

Low Earth Orbit Salvage Concept

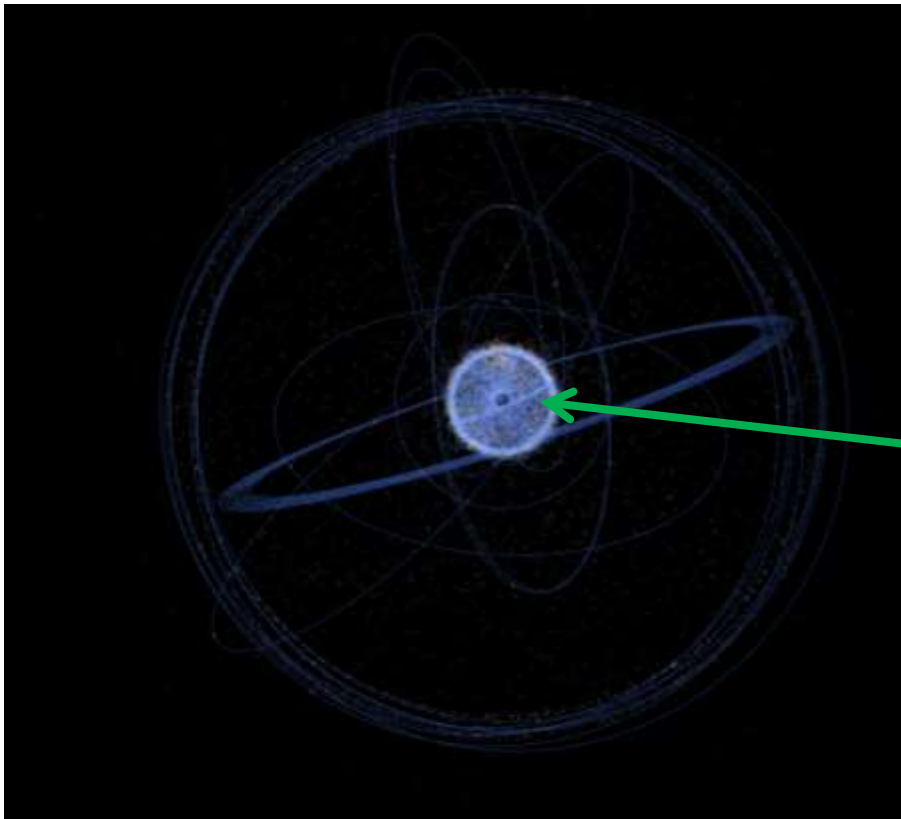
We need a place for everything and
everything in its place

Jay Lewis

Marginal X LLC

This is background to help find a University or Non Profit Partner
and a Business Partner
for a Grant Proposal
due Feb 17 2022

