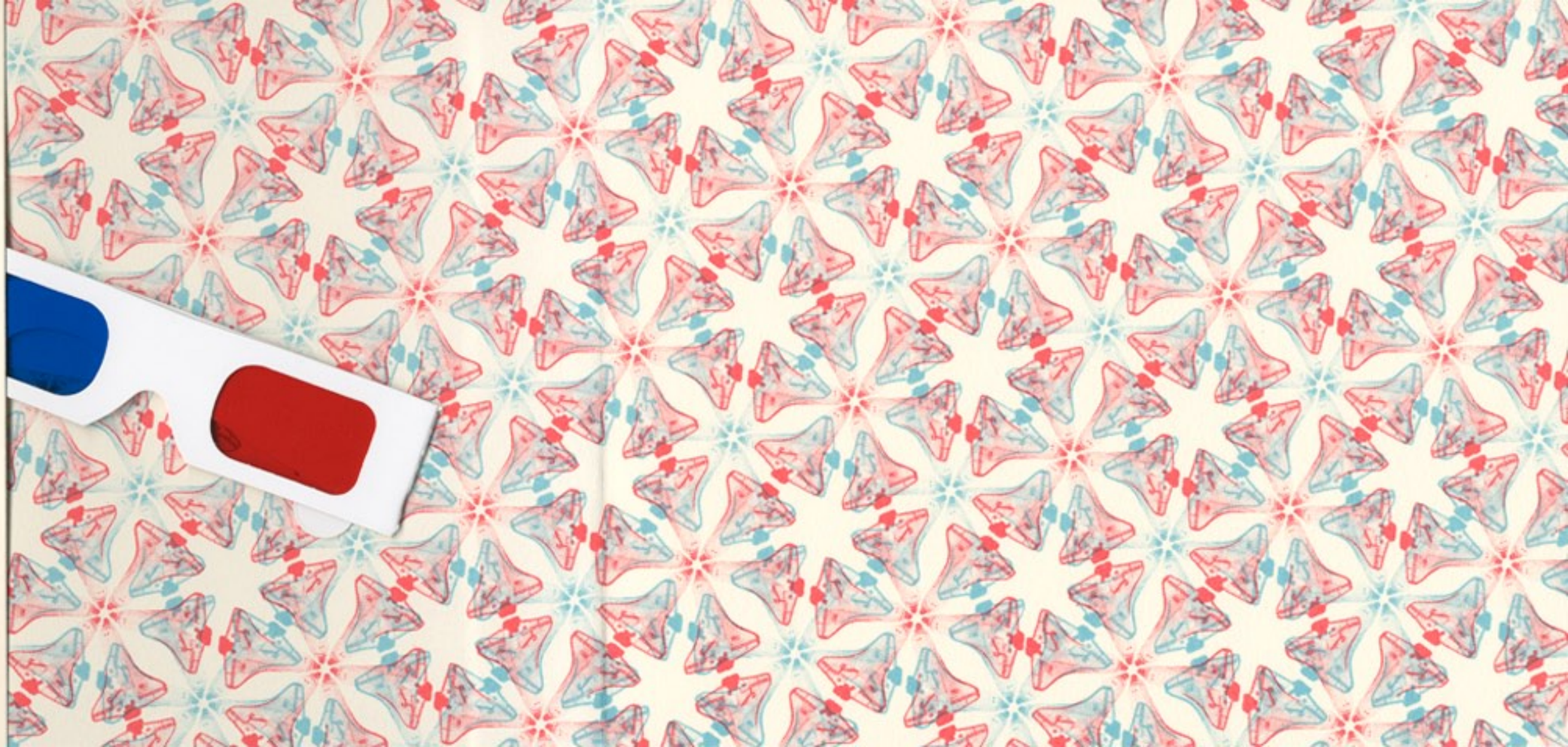
ORBITAL DEBRIS SIMULATOR



ORBITAL DEBRIS SIMULATOR

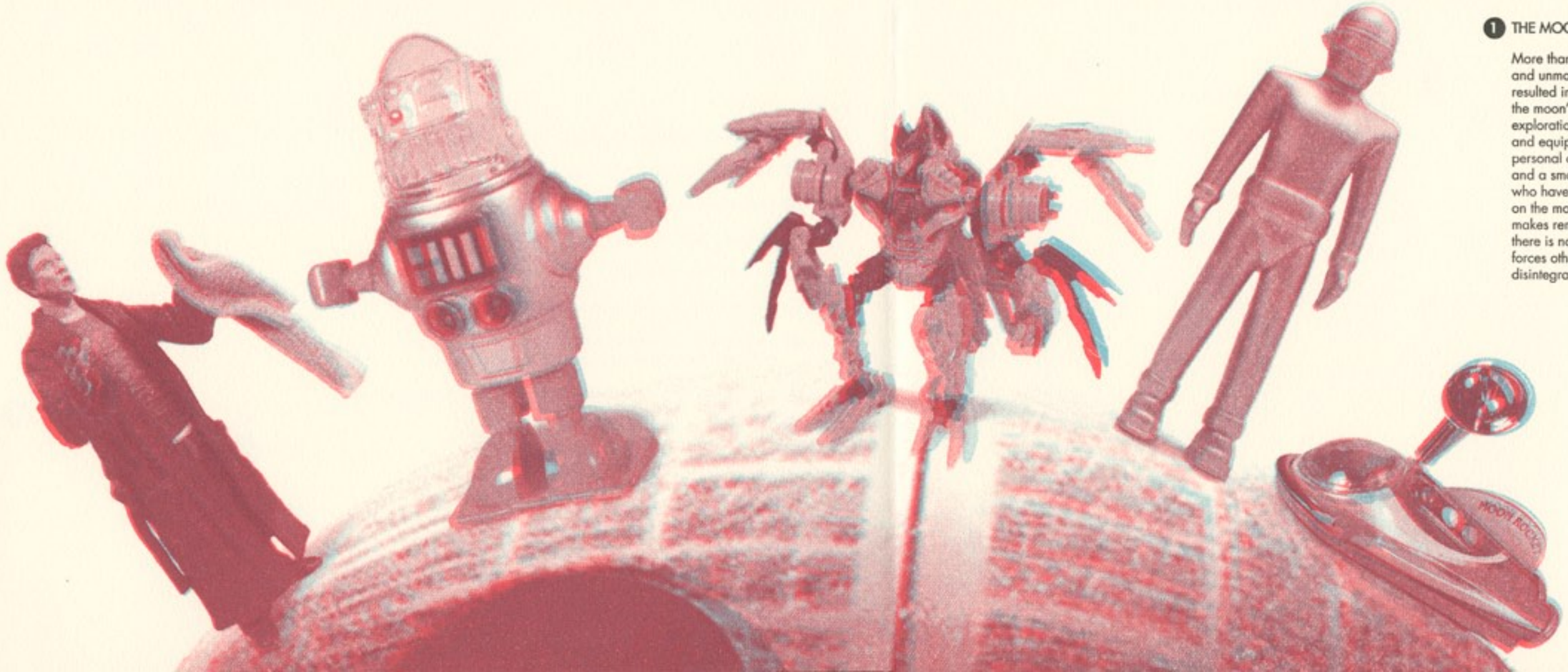
ORBITAL DEBRIS

Orbital debris consists of defunct objects in earth's orbit created by people in the process of space exploration, such as used rocket stages, defunct satellites, explosion and collision fragments, coolant released by nuclear powered satellites, and nuts and bolts. These items eventually burn up when they fall to earth, but while some items in low orbit will fall in a few weeks, others in high orbit may orbit for centuries. Since the trajectories of spacecraft pass through these orbits, collisions with debris at standard orbital speeds of 15,000 – 25,000 miles per hour are a serious concern.

