Space Debris–History and Implications: A Joint Functional Component Command for Space (JFCC SPACE) Solution

Jerry Hill, *Senior Science Advisor, Avum, Inc.* and Dustin Kramer, *Research Engineer, Avum, Inc.*

Abstract—Objects of varying sizes shapes, and origins, referred to as space debris, or space junk, have been accumulating in Earth orbit for over half a century. This paper, written from the perspective of Avum, Inc.'s Senior Science Advisor Jerry Hill, discusses sources of space debris and the implications of this debris to working near Earth space vehicles and orbiting laboratories.

1 Background

In October, 1957, I was a young college student of 17 with a head for planets, stars, solar systems and, at that time, the little known Science of Cosmology. On my drives home from Hope College, a small Liberal Arts school located in the placid town of Holland on western Michigans central coast, I would ponder my future and which path my life would take. My mind was awash in Mathematics, Physics, and the schools one and only Astronomy course, as I made the 70-mile drive home each Friday night...

My weekend drive home was not unusual, but on one particular Friday evening, the 4th of October, 1957, the pop music to which I was listening was interrupted with an eerie beep, beep, beep from a source announced as being a first ever artificial Earth orbiting satellite, called Sputnik. The Soviet Union had launched the first artificial satellite into Earth orbit. The news was scintillating to my young mind, a mind filled with wonder at the planets of the Solar System; their names, mass, distance from the Sun and how many moons they had.

Only two years earlier a very first satellite launch had been the subject of a Science Fiction TV show that I had watched. I was completely fascinated by the prospect of such an event. Little did I know at that time how close mankind was to that very achievement.

In the years after graduation from college, I was to spend 4 years as an officer in the Air Force where I would learn computer programming. This was, mind you, in a world where drives of a hundred miles or farther were common in reaching the nearest computer.

After serving as an Air Force computer systems instructor, training officers, such as those employed by NORAD in Cheyenne Mt. near Colorado Springs, I was to continue my career in Sunnyvale, California. Here I designed and wrote code for scheduling computer programs that were to send commands to a gradually increasing number of on board satellite systems, and download payloads from low earth orbit and geocentric satellites for the Air Force.

- *J. Hill is responsible for Avum's Program Execution and Life-Cycle Engineering. E-mail: jhill@avum.com*
- *D. Kramer is a Research Engineer at Avum, Inc., playing an integral role on the company's Research and Development team. E-mail: dustinkramer@avum.com*

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This background subsequently led to my consulting for the Air Force Satellite Control Facility (AFSCF), including trips to all seven Satellite Tracking stations worldwide, the most distant from Sunnyvale being half way around the world at the Seychelles Islands located in the Indian Ocean. This assignment was followed by my leading a project to upgrade the ground telemetry system supporting polar satellite launches from Vandenberg Air Force Base. At no time did it ever occur to me and most, if not all other of my contemporaries that these satellites and associated booster rockets remaining in orbit after their useful life, could be viewed as a navigation hazard to future astronauts.

Now fast forward to the 1990s. I was managing technical staff who worked on such JPL projects as the Magellan mission to map the surface of Venus, the Mars Observer, the Galileo Jupiter probe, and the Cassini probe to Titan, Saturns largest moon. These missions followed my managing the somewhat less spectacular, but no less important oceanographic satellites such as Topex Poseidon and Jason that map the surface temperature and currents of the Earths oceans. These satellites provided scientists a greater understanding of our home planet. Scientific data representing virtually every square foot of our oceans, included down-linked data consisting of infrared radiometer and radar altimeter measurements of ocean surface temperature and height differential accurate to within one centimeter. These data were, and are applied to predicting phenomena such as El Niño and La Niña.

In retrospect, I find it nothing short of amazing how routine this all became to me and to hundreds or thousands of my contemporaries; scientists and system analysts, representing over a dozen countries now involved in similar activities.

However, we have, in the exuberance of repeated, almost routine success in achieving a growing number of satellites launched into Earth orbit over the years, given very little, if any thought to the rapidly increasing residual debris now orbiting the planet, as shown in Figure 1 on the next page. As a result we are learning that, contrary to popular belief, space, at least near-Earth space is not nearly as expansive or as empty as we might like to believe.

