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The Looming Space Junk Crisis: It's Time to Take Out the Trash

Illustration: Simon C. Page

On clear winter nights, when the trees are bare, Donald Kessler likes to set up a small telescope on the back deck of his house in Asheville, North Carolina, and zoom in on the stars shining over the Blue Ridge Mountains. It's not the most advanced home observatory, but the retired NASA scientist treasures his Celestron telescope, which was made in 1978. That also happens to be the year Kessler published the paper that made his reputation in aerospace circles. Assigned to the Environmental Effects Project Office at NASA's Johnson Space Center in Houston, the astrophysicist had gotten interested in the junk that humans were abandoning in the wild black yonder—everything from nuts and tools to defunct satellites and rocket stages the size of school buses.

In that seminal paper, “Collision Frequency of Artificial Satellites: The Creation of a Debris Belt,” Kessler painted a nightmare scenario: Spent satellites and other space trash would accumulate until crashes became inevitable. Colliding objects would shatter into countless equally dangerous fragments, setting off a chain reaction of additional crashes. “The result would be an exponential increase in the number of objects with time,” he wrote, “creating a belt of debris around the Earth.”

At age 38, Kessler had found his calling. Not that his bosses had encouraged him to look into the issue—”they didn’t like what I was finding,” he recalls. But after the paper came out, NASA set up the Orbital Debris Program Office to study the problem and put Kessler in charge. He spent the rest of his career tracking cosmic crap and forming alliances with counterparts in other nations in an effort to slow its proliferation. His description of a runaway cascade of collisions—which he predicted would happen in 30 to 40 years—became known as the Kessler syndrome.

While the scenario was accepted in theory by NASA officials, nothing much was done about it. Capturing and disposing of space junk would be expensive and difficult, and the threat was too far in the future to trigger much worry. After Kessler retired in 1996, he grew a trim gray beard, peered through his telescope on those clear nights, and waited. “I knew something would happen eventually,” he says.

Then, on February 10, 2009—just a little more than three decades after the publication of his paper—the Kessler syndrome made its stunning debut. Some 500 miles over the Siberian tundra, two satellites were cruising through space, each racing along at about 5 miles per second. Iridium 33 was flying north, relaying phone conversations. A long-retired Russian communication outpost called Cosmos 2251 was tumbling east in an uncontrolled orbit. Then they collided. The ferocious impact smashed the satellites into roughly 2,100 pieces. Repercussions on the ground were minimal—perhaps a few dropped calls—but up in the sky, the consequences were serious. The wreckage quickly expanded into a cloud of debris, each shard an orbiting cannonball capable of destroying yet another hunk of high-priced hardware.

As Kessler received reports of the collision from former colleagues at NASA, he realized that the situation had played out pretty much as he'd foreseen. After all, he had forecast that the first satellite collision would happen around this time between objects of roughly this mass. Like an opening shot in a war, the crash served as a signal that the syndrome had gone from theory to reality. "Some people weren't aware how fast these objects are going," he says. "At those speeds, even something quite small can create tremendous damage."

Almost immediately after the accident, a military unit called the Space Surveillance Network sprang into action. Run by the Joint Space Operations Center at California's Vandenberg Air Force Base, the network uses a system of radar installations and optical sensors to monitor space junk. Before the Iridium-Cosmos incident, it had been tracking 120 active satellites and worrying about an average of five potential collisions, or "conjunctions," per day. The crash took everyone by surprise. "It wasn't even on their list of possibilities that day," an Iridium spokesperson says.

The operations center moved quickly to double its computer capacity. By early 2010, it was keeping a close eye on 1,000 active satellites, 3,700 inactive satellites and rocket pieces, and another 15,300 objects the size of a fist or larger—a level of awareness that revealed a much higher daily average of 75 possible collisions. And that's ignoring the danger posed by the estimated *half-million* smaller pieces of debris the size of a marble or larger. Too small to track from the ground, each of those tiny projectiles is capable of severely damaging a satellite.