The vast majority of the estimated tens of millions of pieces of space debris are small particles, like paint flakes and solid rocket fuel slag, the impacts from which cause erosive damage similar to sandblasting. The damage from pieces smaller than one centimeter can often be mitigated by spacecraft shielding. Collisions with larger objects are avoided by moving the spacecraft, which requires careful tracking of the debris. Of the estimated 600,000 objects larger than one centimeter only 19,000 are large enough to be tracked, leading to wide uncertainties in estimations of quantities and trajectories.

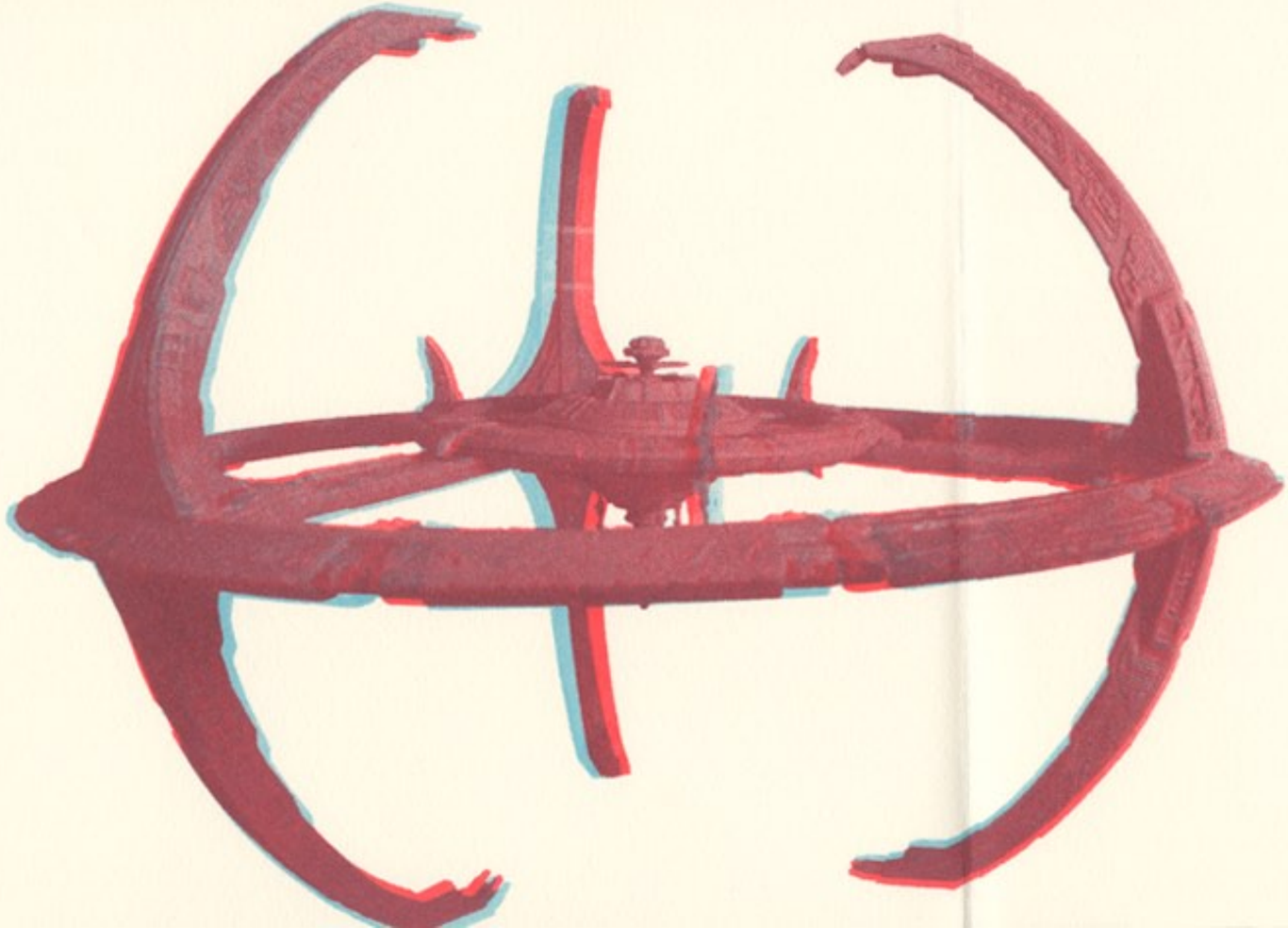
The following pages describe orbital debris (circa January 2010) through a tour of the environment from the moon to the earth, with key features indicated along the way.

