The Space Debris Problem

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The Definition

Space debris, orbital debris, or space junk encapsulates any man-made object orbiting Earth that is currently not in use. This includes anything from defunct artificial satellites to tiny flecks of paint from spacecraft.

01 Introduction To The Problem

The Sheer Quantity

Classifications

We categorize space debris by size. We currently have three classifications which are any objects greater than 10 cm, objects between 1 cm and 10 cm, and lastly objects between 1 mm and 1 cm. will refer to these classifications as Type 1, Type 2, and Type 3 with Type 1 being the largest*

Estimates

Speaking of the largest, there are ~54,000 of these objects that we are currently tracking. For Type 2 objects, we estimate around 1.2 million. Conservative Type 3 estimates quote 130 million objects while more aggressive ones say there's upwards of 160 million. ESA states ~140 million Type 3 objects are currently orbiting Earth.[1]

Problems

These objects are a lot smaller than many expect. I mean, does a 1 cm large pebble really matter? It's important to keep in mind that in order to stay in orbit, objects must move at least 17,000 mph! Any interaction with an object could cause damage to satellites or rockets. Aside from this, dense clouds of smaller debris may inhibit ground observation.

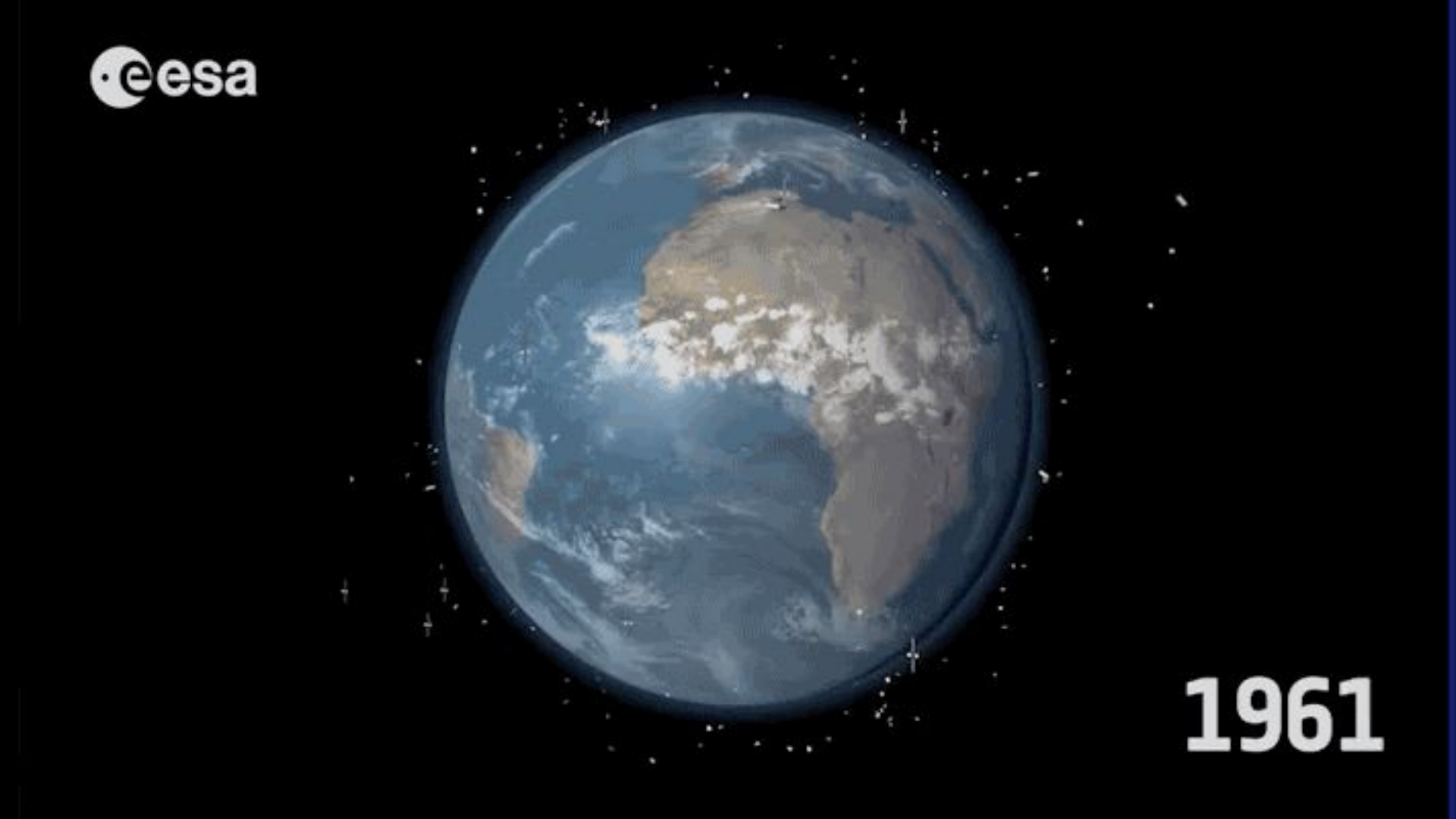
*Note: There are no official names for these classifications, I am using this naming convention for the sake of simplicity

Why Must We Act Now?

The Kessler Syndrome

It's easy to say the cost of removing space debris far outweigh the cost of slight course adjustments or sparse repairs that result from it. It's easy to ignore the large amount of junk in orbit to focus on more pressing matters here on Earth. So why is this problem so important?