Just a month after the Iridium accident, a stray motor chunk hurtled toward the International Space Station. Cruising at an altitude of 220 miles, astronauts aboard the $100 billion laboratory were going about their daily chores at around noon EDT when they received a warning—prepare for possible impact. The crew was directed to scramble into the station's equivalent of a lifeboat, an attached Russian-made Soyuz capsule. It would give them a chance to abandon ship, if necessary. After a few minutes, the motor zipped by, missing the ISS by just a few miles—in space terms, a close call.

Then on December 1, with almost no warning, a small chunk from a different Cosmos satellite hurtled toward the ISS, coming within a mile of a direct hit. Due to its speeding-bullet velocity, even this fragment could have had an impact equal to a truck bomb. "A 10-centimeter sphere of aluminum would be like 7 kilograms of TNT," says Jack Bacon,

a senior NASA scientist charged with keeping the ISS safe. “It would blow everything to smithereens.”

Incidents like these served as clear signs from above that something must finally be done about space junk. Its proliferation threatens not only current and future space missions but also global communications—mobile phone networks, satellite television, radio broadcasts, weather tracking, and military surveillance, even the dashboard GPS devices that keep us from getting lost. The number of manufactured objects cluttering the sky is now expected to double every few years as large objects weaken and split apart and new collisions create more Kesslerian debris, leading to yet more collisions.

NASA’s Bacon puts it bluntly: “The Kessler syndrome is in effect. We’re in a runaway environment, and we won’t be able to use space in the future if we don’t start dealing with this now.”

A Brief History of Space Junk

1962

The Telstar 1 satellite relays the first phone calls and TV signals across the Atlantic. It fails the next year. It’s still out there.

1965

A Gemini 4 astronaut loses a glove on the first US spacewalk. It burns up in the atmosphere a month later.

1979

Skylab’s reentry rattles windows and drops fragments onto the outback in western Australia.

1985

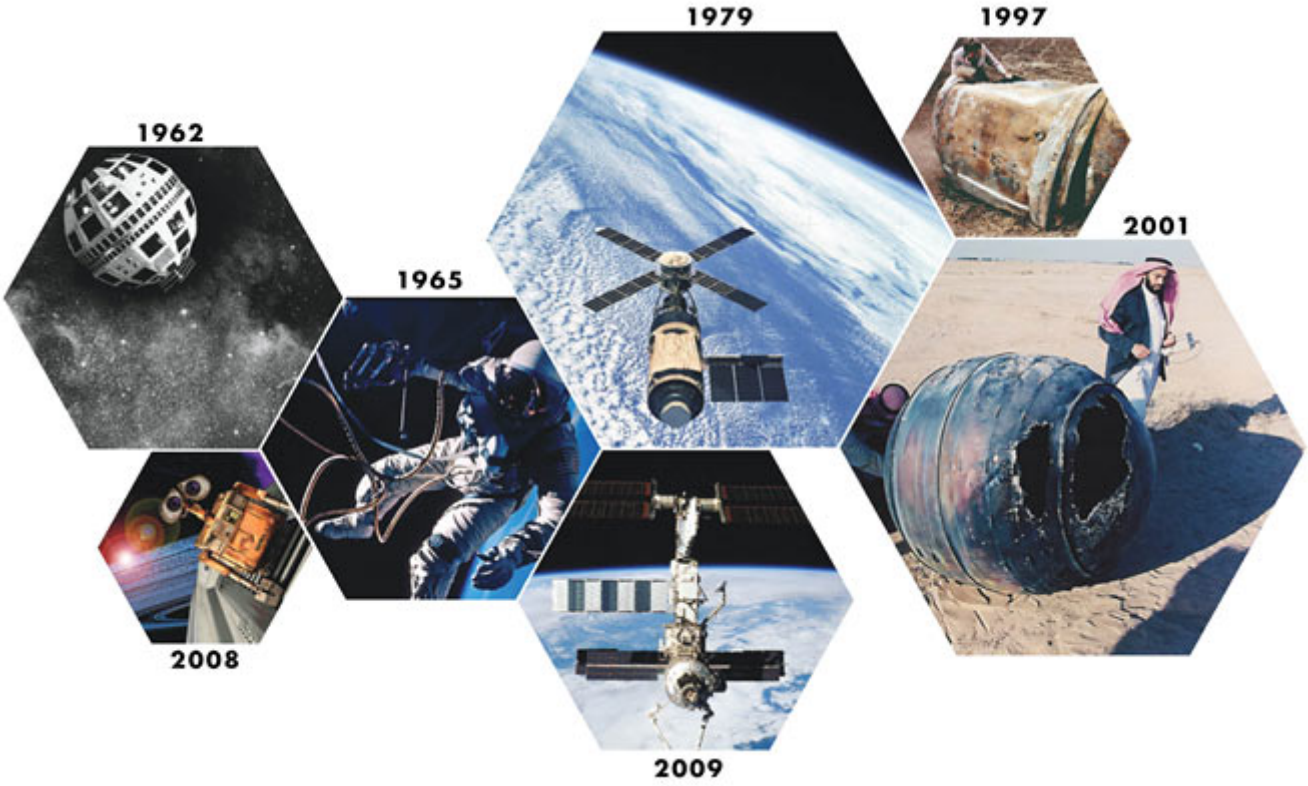
The number of cataloged orbiting debris objects (over 10 centimeters in diameter) reaches nearly 6,500.