1. The Moon [233,815 miles from earth]
2. Geosynchronous Orbit [22,236 miles from earth]
3. Medium Earth Orbit [1,240 – 21,611 miles from earth]
4. Low Earth Orbit [100 – 1,240 miles from earth]
5. Low Earth Orbit: Collisions [497 – 530 miles from earth]
6. Low Earth Orbit: The A-Train [438 miles from earth]
7. Low Earth Orbit: The Hubble Space Telescope [360 miles from earth] & the Long Duration Exposure Facility [316 miles from earth]
8. Low Earth Orbit: The International Space Station [199 – 216 miles from earth]
9. Earth



1 THE MOON

More than 70 missions to the moon (manned and unmanned, orbital and landing) have resulted in 374,786 pounds of objects left on the moon's surface, including 'Moon Buggy' exploration vehicles, numerous ship parts and equipment, and commemorative and personal objects such as photos, golf balls and a small statue memorializing astronauts who have died on missions. They will remain on the moon for eons because their weight makes removal costly and impractical, and there is no atmosphere or any other erosional forces other than asteroid collisions to disintegrate them.



2 GEOSYNCHRONOUS ORBIT

Objects in geosynchronous orbit travel around the earth at the same rate as the earth's spin, so that the object will return to exactly the same place above earth at the same time each day. If such an object is directly above earth's equator, in 'geostationary' orbit, it will constantly maintain the same position relative to the earth and so will appear to hover in the sky. Since it is relatively easy to aim signals at such fixed objects, this orbit is typically used for telecommunications satellites to reliably and continuously relay information.

When they reach the end of their service lifetime, satellites at this distance—over 22,000 miles past the orbiting altitude of the International Space Station—cannot be easily retrieved. Instead they are moved to 'graveyard orbit' with the last of their fuel supply, about 180 miles past geosynchronous orbit, where they are less likely to interfere with operational satellites below. Most of the several hundred defunct satellites now in graveyard orbit were programmed to discharge batteries, dump coolant, and release compressed gasses and any other energy source to prevent explosions. But some have exploded nonetheless, which can spray debris toward the operating satellites and make collisions between the defunct satellites more likely. Any objects in geosynchronous orbit or higher will likely remain orbiting for hundreds of years.

3 MEDIUM EARTH ORBIT

Launched into medium earth orbit in 1958 as the fourth artificial earth satellite, Vanguard 1 is the oldest piece of orbital debris, and is predicted to remain in orbit for 240 years. About the size of a grapefruit, Vanguard 1 tested the effects of space on satellite systems and assisted in earth measurements. It was joined by the Telstar satellites in the early 1960s, which relayed the first telephone calls, fax images, and live transatlantic television feed through space. These early satellites were defunct by 1964 and are still in orbit.

Today, medium earth orbit is typically used for navigational satellites. 20-30 satellites of the Global Positioning System orbit at an altitude of 12,550 miles, and broadcast signals that GPS receivers use to provide three-dimensional location (latitude, longitude, and altitude) and precise timing anywhere on earth with an unobstructed view of four or more of the GPS satellites. The GPS satellites orbit at different directions and angles to maximize coverage of the earth's surface.

Objects orbiting earth can go in any direction—over the poles, around the equator and at any angle in between. The orbits can be perfectly circular, or they can be elliptical, moving farther from or closer to the earth at different points.

4 LOW EARTH ORBIT

Most orbital debris resides within low earth orbit, where the most human space activity takes place. With the exception of the lunar flights of the Apollo program, all manned spaceflights have been in low earth orbit, including all space shuttle and space station missions.

