to move.[3] Meanwhile some 35,321 cataloged objects have already reentered over the decades, which shows both that orbit has churn and that we are now adding to it faster than it drains.

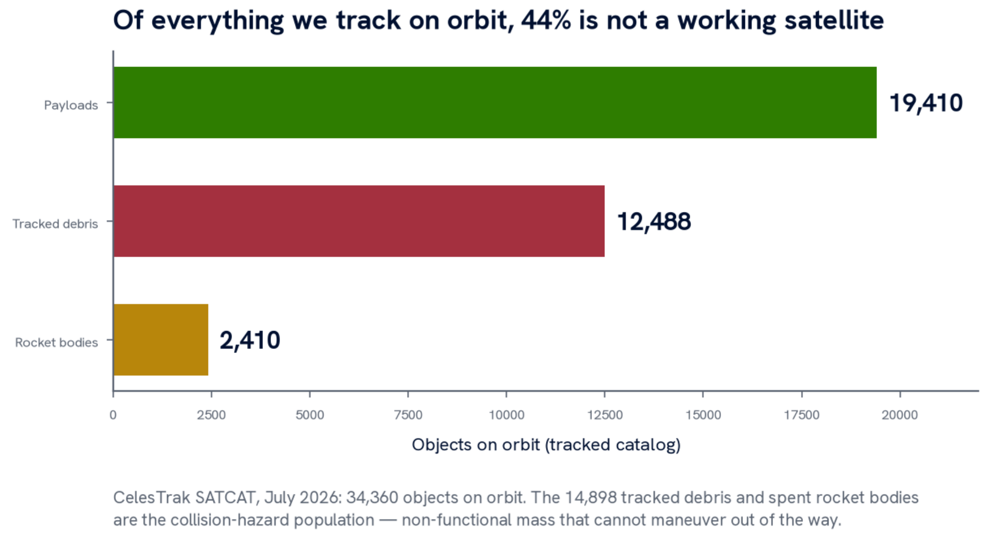


Figure 2. Composition of the tracked on-orbit catalog (CelesTrak SATCAT, July 2026). The 14,898 debris fragments and spent rocket bodies are the collision-hazard population: they cannot maneuver, so avoidance is entirely the responsibility of the working satellites around them.

For scale on the human enterprise behind these numbers: since the first launch in 1957 there have been roughly 7,270 launches, placing about 26,890 satellites in orbit, of which about 18,340 remain in space and roughly 15,900 are still functioning.[1] More than 660 break-ups, explosions, and collisions have fragmented objects on orbit, and the total mass now circling the Earth exceeds 16,600 tonnes.[1]

## 3 Where the junk actually is

Averages hide the real danger, because debris is not spread evenly. Sort every tracked object by altitude and a sharp pattern appears: working satellites and dead ones live in almost completely different neighborhoods.