1997

A fuel tank from a Delta II rocket smashes into a yard near Georgetown, Texas. Fortunately, no one is injured.

2001

A titanium motor casing from a Delta II rocket crashes into the Saudi Arabian desert.



2005

The number of cataloged debris objects in orbit tops 10,000.

2007

A Chinese test weapon shoots down the Fengyun-1C satellite, creating some 3,000 new pieces of trackable space junk.

2008

Pixar's *Wall-E* depicts a thick belt of space waste circling Earth.

2009

The first satellite collision occurs. Cosmos 2251 hits Iridium 33, creating some 2,100 new pieces of debris.

2009

An object headed toward the International Space Station forces the crew to prepare for an emergency escape.

2010

The number of cataloged debris objects reaches 15,000.

Photos: Wall-E: Pixar; all others: NASA

Since the dawn of the space age, NASA has operated under what it calls the big sky theory—the notion that, given the vastness of space, it's perfectly fine to discard mission waste or abandoned rocket stages up there. After all, these objects would likely fall out of orbit and burn up as they reentered Earth's atmosphere. The only question was when.

Some would take just a few years, while those in higher orbits might not descend for decades. “We didn’t think twice about it,” says former astronaut Bryan O’Connor, now one of NASA’s top safety officers. Russia and other nations have also been launching missions under the same assumption—that even if a giant solar panel happened to fall off the back of a shuttle, you could simply wish it bon voyage.

In the midst of all this complacency, Kessler wasn’t the only voice raising concerns about the big sky theory. Arthur C. Clarke, who in the 1940s conceived of communications satellites, wrote a 1979 novel, *The Fountains of Paradise*, in which all the space junk that had been accumulating “had to be located, and somehow disposed of.” He imagined what he dubbed Operation Cleanup: Space fortresses armed with high-powered lasers would sweep the skies, vaporizing the debris. If we didn’t act, Clarke warned, Earth would be cut off from space and we’d lose the ability to communicate by satellite and explore the heavens. “We would sink back into a dark age,” he wrote. “During the resultant chaos, disease and starvation would destroy much of the human race.”