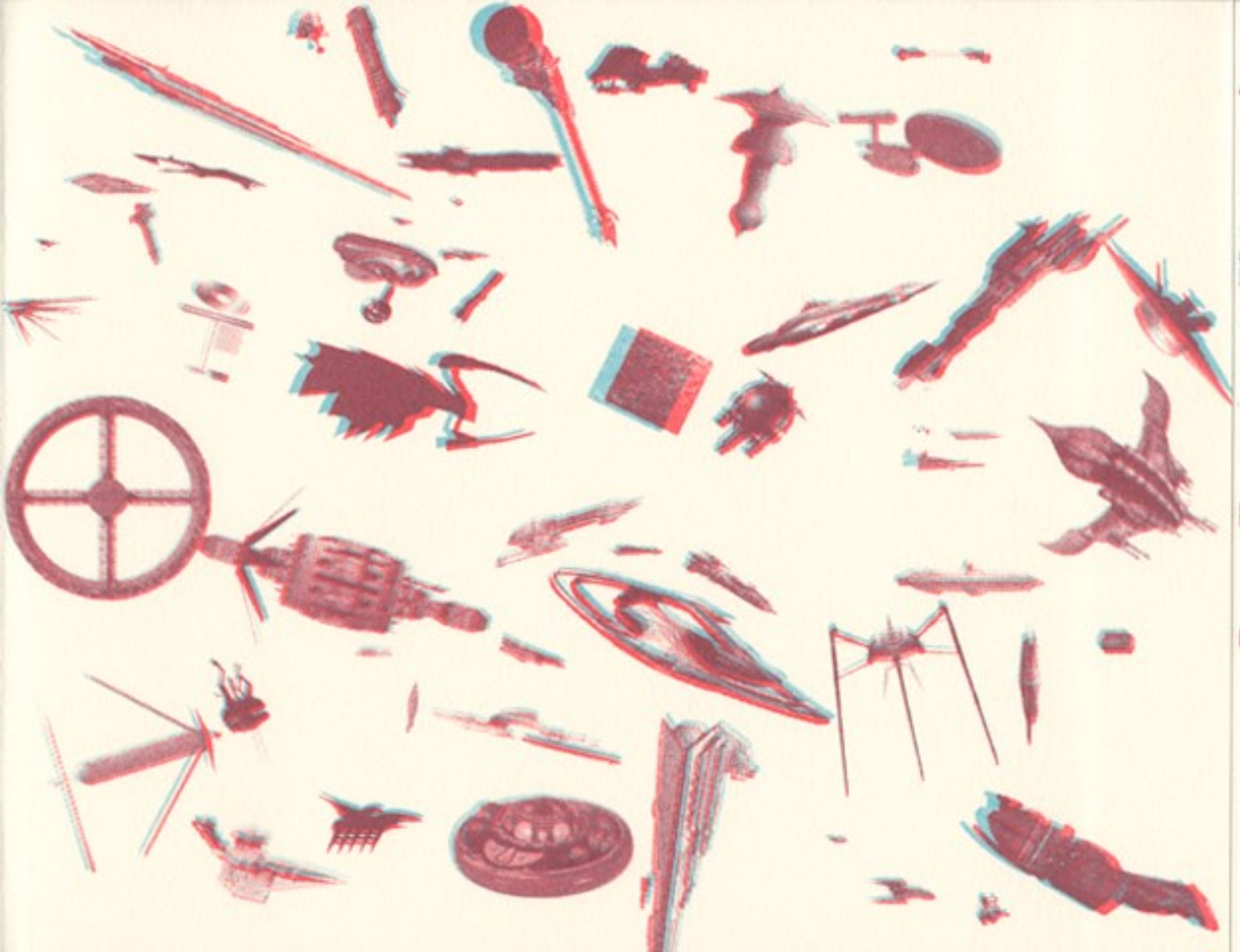
A majority of artificial satellites are placed in low earth orbit, since it requires less energy to place a satellite into a low earth orbit and the closer proximity allows the use of less powerful amplifiers for successful communication transmission to earth. Satellites in low earth orbit also benefit from the protection of the earth's magnetic field; solar cells, integrated circuits and sensors can be damaged by radiation and so satellites in higher orbits require more radiation shielding. Satellites in low earth orbit travel at about 17,025 miles per hour, making one complete revolution around the earth in about 90 minutes.

5 LOW EARTH ORBIT—COLLISIONS

There have been several major impact incidences in low earth orbit, creating large spreading clouds of orbital debris. In January 2007, China intentionally shot a Fengyun-1C weather satellite at an altitude of 530 miles for target practice, creating millions of pieces of debris—over 35,000 pieces one centimeter or larger, and more than 2,300 pieces large enough to be tracked.

And in 2009, two large communications satellites, the Iridium 33 American satellite and the non-operational Russian Kosmos 2251, collided 497 miles over Siberia, destroying both and creating more than 600 pieces of debris.

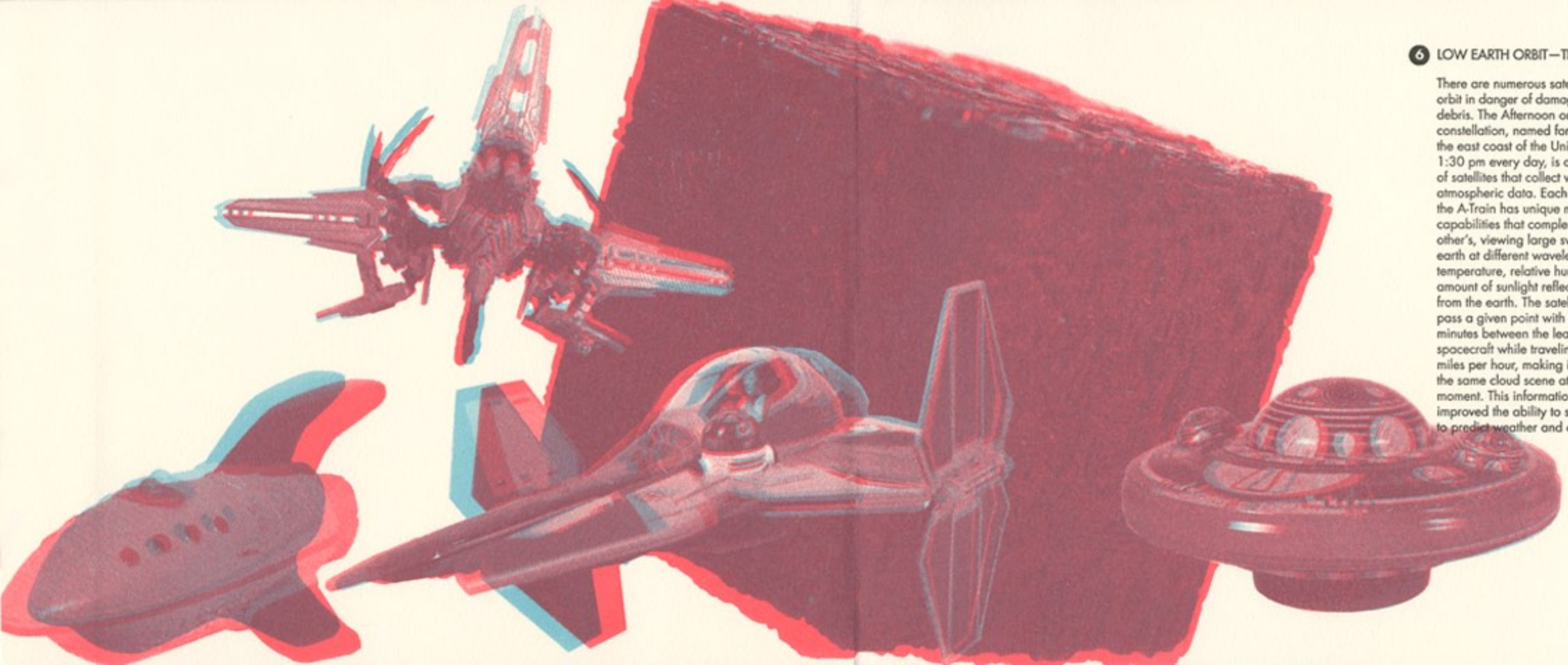
The greatest concentration of orbital debris is around the altitudes where these collisions took place, and debris from these incidents will likely persist for decades.