Near Earth tracked junk



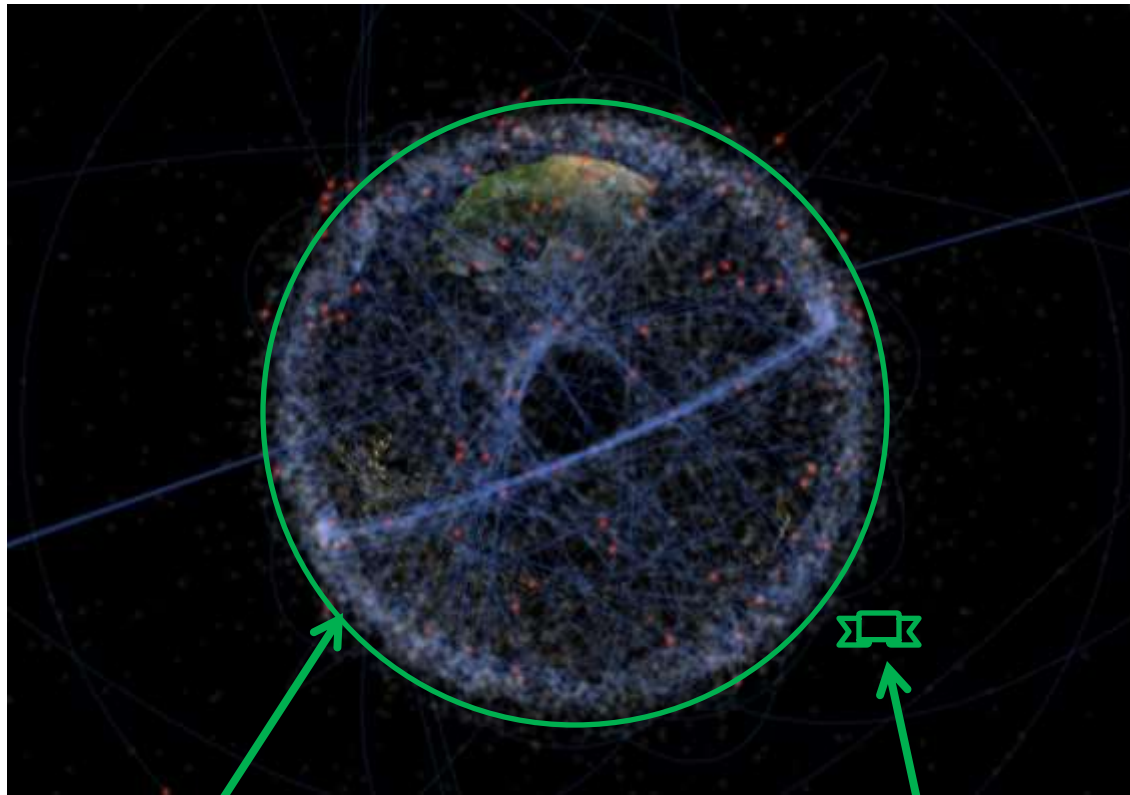
Vast majority of active satellites, junk and debris in are in lower LEO

That's also where all the large new constellations are going

Anything flying to higher orbits, the moon and beyond must pass through this zone

<http://stuffin.space/?intIdes=1991-009D&search=o>

LEO is 100Km-2000 Km



Vast majority below ~1500 Km

MEO starts at 2000 Km – far less risk of encountering or becoming debris

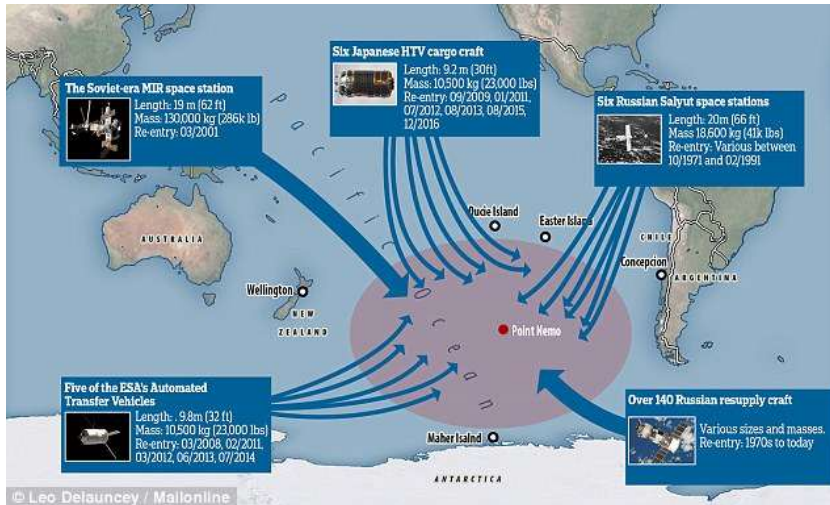
Most plans dump junk into the air and sea



<https://clearspace.today/clearspace-sa-signs-service-contract-with-esa-to-carry-out-the-first-mission-to-remove-space-debris-in-orbit-in-2025/>