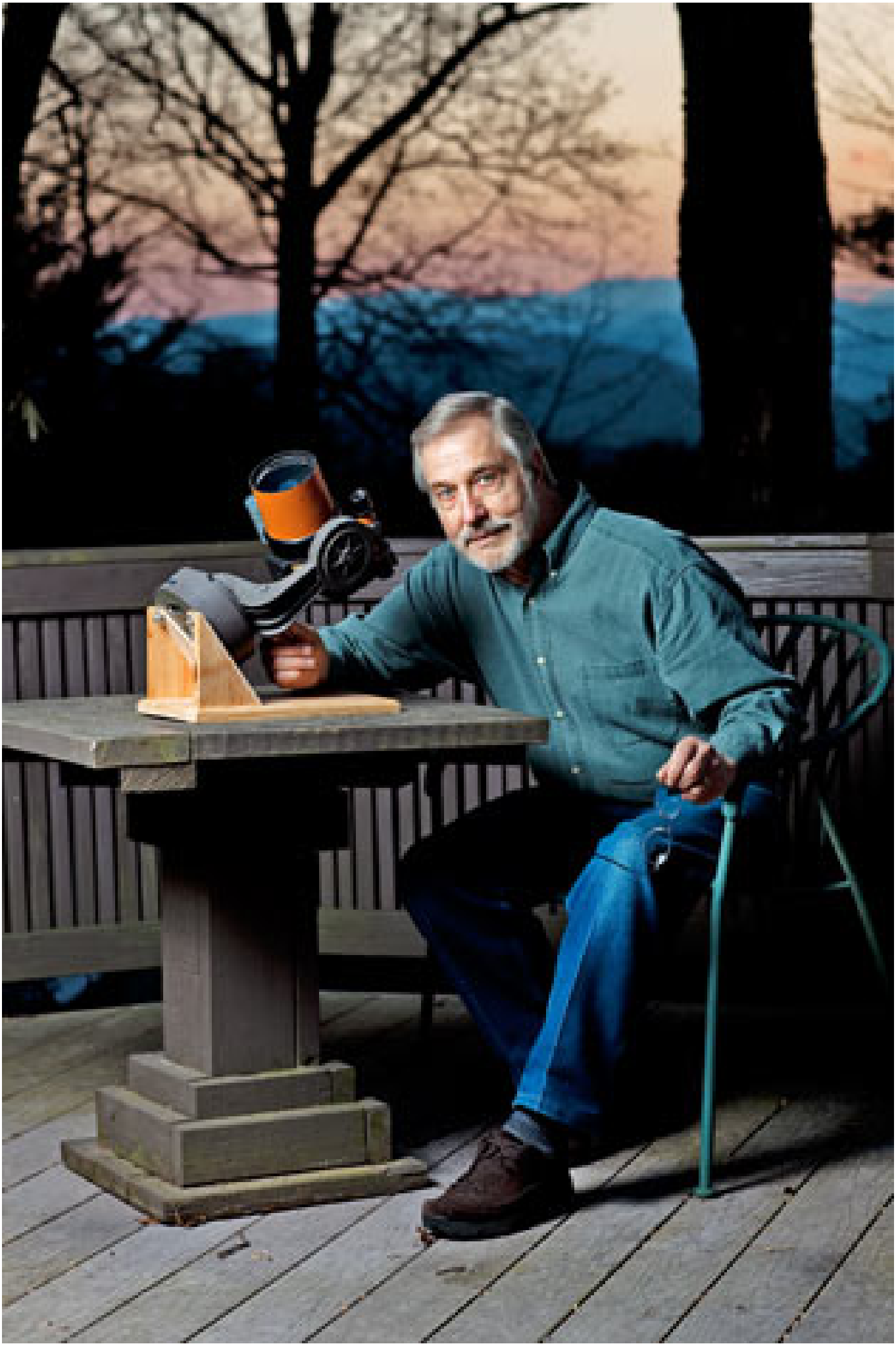
To stave off such a day, Kessler and his colleagues at the Orbital Debris Program Office developed some guidelines to slow the accumulation of space junk. The rules limited what could be abandoned, and they required satellite operators to help clean up the crowded geosynchronous belt 22,400 miles above Earth by maneuvering retired spacecraft into slightly higher “graveyard orbits” out of harm’s way. By 2008, similar guidelines had been adopted by most of the major space agencies around the world.

The new rules did slow the growth of space debris. And thanks to gravity, stuff continued to fall from the sky. Roughly once a day, an object in the official US catalog of debris drops out of orbit and turns to ash on reentry. Once a week or so, an object that’s too big or dense will survive reentry and plunge to Earth, but it typically plops down unnoticed in an ocean or some unpopulated expanse. (There are exceptions: An upper rocket stage once landed in the desert of Saudi Arabia, to the surprise of local shepherds, and in 1997, a steel fuel tank slammed into a yard in Texas.)