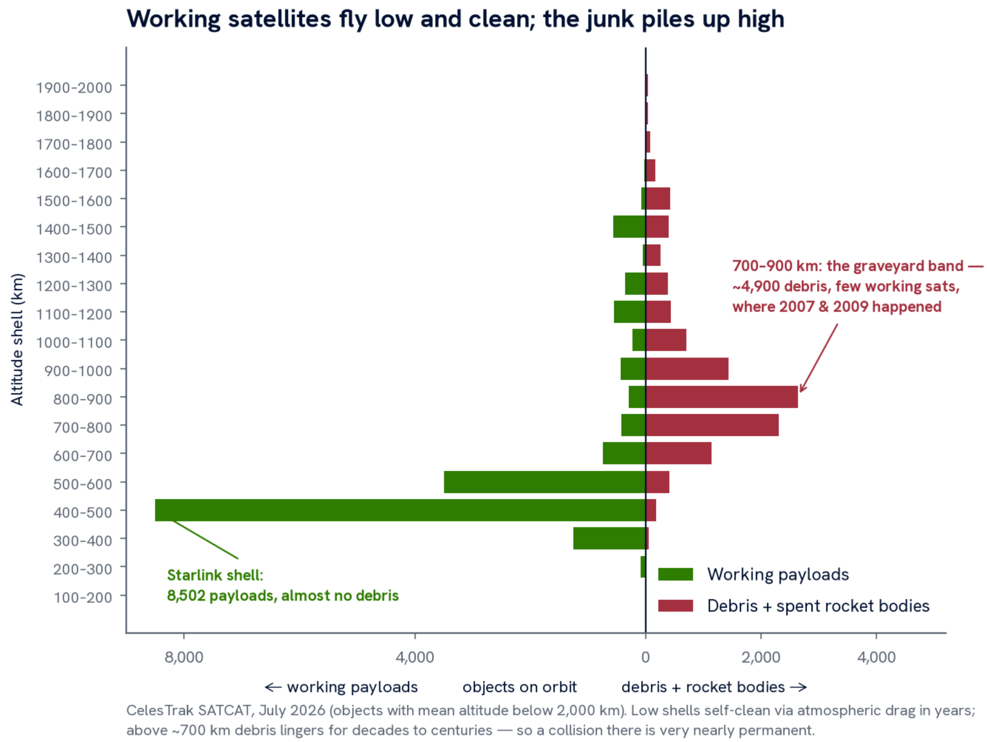


Figure 3. Every tracked object below 2,000 km, sorted into 100-kilometer altitude shells — working payloads to the left, debris and spent rocket bodies to the right (CelesTrak SATCAT, July 2026).

The busiest band for working satellites is 400–600 km, where nearly 12,000 payloads — most of them Starlink — fly with almost no debris beside them. That is not luck. At those altitudes the thin upper atmosphere still exerts drag, so anything that stops maneuvering spirals down and burns up within a few years. The neighborhood cleans itself.

Higher up, the picture inverts. In the 700–900 kilometer shells there are only a few hundred working satellites but roughly 4,900 pieces of debris and spent rocket hardware — and at those altitudes drag is so weak that an object can stay up for centuries. This is the orbital graveyard, and it is no coincidence that the two worst break-ups in history happened right here. A collision at 450 km is a bad month; a collision at 850 km is a bad century.

## 4 The Kessler syndrome: a problem that outlives the launch

In 1978 NASA scientist Donald Kessler and a colleague described a threshold effect: once the density of objects in an orbit passes a certain point, collisions begin to generate debris faster than the environment removes it, and each collision raises the odds of the next.[9] The result — now called the Kessler syndrome — is a slow chain reaction that can, in the worst case, render a band of orbit unusable for generations. It is not science fiction: it is a straightforward consequence of adding mass to a region that clears slowly.

The most sobering finding in the recent record is about momentum. ESA's analysis concludes that even if all launches stopped today, the number of debris objects would keep growing for more than two centuries, because collisions among what is already up there would create new fragments faster than the atmosphere pulls them down.[2] The problem, in other words, has its own inertia. That reframes the governance question: this is not only about restraining future launches but about managing a hazard that is already self-sustaining.

## 5 Four events that made the case

The debris problem is not a projection. Four real events — two deliberate, two accidental — already define the risk, and together they teach the single most important lesson about orbit: where a break-up happens matters as much as how big it is.