- This air pollution might not be harmless on this scale
 - <https://www.popularmechanics.com/space/satellites/a36651845/satellite-pollution-starlink-ozone/>
 - Burns into reflective aluminum oxide which could turn into unwitting geoengineering and/or damage the ozone layer

Larger objects end up in the sea



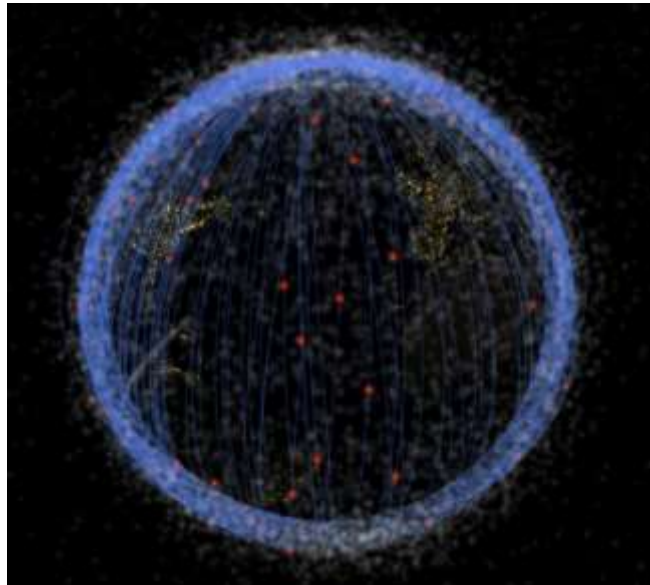
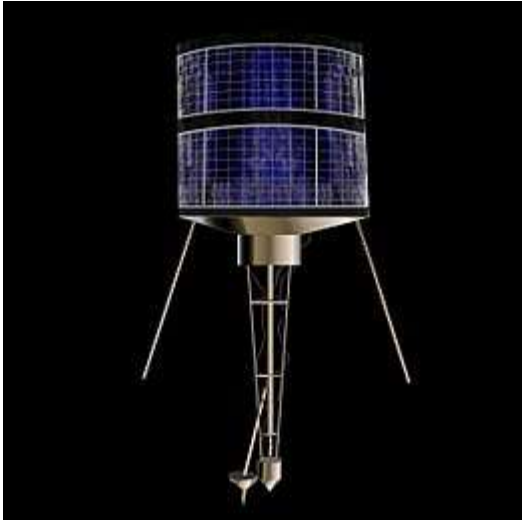
- These are not certain to be harmless
 - <https://www.dw.com/en/sea-burials-where-space-stations-rockets-rust-in-peace/a-57529488>
 - Hydrazine fuel and Beryllium alloys are very toxic

Beamed Energy Bootstrapping

- Goal = Giant Power Satellites in GEO to beam to rectennas on earth for indefinite clean power
 - Intermediate step is a medium power sat at MEO to beam to rectennas on hydrogen tugs in LEO
 - Can get to that by having smaller power sats in LEO drive hydrogen tugs near them
 - The first 2 tugs need an oxygen stage to get through the debris first
 - Skylon rockets use fuel and beamed power to lift everything to LEO

Could we use salvage to salvage salvage?

Kosmos 2251 + Iridium 33 Debris



In 2009 two objects became two hundred when the Russian derelict hit an active Iridium after years of near misses



https://en.wikipedia.org/wiki/2009_satellite_collision

Could these be collected and reassembled shortly after impact as a science or art installation?

Example: Alternative fates for Iridium

- Background
 - Communication constellation with an 8 year design life and spares on orbit to move into place as needed
 - “The original Iridium satellites launched in 1997 to 2002 maintained the constellation until 2017, at which time it was reported that 64 of them still remained in operational service.”
http://www.rod.sladen.org.uk/iridium_launch.htm
 - 30 failed in a way that prevented deorbiting
- 2019: “Iridium would pay to deorbit its 30 defunct satellites — for the right price”
 - <https://spacenews.com/iridium-would-pay-to-deorbit-its-30-defunct-satellites-for-the-right-price/>
 - 7 low enough to fall into the air, 23 will take 100 years
 - 700-1000 Km range
 - Iridium CEO Matt Desch: \$10K per deorbit is a “no brainer” but not much of a business case for more
 - What is the value of bad publicity or insurance liability if destruction caused again like Iridium 33 (if Kosmos 2251 was the active one)?