Yet much of the progress from the international effort was undone in a single moment. On January 11, 2007, the Chinese government staged a demonstration of its military might by firing a projectile at one of its own retired satellites, the Fengyun-1C, in low Earth orbit. The “kinetic kill vehicle” scored a bull’s-eye, blasting the satellite into 3,000 trackable pieces. (Even though its space program is relatively young, China already

accounts for 31 percent of all debris traceable to specific launches—comparable to the shares of Russia and the US.) It wasn't long before the Chinese test started causing trouble. In May 2009, a roughly 4-inch fragment from the Fengyun explosion whizzed by space shuttle *Atlantis*, which at the time was in the vicinity of the Hubble Space Telescope on a repair mission. Had it struck either one, it could have done catastrophic damage.

The Chinese debris, combined with the Iridium-Cosmos collision, finally revealed the bankruptcy of the prevailing philosophy governing space. "The big sky theory is no longer a viable concept for space operations," says Chris Moss, chief of strategy for the military's Joint Space Operations Center. Officials at NASA now acknowledge that orbital debris is the biggest threat to the International Space Station. And the call for action is global, says Heiner Klinkrad, the top debris expert at the European Space Agency: "Debris removal is the only cure to the Kessler syndrome."



Donald Kessler, the dean of space debris.
Photo: Anna Knott

Last December, at a Marriott not far from Darpa's headquarters in Arlington, Virginia, about 175 people filed into a meeting hall to take part in the first-ever International Conference on Orbital Debris Removal, sponsored by Darpa and NASA. The gathering attracted a group of idealistic innovators, members of a self-proclaimed "debris community" that no one knew existed in such numbers. "This reminds me of Boy Scouts, with their motto 'Leave no trace,'" said Patrick Moran, an engineer with California-based Aerospace Corporation. "The same rigor must now be imposed on space." The three-day meeting featured an address by none other than Donald Kessler, the dean of space debris. The official purpose of the conference was an open "call for information," but in some respects it resembled an episode of *American Idol*, with rocket scientists as contestants—and with Kessler, his old NASA colleagues, and Darpa officials serving as judges. Darpa had had only scant involvement with the debris issue, but the agency's director of tactical technology, David Neyland, kicked off the conference by noting that Darpa was created "to look across different tech domains to prevent surprises, and orbital debris is a surprise"—one with national security consequences for US spy satellites.

As in the early rounds of a talent contest, many of the acts didn't seem quite ready for prime time. A librarian from a university about 90 miles from Roswell, New Mexico, proposed launching giant sticky space balls that would adhere to objects and drag them out of orbit. A grad student outlined his plan to attach sails to the space trash, gently floating the pieces earthward. One engineer from Colorado insisted that a giant inflatable doughnut would do the trick by bouncing rubbish down into the atmosphere.

Then there were the inevitable laser-based approaches. A former Los Alamos National Lab scientist presented a long-standing plan involving a giant laser station on a Hawaiian peak. A professor from Alabama proposed zapping debris with lasers attached to satellites, causing the junk to plummet into the atmosphere.

But three of the plans seemed to hold real promise. The first came from 72-year-old Jerome Pearson, an engineer best known for imagining the space elevator concept in the 1970s. Pearson showed up with an animated demo that looked remarkably like the old *Space Invaders* videogame. Now president of South Carolina-based Star Technology and Research, he proposed a seven-year mission in which a dozen suitcase-sized

spacecraft would piggyback on other launches. Every vehicle would hold 100 lightweight nets, each as big as a house. Onboard video cameras would allow ground crews to drape the nets over hunks of junk by remote control. The craft would drag the debris out of orbit, then return to search for more. Pearson claimed his system could capture 2,500 or so objects in the most crowded and dangerous bands of low Earth orbit. The estimated price tag: $240 million.

The second plan came from NASA's Bacon, who outlined a scheme to launch a 10-ton mother ship that would hold 10 additional tons of mass-produced nanosatellites, stored like larvae in a honeycombed nest. Once released, the nanosats would approach objects, toss lightweight nets over them, and then tow the debris into the atmosphere. Bacon's plan is suitable mainly for pieces of junk lighter than 2 pounds in low Earth orbit. Heavier items—rocket stages, satellites—would remain. He estimates that each launch of a mother ship would cost $100 million, with as many as 12 missions needed.