2 Problem

These activities resulted, and continue to result in hundreds of satellites, rocket boosters, nuts, bolts and other discarded paraphernalia to remain in orbit to clutter the space surrounding our planet with what has become recognized as a potential

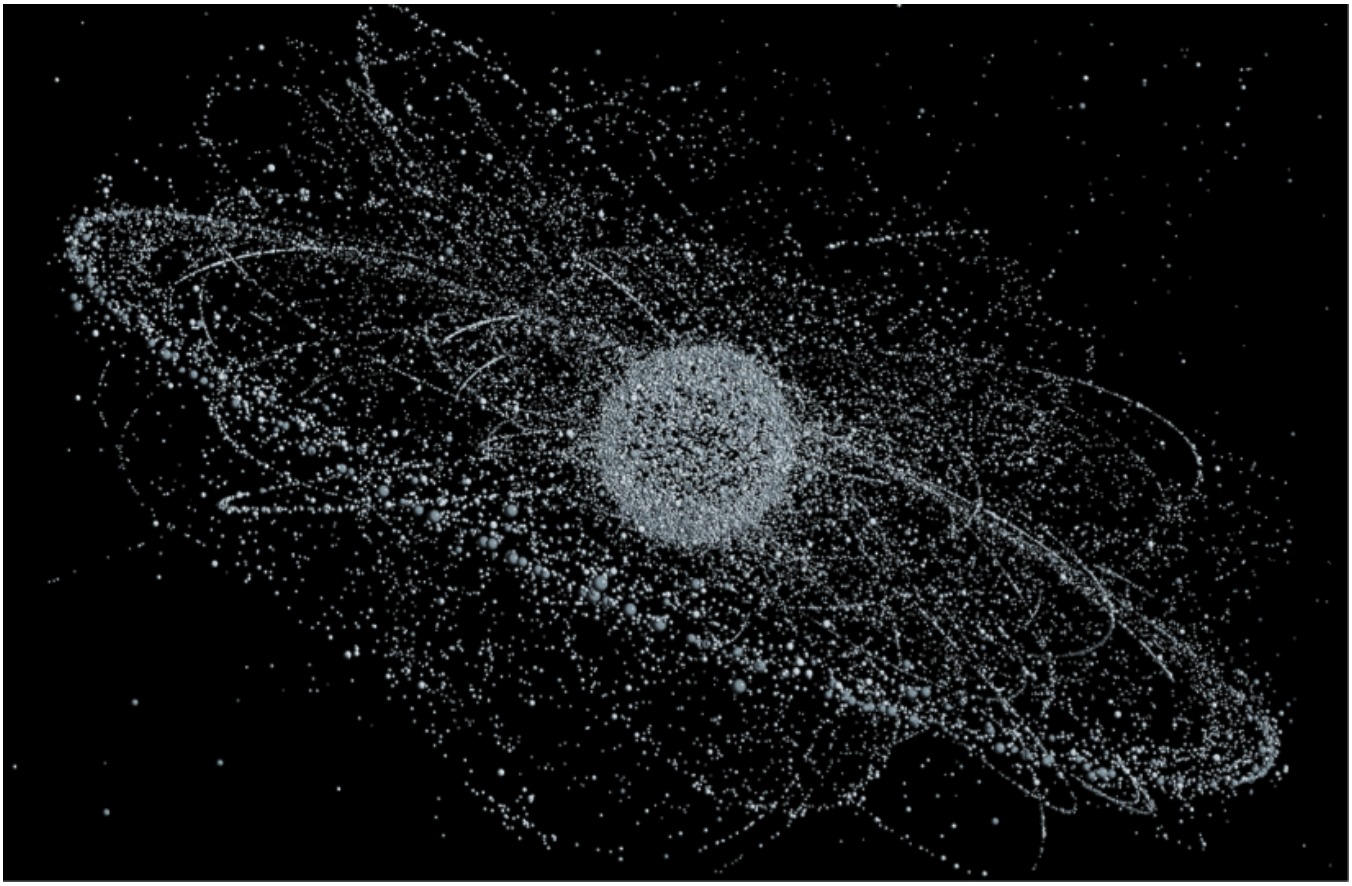

Fig. 1: NASA model of orbiting debris.

hazard to scientific and Department of Defense (DoD) data gathering missions operating within and through the ever burgeoning field of debris. This has now become recognized as an accident waiting to happen and not so much a matter of if, but of when.

The following quote was recently used by NASA to illustrate the contrast between current and early 1960s views of near-Earth space:

> "Space is big; Space is dark; You'll always find a place to park - Burma Shave" - S. Harris.

While tongue-in-cheek, this quote does indicate a lack of appreciation for what would ultimately become a menacing problem, with no fewer than 13 countries having now launched satellites into Earth orbit.

Surprisingly, to me at least, the latest addition to this fraternity is Ecuador, which is interesting if for no other reason than its comparable size relative to the original launches of the two super powers, the USSR and USA. In any event, they are all contributing to the dizzying number of orbiting artifacts, which represent a continually growing risk to space vehicles, astronauts, and the DoD mission.

These artifacts, numbering in the thousands, are being tracked, categorized and stored in DoD servers, from large discarded booster rockets down to orbiting trash around 10 centimeters (4 inches) in diameter.