Can we salvage everything to set a baseline for what is possible?

Why iridium?

- I am already somewhat familiar with it
 - When I started at Viasat I studied that some as a huge success story from a reliability point of view
 - 8 year goal and lasted orders of magnitude longer
 - Steps to make Iridium next an example to consider
 - Imitated some, improved on others
- Its historically significant
 - First cell signal from space?
 - Had an collision that illustrates the danger
 - Multiples provide opportunism that won't make sense for 1 or 2
- Iridium said they will fund deorbiting the derelicts stuck for 100 years

Salvage Iridium's

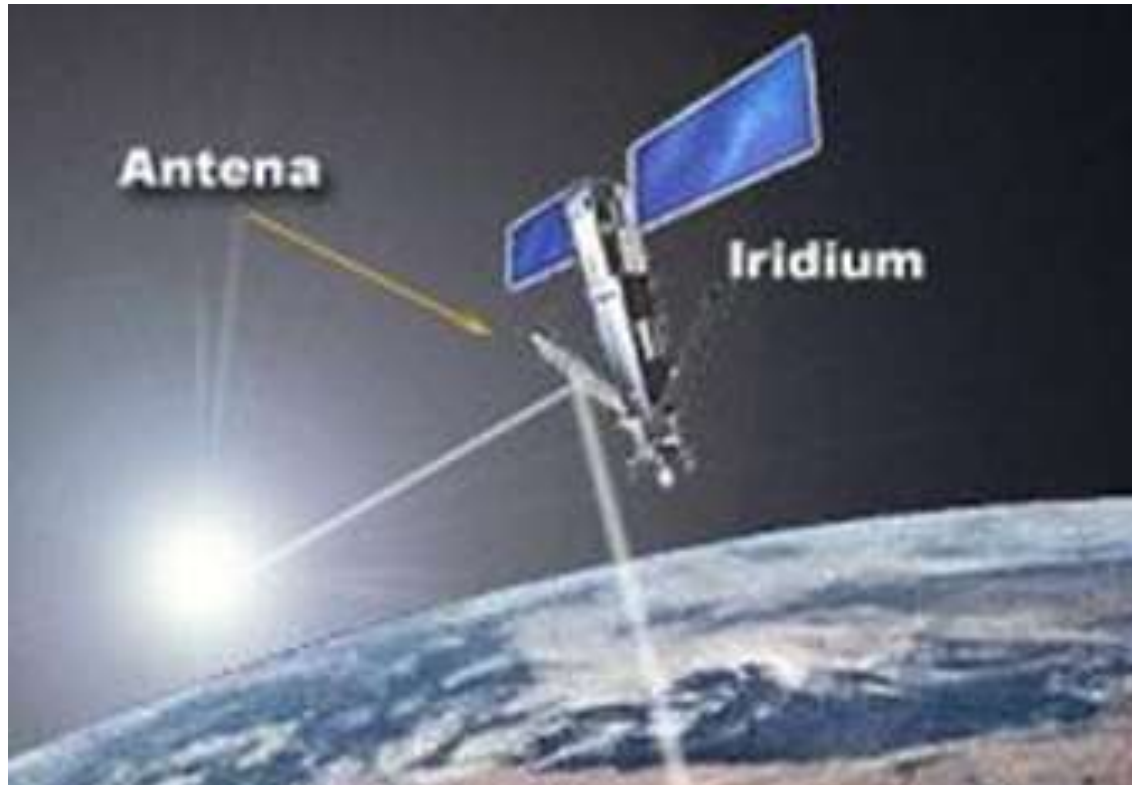
- 23 failed for various reasons, most at launch or early
 - Most (all?) have fuel
 - Since most failures were early probably all or most of a full tank
 - The others were deorbited fully functional, part out some to make the rest functional
 - Estimate 5 can be recovered from 1 so 3-5 can be parted out to
 - 1 of the parted out but mostly intact to MEO Museum
 - 1 parted out mostly intact to a collector on earth
 - 1-3 moved together and left in mid LEO as the start of a salvage yard
- 200 Debris to earth for science/art installation