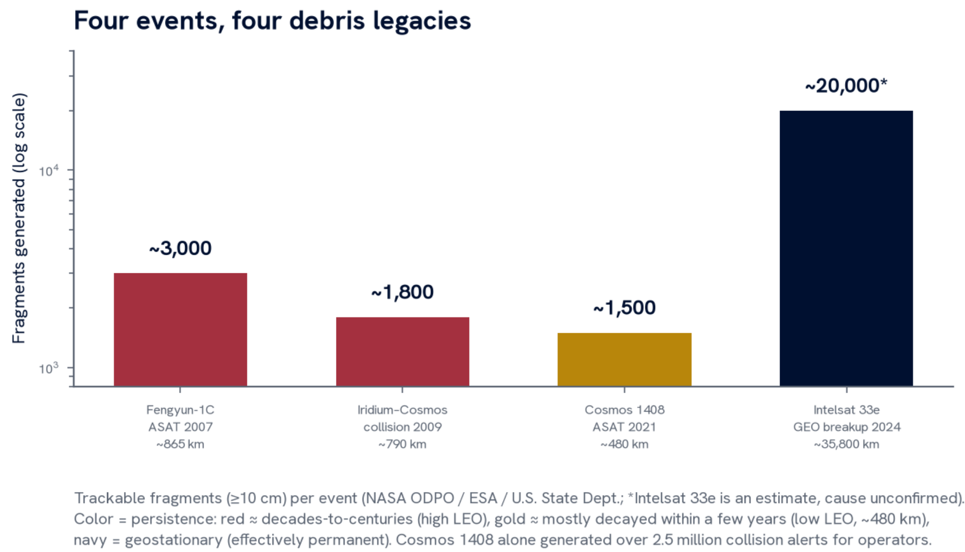


Figure 4. Trackable fragments (10 cm or larger) generated by four landmark events, on a logarithmic scale, colored by how long the debris will persist (NASA Orbital Debris Program Office, ESA, and U.S. State Department figures).

Fengyun-1C (11 January 2007). China destroyed one of its own defunct weather satellites with a missile at about 865 kilometers — the single worst fragmentation event on record. It produced more than 3,000 trackable fragments and an estimated 35,000 smaller ones, and because it happened so high, roughly half of those fragments were still in orbit nearly two decades later. In 2013 a Russian research satellite, BLITS, was knocked out of operation by a suspected Fengyun-1C fragment. One test, permanent consequences.[10]

Iridium 33 and Cosmos 2251 (10 February 2009). The first-ever hypervelocity collision between two intact satellites — an operational U.S. communications satellite and a long-dead Russian one — at roughly 789 kilometers. It generated more than 1,800 trackable fragments and proved Kessler's thesis in the most literal way: the dead satellite could not move, no one had the authority to move it, and the two simply ran into each other. This was not malice; it was neglect at closing speed.[10]

Cosmos 1408 (15 November 2021). Russia destroyed a defunct Soviet-era satellite with a ground-launched missile at about 480 kilometers, creating more than 1,500 trackable fragments and forcing the seven astronauts aboard the International Space Station to shelter in their return capsules. By one commercial tracker's count, this one event generated more than 2.5 million collision alerts for satellite operators. Yet because it happened low, most of the cloud had decayed within a few years — a direct, real-world illustration of the altitude lesson in Figure 3.[11]

Intelsat 33e (19 October 2024). A communications satellite broke apart in geostationary orbit, roughly 35,800 kilometers up, scattering an estimated 20,000 fragments (the cause has not been publicly confirmed). At that altitude there is no atmosphere at all to pull anything down: the debris is, for practical purposes, permanent. The graveyard has an upper floor as well as a lower one.

## 6 Who can see the danger

Avoiding a collision requires knowing where everything is — what the field calls space situational awareness (SSA). Historically the most complete catalog has been maintained by the U.S. military, which tracks objects with radar and optical sensors and issues warnings when two are predicted to pass dangerously close. Commercial and allied sensors now add to the picture. But tracking has hard limits: the smaller the object, the harder it is to see, and the 1.2 million fragments in the one-to-ten-centimeter band are essentially invisible to routine tracking — which means collision avoidance protects against the objects we can see while the larger, unseen population accumulates risk.

The practical consequence is a daily workload. Operators of large constellations now receive many thousands of close-approach warnings and perform collision-avoidance maneuvers routinely. Every maneuver costs fuel and shortens a satellite's life, and every maneuver depends on someone else's data being accurate — a coordination dependency this series' companion note takes up in detail.

## 7 Can we clean it up?

If orbit does not clear itself above a few hundred kilometers, the obvious question is whether we can clear it deliberately. The honest answer in 2026 is: the first tentative demonstrations are flying, but nothing at scale, and no one has settled who pays.