The third concept was from Rob Hoyt, CEO of Tethers Unlimited, a Seattle-area space contractor. For the past 15 years, Hoyt has been developing a system called Rustler, to "round up space trash [for] low Earth orbit remediation." He envisions midsize space vehicles—400 pounds or so—piggybacking on satellite launches. Once in orbit, such a craft would sidle up to junk and attach an electrodynamic tether—a wire-mesh kite tail up to 6 miles long—then send an amp of current through the material. The current would interact with Earth's magnetic field, producing a drag effect and lowering the debris into the atmosphere. Hoyt's approach drew praise from Kessler and others for its simplicity and relatively low price. According to Hoyt, a test mission to take out a few tons of trash could cost just tens of millions of dollars.

Which brings up the problem of how to pay for deploying any of these technologies. One idea would be to assess a fee on commercial satellite companies—which would benefit, after all, from safer skies. Eventually, aerospace firms may equip their satellites with built-in disposal devices so they can be pulled out of orbit when their missions are complete. Hoyt has just such a product, called Terminator Tape, a 3-pound package containing a tether that can be unfurled automatically using the spacecraft's own electronics.

By the end of the conference, there was a sense that removing the junk is actually possible. "I've gone from being totally skeptical to thinking maybe something will work," Kessler says. "We can bring things down; it's just going to cost a lot."

Eric Christiansen knows just how damaging space junk can be. From his office at NASA's Johnson Space Center in Houston, he directs a team that studies what happens when orbiting objects get whacked, slammed, pierced, and pummeled. His lab has a wonderfully badass name: the Hypervelocity Impact Technology Facility. The impacting actually happens a few hundred miles away, at NASA's testing range near White Sands, New Mexico. There, technicians operate a cannon that uses gunpowder and pressurized hydrogen to fire plastic slugs at shields and panels. Just like real space junk, the projectiles can approach speeds of 5 miles per second.

Christiansen and his colleagues study the results and use their findings to help develop stronger materials and designs for spacecraft. They're also working on shields that might provide protection from stray projectiles. "This is the lightest shield that will stop a 2-centimeter projectile," he says, pointing to a multilayer Kevlar and ceramic panel for the ISS.

Some of the mangled hardware is on display at the space center. The most treasured of these objects is a piece of window glass from a 1983 *Challenger* mission. Dinged by debris, it entered the collection when Kessler worked at NASA. "Don gave this to me," Christiansen says, "and he said, 'You protect this and leave it to the next guy.'"

Christiansen collaborates with the Orbital Debris Program Office, which does much of its work in a corrugated metal building. The office—run by Kessler's successor, Nicholas L. Johnson—is improving its ability to forecast crashes and spot some of the smallest space bits using a huge telescope on a Chilean mountaintop, which will be joined in 2011 by a new scope on a Pacific atoll.

This happens to be the day after the Obama administration announced it was canceling Constellation, NASA's grand plan to return astronauts to the moon by 2020. Along with the final phase-out of the Space Shuttle Program and the move to privatize launches, it all seems to represent a massive resetting of NASA's priorities. Perhaps that makes it the opportune time to get serious about tidying up the skies. The main obstacle, of course, is funding. But included in NASA's proposed 2011 budget is a first-ever provision to award $400,000 research grants for orbital debris removal and other projects. The allocation would be part of a new "mission directorate" called Space Technology, funded to the tune of almost $5 billion over the next five years. "We're hoping NASA will be able to take charge," Star Technology's Pearson says.

For Donald Kessler, now 70, that would be welcome news. Standing on his back porch, he doesn't need his telescope to spot the man-made spacecraft whizzing overhead. "Anyone can see satellites with the naked eye," he says. "Several pass by every hour." Sooner or later, he says, word will arrive that another one has been smashed and shattered, and the fragments will escalate the danger to all space missions. The man with the syndrome named after him will keep watch and wait for the next call.

Evan I. Schwartz (www.evanischwartz.com) *wrote about the invention of television in issue 10.04.*