Ask Iridium for expert help, assembly documents, etc instead of funds. Less cost for them and more valuable for us

Business Model

- Clean up costs to deorbiting
 - What are others charging?
- Iridium \$10K opening bid each, perhaps \$100K? Perhaps settle around \$30K
 - $23 * 30K = \$700K$ total
- Auctions
 - The collision art
 - MEO, and recovery

Iridium's salvaged for power satellites



<https://devoncsharpe.wordpress.com/2010/04/18/the-iridium-satellite-constellation/>

- Communications use relatively less power. Higher RF frequency and shorter range transfer more power

Steps

1. Remove Communications assemblies
2. Add Power Assemblies
3. Use this and the fuel to move to the next one and repeat

Scrap yard

- Clumps are better
 - Can avoid
 - Can move as a unit
 - Can reuse useful parts
 - Can mine for recycling
- Lasers can maneuver debris
 - Vaporize the leading edge slows it into a lower orbit
 - Vaporize the trailing edge can accelerate to a higher orbit
 - Vaporize a side to move it within an orbit
- Moving everything to clumps will take far less energy than dumping everything into the air

Steps like compounding Interest

- Grab the first, use its fuel and power to go to the next.
 - Disassemble
 - Replace the Comm payload with a rectena payload
 - Take the unused parts
 - Solar powered fuel tug
- Go to the 2nd
 - Repeat all steps and now have more solar power and more fuel
- Repeat for all but the last 2
 - Burning fuel to reach each so the speed needs to match what the next will provide
 - For a margin of safety perhaps assume the next will have had a leak and no refuel until the one after that
- Grab the 22nd as is
- Bundle the obsolete comm and other scrap to leave in place. Anyone that wants parts or aluminum and copper recycling can visit.
- Use the 21 iridium solar array rectena and all remaining fuel to move it higher. Perhaps the edge of MEO, perhaps part way to 1500 KM.
- The 21 Iridium transport power rectena at the MEO museum can power the foam recovery bot

Foam recovery Bot

- Foam Bot Delivered to LEO with any rocket
- 22IridiumSolar Rectena provides electric propulsion
- Pick up the 23rd intact Iridium
 - perhaps the one with the least solar and lowest fuel, or the oldest one
- Foam encapsulate it to demonstrate this process and add cushioning
- Move it to lower starlink orbit and wait
- After a cargo starship delivers a batch of starlinks put the package in for return to earth
- Move to the Iridium33/Kosmos2251 orbit and spiral around foaming everything to make all the small parts larger
- Once everything has been foamed push them all together and foam the total
- Move the final package to starlink orbit to be put in a cargo starhship for return to earth

Debris Reconstruction



1996 Boeing 747 flying from New York City to Paris exploded in midair

- Dissolve the foam
- Piece together whatever can be
 - Similar to an aircraft reconstruction
 - <https://www.nytimes.com/2021/02/25/nyregion/twa-flight-800-reconstruction.html>
 - <https://www.cbsnews.com/news/reconstruction-of-mh17-reveals-final-moments-of-doomed-flight-60-minutes-2020-02-23/>
 - This could fill the volume of a room and illustrate the moment after impact