5.1 LOW EARTH ORBIT —THE KESSLER SYNDROME

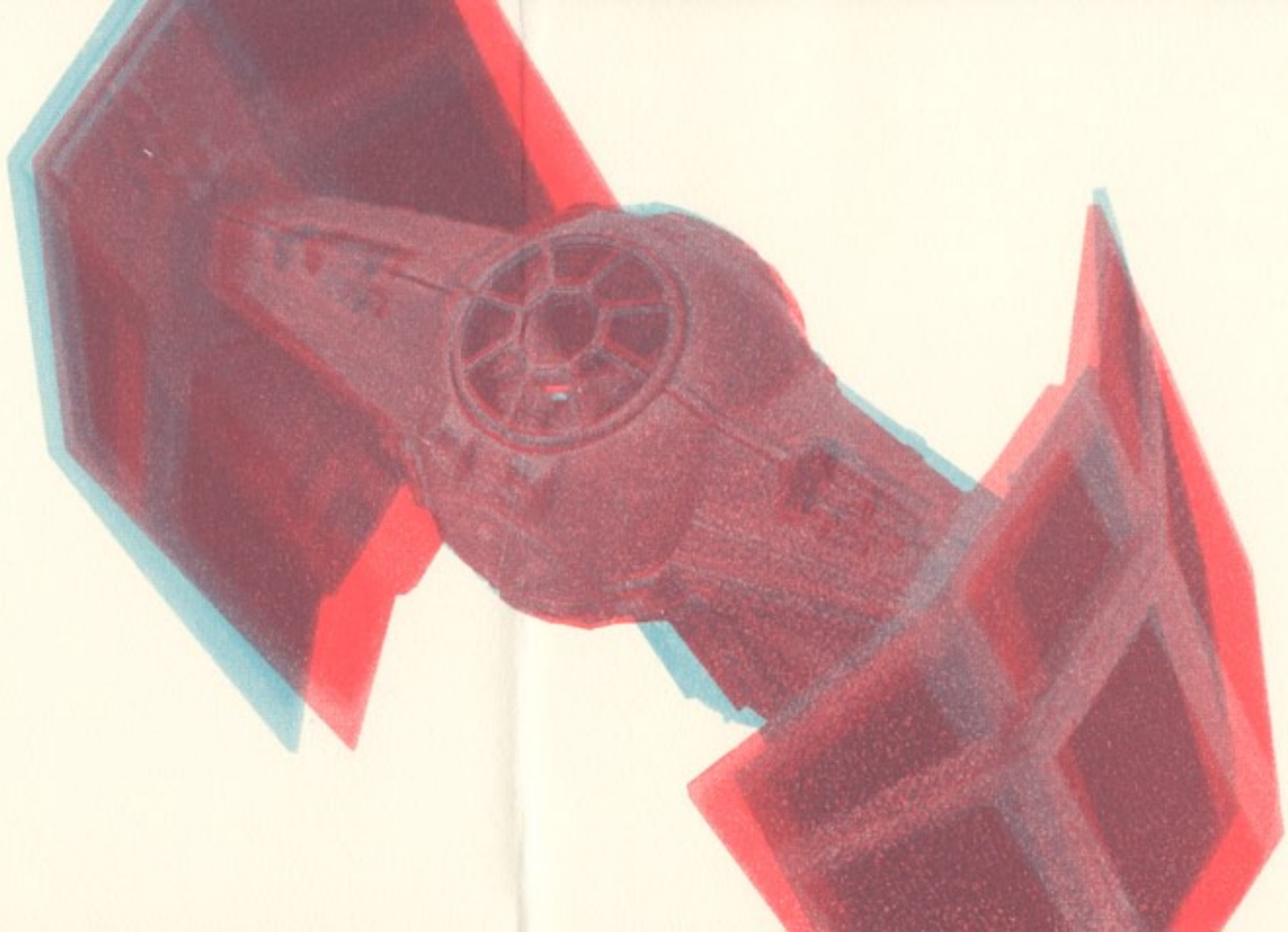
A major concern about orbital debris is the scenario forecast by NASA scientist Donald J. Kessler in 1978, in which the volume of debris in low earth orbit becomes large enough that objects strike each other frequently, creating more debris and further impacts, resulting in a runaway cascade of collisions.