Think of an unused satellite in LEO on a collision course with one of the 54,000 tracked type 1 objects. We neither have the desire nor ability to adjust its course to avoid the object so it collides. At 17,000 mph, the object shatters part of the satellite sending pieces of it flying. Each one of those pieces now has the capacity to do the same thing to another satellite whether man-made or natural. Every rocket we send into space adds more fuel for space debris to multiply. This problem is exponential and eventually, we will be unable to send anything off our planet and things already in orbit will be demolished. This is called the Kessler Syndrome. [2]


esa
1961

02

Happenings And Solutions

The 4 Problems With Space Debris And Existing Solutions

Detection

We mainly use the radar, HUSIR, located in MIT's Lincoln Laboratory to detect space junk. It emits a radar beam parked in a fixed location and the debris environment passes through it. It detects the size, shape, and orientation[3].

Characterization

In order to determine how to best remediate it, we need to know whether an object is man-made or natural, its physical composition and much more. We do this by studying the emission, absorption, and radiation of light from these objects.

Tracking

This is by far the most difficult problem we deal with. With so many objects all with their own speed and direction, it's impossible to accurately track. The ORDEM 4.0 [4] software and the LEGEND evolutionary model [5] provide a start.

Remediation

This is the logistical problem of curbing space debris. [6] Our current solutions are catching objects and either adjusting their path to enter our atmosphere or recycling it. Cutting edge development is working on lasers to nudge debris back into our atmosphere.

Going More In Depth With Tracking

ORDEM 4.0

The ORDEM 4.0 software uses observations from HUSIR, other radars, telescopes, and other new technologies to compute debris fluxes. This means they calculate the largest probability of impact between debris anywhere in our orbit from LEO (altitude of 200 km) to geosynchronous orbit (GEO altitude of ~35000 km). [4] This software must be constantly updated in order to remain accurate due to the sheer amount of variables.

LEGEND

Quoting NASA's Orbital Debris Program Office, "LEGEND is a full-scale, three-dimensional, debris evolutionary model." [5] The model provides the time, altitude, longitude, and latitude of each debris as both a historical simulation and a future projection. This makes it the most complex and advanced model of Earth's orbit pertaining to space debris. However, it is only currently tracking around 25,000 objects.

Introduction To My Software

The Kessler Observatory

Honing in on the tracking aspect of the problem, my software plans to intake the debris fluxes from ORDEM 4.0 and combine it with the projections of the LEGEND model to provide users with an accessible map of space debris hotspots and insight as to when the most dense clouds of space debris are obscuring their path to the stars.

The next slide holds a sample UI.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

03

Real World Applications

Effect On Individuals

Astronauts/Physicists

Having such ready availability to ORDEM 4.0 and LEGEND data will expedite the planning process and allow the scientists to plan launches farther ahead and with better efficacy than what they can do now.

Astronomers

Perhaps the most obvious use for the Kessler Observatory, this allows astronomers to book viewing times at telescopes with confidence that they will have an unobstructed view.

The Common Person

Aside from pure curiosity and hobby Astronomers, this app makes it easier to educate broader masses to the dangers that space debris may pose.

Long Term Benefits

Obviously, it's super difficult to nail any long term benefits but at a base level this app will increase the rate of our astronomy research even if it doesn't bring astronomy to a larger population. If we want to be generous however, this may positively impact the efforts and funding put into the space debris problem and start us on the journey of reducing space debris rather than just curbing it.

The Kessler Observatory Software

Design Process

My first thought was tracking individual objects in LEO however it didn't seem feasible that I can come up with something to compete with the industry greats. From this I came up with the idea of tracking the density of space debris and displaying it somehow, which would be much easier.

Originally I planned on intaking HUSIR and LiDAR data and simply saying an imported algorithm would take care of anything above my expertise. After further research I learned about the debris fluxes shown by ORDEM 4.0 and it lined up perfectly with what I intended to do with my application. This started the highway of ideas from which I expanded on and eventually finished my software idea with.

keppler_observatory.py

Function to read debris fluxes from ORDEM 4.0
	read ordem_data.csv
	create debris dictionary
	locate debris dictionary keys with the largest flux value magnitude
	note large magnitude dictionary keys
	return debris dictionary

Function to read predictive modeling from LEGEND
	read legend_data.csv
	create debris cluster dictionary
	return debris cluster dictionary

Function to convert debris fluxes from ORDEM 4.0 to debris density
	identify identical spacetime locations between legend data and ordem data
	use highlighted ordem dictionary keys to focus on their associated legend data
	utilize legend prediction software and current 3d model to achieve numerical debris density

Function to read user location
	intake user location
	read debris density at user longitude and latitude at any altitude.
	return location specific debris density data

Function creating a gradient based on debris density

Function displaying a weekly calendar with various debris densities and their specific times

Unanswered Questions

What data does the LEGEND model hold?

How malleable is my code to new software and data models?

Citations

[1] ESA'S ANNUAL SPACE ENVIRONMENT REPORT
https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf

[2] Kessler Syndrome And The Space Debris Problems
https://www.space.com/kessler-syndrome-space-debris

[3] HUSIR measurements of the orbital debris environment
https://ntrs.nasa.gov/api/citations/20205006606/downloads/TP-2020-5006606_HUSIR%20CY18%20Report_final.pdf

[4] An Overview of ORDEM 4.0
https://www.hou.usra.edu/meetings/orbitaldebris2023/pdf/6026.pdf

[5] How Do You Clean Up 170 Million Pieces Of Space Junk
https://fas.org/publication/how-do-you-clean-up-170-million-pieces-of-space-junk/