A NASA computer-generated image of currently tracked objects in Earth orbit is shown in Figure 1 above. Debris in this NASA-generated model comprises around 95% of the non-functional debris larger than 10 centimeters in diameter. There are also many thousands of even smaller objects which are not included in this model, but which could cause major damage to functional satellites, including the International Space Station.

As stated, not all orbiting objects are of a size (diameter of 10 centimeters or larger) that can be tracked given current technology. In fact, according to the web site space.com, there are in the neighborhood of 500,000 objects, from those smaller than 1.27 centimeters (1 inch) in diameter to the largest discarded space booster rockets, about 21,000 of which are being tracked by the Department of Defense U.S. Space Surveillance Network, and stored on servers by the Joint Functional Component Command (JFCC), by Vandenberg Air Force Base.

This is all while recognizing that even some unknown number of debris no larger than a grain of sand, if impacting a manned satellite or vehicle, can cause equipment, or life threatening damage.

Remember, this debris may be traveling at orbital velocities of several thousands of feet per second, which can be much greater or much smaller, depending on the angular velocity between two converging objects. This is further aggravated by the fact that orbits cross each other depending on their inclination to the equator, and whether they are circular, elliptical, sun-synchronous, and if elliptical, their degree of eccentricity.

Consider, if you will, a metropolitan freeway system, with no interchanges, and where it was legal to travel in either direction on both sides of the divided highway, or to cross surface streets without regard to oncoming or cross traffic.

With a small number of vehicles, the likelihood of a collision is small, but as more oncoming and cross traffic is added, the likelihood of collision increases geometrically until it becomes

inevitable that one or more collisions will eventually occur. Collisions have already occurred in the case of Earth orbiting debris.

Notwithstanding that our degree of situational awareness is becoming increasingly better, a solution that can reasonably be implemented to eliminate or significantly decrease the likelihood of a catastrophic collision with a manned vehicle is extremely uncertain over time.

3 Solution

Current solutions are fairly primitive, focusing on detection and avoidance. That is, maneuver a spacecraft to avoid contact with detectable debris. However, objects too small to be detected, say smaller than a baseball, can still inflict extensive damage and even destroy a spacecraft, given a high enough angular velocity.

Other solutions may include devising means to return larger objects from orbit, essentially de-boosting them. It may also be possible to destroy the smaller objects with some yet untried method, with care being taken to avoid possible related side effects.

But for now, the focus is on what we *can* do, that being, detection and tracking of any object that is large enough to be detectable. Within the scope of current technology, NASA does have plans for possible mitigation, as shown in the following quote from their web site:

> "Currently there are several efforts to mitigate the problem:
>
> - Pieces of space debris are tracked by radar, so that spacecraft can be steered around them.
> - Spacecraft can be built to survive impacts from space debris. This will also protect them from meteoroid impacts.
> - Several of the space faring nations have agreed to measures to reduce the number of derelict satellites that could hit working satellites by steering aging satellites into otherwise useless orbits or into paths that will cause them to harmlessly burn up in the atmosphere of the Earth."

As can be seen from this quote, solutions are not yet adequate to cope with the growing risk and the degree of safety ultimately required to reduce risk to the desired level.

4 Conclusion

Currently there does not yet seem to be a solution imminent that is capable of completely eliminating the risk of collisions with orbiting debris in Earth orbit by working vehicles, either manned or unmanned.

Avum is currently working for JFFC Space in cooperation with Scitor Corporation and Vandenberg Air Force Base personnel to assist in the manual avoidance of these debris. Avum's role in this effort is furnishing servers to record ephemeris of 21,000 objects in Earth orbit that are 4 inches in diameter and larger. The servers are located in the Avum Agoura Hills office, about 100 miles south of Vandenberg Air Force Base, California.

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Jerry Hill Mr. Hill, as Senior Science Advisor for Avum, Inc., brings to the company his 40 years of experience in computer system architecture, design, and process-driven system development. He has worked in the capacity of System Architect, and Project Manager in the development of science-based, computer systems for NASA/JPL, Air Force, Navy, and Army contracts. He has proposed solutions for and won at least two contracts with each of these NASA and DoD clients. Mr. Hill is currently focusing on the acquisition of new business for the company, in interoperable Web-based applications, in which they excel.

Dustin Kramer Mr. Kramer is a Research Engineer at Avum, Inc., performing in-depth research, implementation, and analysis for many of Avum's engineering projects. With a degree in Mathematics from UC Berkeley and having performed extensive amounts of research across a broad spectrum of topics, including Pure Mathematics, Physics and Human Psychology, Dustin is well-equipped to provide a comprehensive and unique perspective when approaching problems and developing solutions. Mr. Kramer is currently working to develop service-based Intelligent Agents (IA) to extract meaning and relevance from data through fusion across heterogeneous data sources.