This escalating debris cloud could eventually render low earth orbit prohibitively dangerous or impassible, and the use of satellites and space exploration infeasible for generations.



6 LOW EARTH ORBIT—THE A-TRAIN

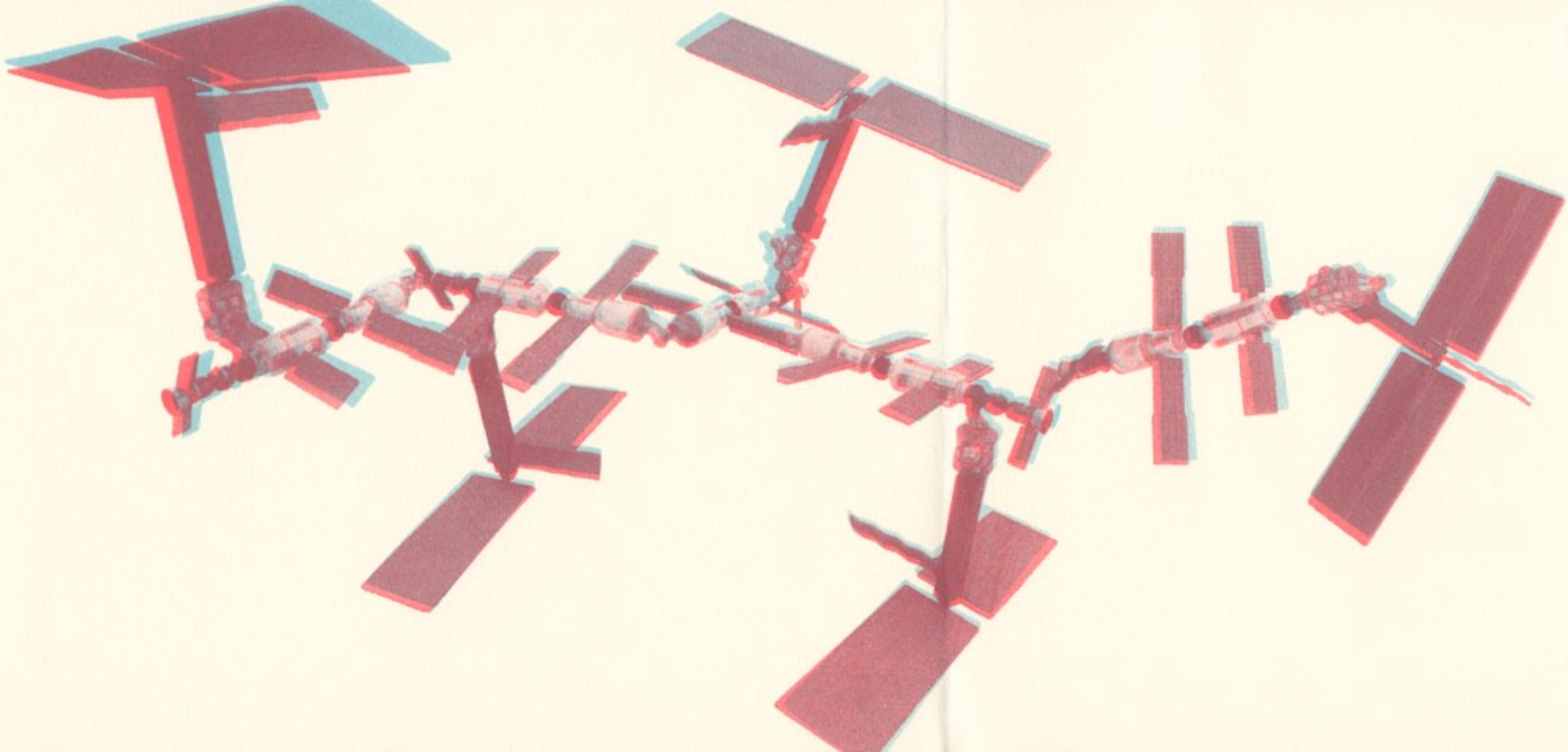
There are numerous satellites in low earth orbit in danger of damage by orbital debris. The Afternoon or 'A-Train' satellite constellation, named for its passage over the east coast of the United States at 1:30 pm every day, is a tight formation of satellites that collect weather and atmospheric data. Each satellite within the A-Train has unique measurement capabilities that complement each other's, viewing large swaths of the earth at different wavelengths to observe temperature, relative humidity and the amount of sunlight reflected back to space from the earth. The satellites in the A-Train pass a given point with approximately 15 minutes between the leading and trailing spacecraft while traveling at over 15,659 miles per hour, making it possible to view the same cloud scene at nearly the same moment. This information has greatly improved the ability to study air quality and to predict weather and climate change.



7 LOW EARTH ORBIT
—THE HUBBLE SPACE TELESCOPE
& THE LONG DURATION EXPOSURE
FACILITY

The Hubble Space Telescope's orbit outside the distortion of earth's atmosphere allows it to take extremely sharp images with almost no background light. Many Hubble observations have led to breakthroughs in astrophysics, such as determining the rate of expansion of the universe. Orbiting approximately 360 miles above the earth's surface, Hubble completes an orbit around earth every 96 minutes, traveling at 29,000 miles per hour. The telescope has been struck numerous times by orbital debris. A meter-wide radiator plate which has been installed on the Hubble since its launch in 1990 has been used for debris-hit analysis; over 680 small impact marks were identified and documented on the this plate so far.