The technology is being proven, one mission at a time. In 2024 the Japanese company Astroscale flew ADRAS-J, which approached a discarded rocket upper stage to within about 15 meters — the first close inspection of a real piece of large debris in orbit, a prerequisite for any future capture. Europe's ClearSpace-1 mission, funded by ESA, is developing a four-armed 'claw' to grab a derelict object and drag it down to burn up. And ESA has demonstrated responsible disposal on its own hardware: in 2023 it steered the retired Aeolus satellite — built before disposal was required — to a controlled, assisted re-entry over open ocean.[12]

The economics are the hard part. Each removal mission today costs roughly what a new satellite costs, to remove a single object out of tens of thousands. That math only works if the highest-risk objects are targeted first and if the cost is shared — which is why ESA has committed to a 'Zero Debris' goal for 2030, requiring its missions to show a better than 90 percent chance of successful disposal, and why a commercial active-debris-removal industry is beginning to form. Prevention remains far cheaper than cleanup: a spent stage that deorbits itself never becomes a target. Cleanup buys time; it does not repeal the arithmetic.

## 8 The governance patchwork

There is no single authority over the orbit. In the United States, the Federal Communications Commission regulates satellite licensing and in 2022 shortened its post-mission-disposal benchmark for low-orbit satellites from 25 years to 5 — a binding rule for FCC-licensed spacecraft that took effect in 2024.[6] That rule replaced a widely-cited but non-binding 25-year guideline that lives in several places at once: the Inter-Agency Space Debris Coordination Committee's guidelines, the U.S. Government's Orbital Debris Mitigation Standard Practices, and the UN's own debris-mitigation guidance.[4,8]

Internationally, the picture is voluntary. UN COPUOS adopted debris-mitigation guidelines in 2007 and 21 long-term-sustainability guidelines in 2019, but these are recommendations, not law.[4,5] The binding instrument that does exist — the 1967 Outer Space Treaty — makes launching states liable for damage their objects cause and requires 'due regard' to others' activities, but it predates mega-constellations and sets no numeric limit on how much debris a state may create.[7] The result is a genuine patchwork: a binding national rule here, a voluntary international guideline there, and a liability treaty that establishes fault in principle without defining a debris threshold in practice.

That patchwork is being actively contested. As several operators prepare constellations of thousands of satellites, the disposal rules themselves are in play — one major operator has asked the FCC to drop the five-year rule as too rigid, while another has argued for keeping it, and astronomers have raised separate concerns about the atmospheric effect of thousands of satellites burning up on reentry.[6] The debate is healthy, but it underscores the governance gap: the rules that determine how crowded orbit becomes are set operator-by-operator and regulator-by-regulator, not for the shared orbit as a whole.

## 9 Why this is a space-governance question

Orbital debris is the textbook example of a commons problem. The benefit of skipping a costly disposal maneuver is private — it accrues to the operator who saves the fuel — while the cost of the added collision risk is shared by everyone who uses that orbit, now and for decades to come. No single national regulator can solve it, because debris does not respect the boundaries of a license: a fragment created by one state's satellite threatens every state's satellites in the same band. And the objects most at risk — the positioning, communications, and Earth-observation satellites that Field Notes 01 and 02 showed the modern economy depends on — sit squarely in the most congested orbits.

> Four lenses on a crowded orbit. The debris problem reads across every instrument of national power. Diplomacy: the only binding rule is a 1967 liability treaty with no debris threshold; everything since is voluntary guidance negotiated at the UN. Information: the whole problem turns on what can be seen — a tracked catalog of tens of thousands sitting atop a modeled population of millions that no sensor can follow. Military: the most complete catalog is held by defense establishments, and deliberate anti-satellite tests have been among the largest single sources of new debris. Economics: orbit is a commons where the cost of cleanup is shared and the benefit of skipping it is private — the classic recipe for under-provision. A governance audience needs all four at once — the integrated view no single-instrument institution is built to hold.

## 10 Questions for policymakers

In the tradition of legislative-reference analysis, this note closes not with recommendations but with the questions a responsible official should be able to answer. They are offered to structure deliberation, not to steer it.

Q1. How much of the orbital region your national operators use is occupied by objects no one can maneuver — and who would your government call if a dead satellite threatened a live one?