The Long Duration Exposure Facility (LDEF) was a cylindrical, bus-sized space experiment rack that exposed various material samples and experiments to the outer space environment for almost 6 years. Launched in 1984 by the Shuttle Challenger, it completed 32,422 earth orbits at an altitude of 316 miles and was retrieved by the Shuttle Columbia in 1990. The experiments contributed greatly to the understanding of orbital debris impacts on different kinds of materials.

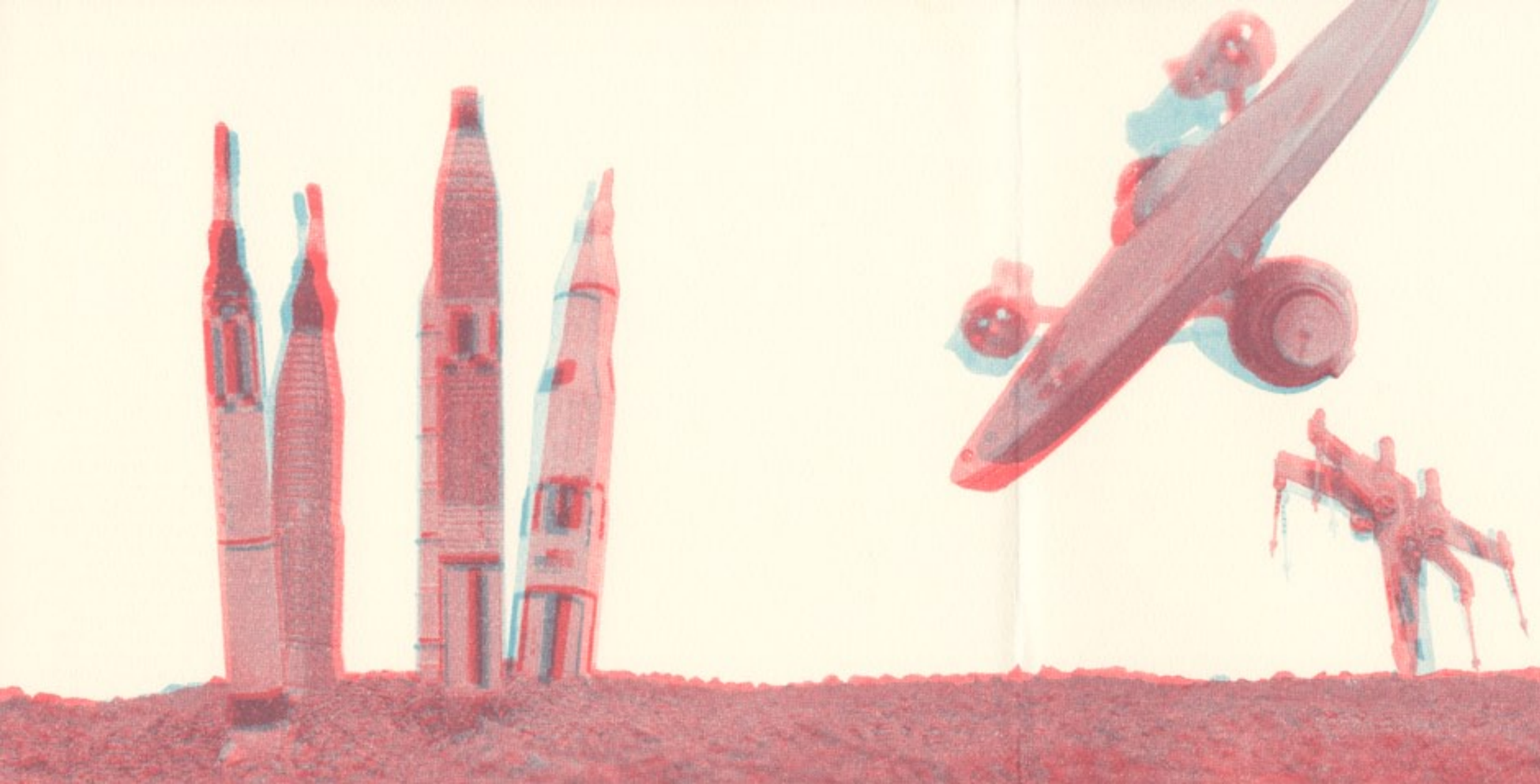


8 LOW EARTH ORBIT —THE INTERNATIONAL SPACE STATION

The largest artificial satellite orbiting the earth (as of 2010), the International Space Station is a research facility conducting experiments in biology, human physiology, physics, astronomy and meteorology. The unique capabilities of the station allow for the development of spacecraft systems for further space exploration. It has had continuous human occupation since 2000.

While the main spacecraft body is protected from microdebris by a thin layer of metal foil, solar panels and observation instruments remain exposed and so are continually worn by debris and micrometeorites. Larger space debris objects likely to impact the station are avoided by altering the station's orbital altitude, in a 'Debris Avoidance Maneuver' (DAM), which is not uncommon. If a collision threat is identified too late to move the spacecraft, the crew performs a partial station evacuation by retreating into an escape module until the threat passes.

The International Space Station gets rid of waste materials by filling a Progress vehicle and sending it down to be burned on atmospheric reentry (and/or to crash into the ocean). The station occasionally contributes to the growth in the amount of orbital debris: during a space walk in 2008 to repair a solar panel, an astronaut accidentally lost a tool bag, which orbited earth for more than eight months before burning up in the atmosphere.

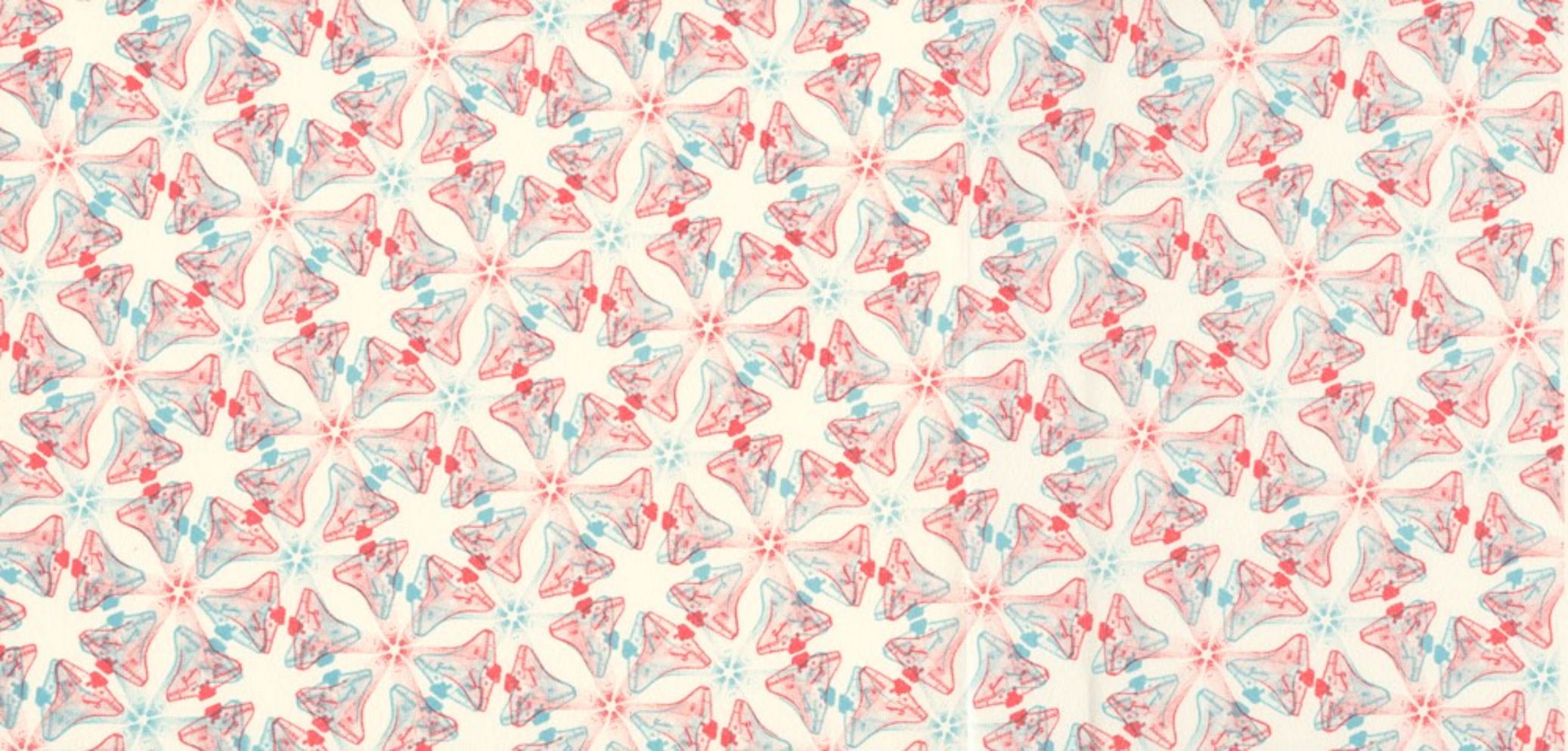


9 EARTH

While most debris from space burns upon atmospheric reentry, some does not burn completely and survives to hit the earth's surface. Where possible, large objects not likely to completely burn up in the atmosphere are maneuvered to crash at the 'Spacecraft Cemetery,' a remote area in the southern Pacific Ocean northeast of New Zealand. Pieces of the defunct Mir space station fell here in 2001, and are routinely joined by waste-filled Progress cargo ships from the International Space Station.

Some pieces of debris fall without such planning, and during the past 40 years an average of one cataloged piece of debris fell back to earth each day. They include: titanium tanks used for drinking water from the Gemini V spacecraft (Australia, 1965), a secret Soviet naval spy satellite with compact nuclear reactors in its radar antennas (Canada, 1978), the motor casing and propellant tanks from a Delta 2 third-stage rocket (Texas and Saudia Arabia, 2001), and miscellaneous debris from a U.S. Navy spy satellite (northwestern United States and Canada, 2008).

One famous example is the 77-ton space station Skylab crashing to earth in 1979, spreading pieces over the Indian Ocean and around the town of Esperance, Western Australia.



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This is 38 in an edition of 75

Heidi Neilson

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IMAGES:

Introductory graphic based on NASA debris visualization

1. Arthur Dent, Robbie the Robot, Soundwave Transformer (c.2009) in robot form, Gort, vintage Japanese 1950s Moon Rocket
2. Deep Space Nine space station
3. Cylon raider model, Spaceship X 100, the starship Enterprise, Deep Space Nine space station
4. Obi-wan Kenobi's Jedi Starfighter, the Nebuchadnezzar, Soyuz spacecraft, the space shuttle Discovery with solid rocket boosters and external tank, Soundwave Transformer (c.2009) in cybertronian jet form, Imperial Shuttle, Cylon Raider, Crystal Hawk Mars Mission Lego ship, Darth Vader's TIE Fighter, the starship Enterprise, lego Millennium Falcon, Klingon Battlecruiser, Spaceship X 100
5. a variety of spaceships
6. Planet Express Ship, Soundwave Transformer (c.2009) in satellite form, Obi-wan Kenobi's Jedi Starfighter, Borg cube, Mars Quest Flying Saucer
7. the TARDIS, Darth Vader's TIE Fighter
8. the International Space Station
9. Apollo-era rockets, the starship Enterprise, X-Wing Fighter