Q2. The tracked catalog is a small fraction of the true debris population. What decisions in your jurisdiction depend on catalog completeness that the catalog cannot actually deliver?

Q3. Post-mission disposal rules differ by regulator (5 years in one regime, 25 in another, voluntary in most). Which rule binds a satellite licensed in your jurisdiction, and is it the same rule its debris will obey?

Q4. The Outer Space Treaty makes launching states liable for damage but sets no numeric debris limit. Would your government know how to establish fault if one nation's fragment destroyed another's satellite?

Q5. Debris mitigation is a classic commons problem: the cost of cleanup is shared, the benefit of skipping it is private. What institutional arrangement could make the incentives point the same way?

Q6. Roughly a fifth of the orbital-hazard population is spent rocket bodies from past launches. Who owns the legacy debris already up there, and who pays to remove it?

Q7. Three of the four largest debris events on record were deliberate anti-satellite tests. Seven nations have since pledged not to conduct destructive ASAT tests, but the pledge is voluntary and the largest testing states have not joined. What would it take to turn a voluntary moratorium into a durable norm — and who convenes it?

Q8. Active debris removal is technically demonstrated but economically unsolved: each mission costs about as much as a new satellite, to remove one object out of tens of thousands. Who should pay to remove a dead object that no longer has an owner — the launching state, an international fund, or a commercial market — and who decides which objects go first?

## 11 Conclusion

Orbit is a shared resource that is filling faster than it drains, and most of what is up there is already beyond anyone's control. We track the largest objects and model the rest; the modeled rest outnumbers the tracked by orders of magnitude. The physics gives the problem its own momentum, and the governance — a binding national rule here, a voluntary guideline there, a liability treaty that names fault without setting a limit — is not yet organized around the thing it must protect, which is the orbit as a whole. What is missing is not data or even rules, both of which are accumulating, but an integrated, neutral view that spans the regulators, the operators, and the borders the debris crosses. Diplo Space offers that view — and stops there, so the choices remain with those who must make them.

## Glossary of key terms

Space debris. Any human-made object in Earth orbit that no longer serves a useful function — spent rocket stages, dead satellites, and fragments from break-ups and collisions.

LEO (low Earth orbit). The region up to about 2,000 km altitude, where most satellites and most debris reside, and where the mega-constellations operate.

Kessler syndrome. A scenario, first described in 1978, in which the density of objects in orbit becomes high enough that collisions cascade — each collision creating debris that causes further collisions.

Conjunction. A close approach between two orbiting objects; operators receive conjunction data messages and may maneuver to avoid a possible collision.

SSA (space situational awareness). Knowing what is in orbit and where it is going — the tracking, cataloging, and prediction that make collision avoidance possible.

MASTER. ESA's statistical model of the debris environment, used to estimate the population of objects too small to track individually.

Post-mission disposal. Removing a satellite from a useful orbit after its mission ends — by deorbiting it to burn up, or moving it to a disposal orbit.

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9. D. J. Kessler and B. G. Cour-Palais, “Collision Frequency of Artificial Satellites: The Creation of a Debris Belt,” Journal of Geophysical Research, 1978 (the original statement of the cascade now known as the Kessler syndrome).
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11. U.S. Department of State, press statement on the Russian direct-ascent anti-satellite test destroying Cosmos 1408, 15 November 2021 (identification of roughly 1,500 trackable fragments; ISS crew sheltering).
12. European Space Agency, Space Safety Programme, materials on active debris removal and the Zero Debris approach — ClearSpace-1, the Aeolus (2023) assisted re-entry, and the ≥90% successful-disposal target — with Astroscale ADRAS-J rendezvous reporting.

About Diplo Space. Diplo Space is a neutral, nonprofit translation layer for space governance: we turn contested, technical, space-dependent systems into material a non-specialist official can navigate — every claim traced to a public primary source, and no policy position taken. This note applies that method to orbital debris and space situational awareness: how much is up there, how much we can actually see, and why the risk to a shared orbit is a cross-border governance question. Its companion, Who Owns the Traffic Lane?, does the same for space traffic coordination.