2014 Boeing 777 shot down by a Russian Warhead over Ukraine. 8000 fragments recovered

Kosmos and Iridium are smaller but the collision can fill any volume

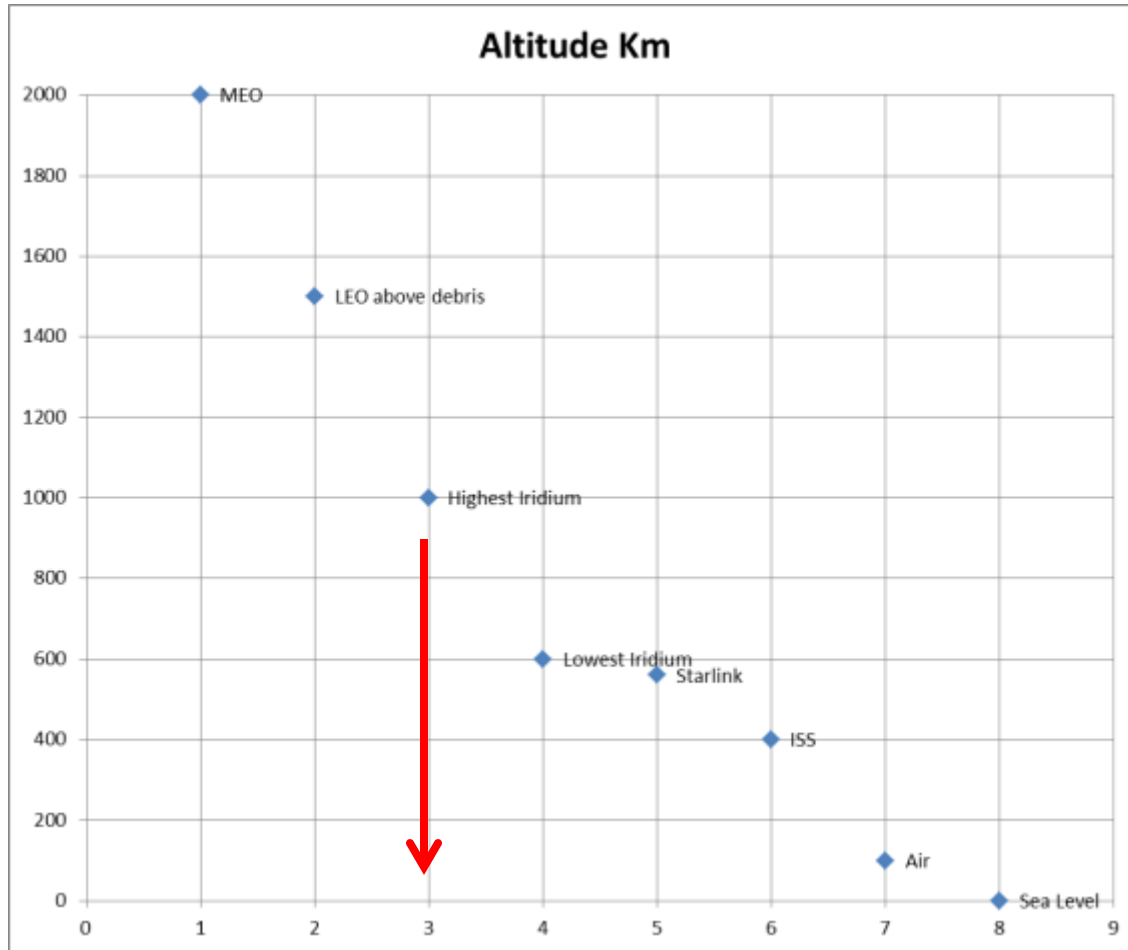
Final Result or Iridium Cleanup

- X KG and N items removed form LEO with no pollution in atmosphere or ocean
 - Add the al pollution worry
- One of the oldest Iridium Sattelights is the first exhibit at the MEO Museum in upper LEO
- One of the oldest Iridium sattelights has been delivered to a customer on earth and is sitting in their lobby, living room or whatever
- The

Future From there

- MEO Museum
- Scrap Yard
- Collector Delivery

Levels and Deorbiting



Debris must be moved below 600 for air to drag it down in 3 years or less

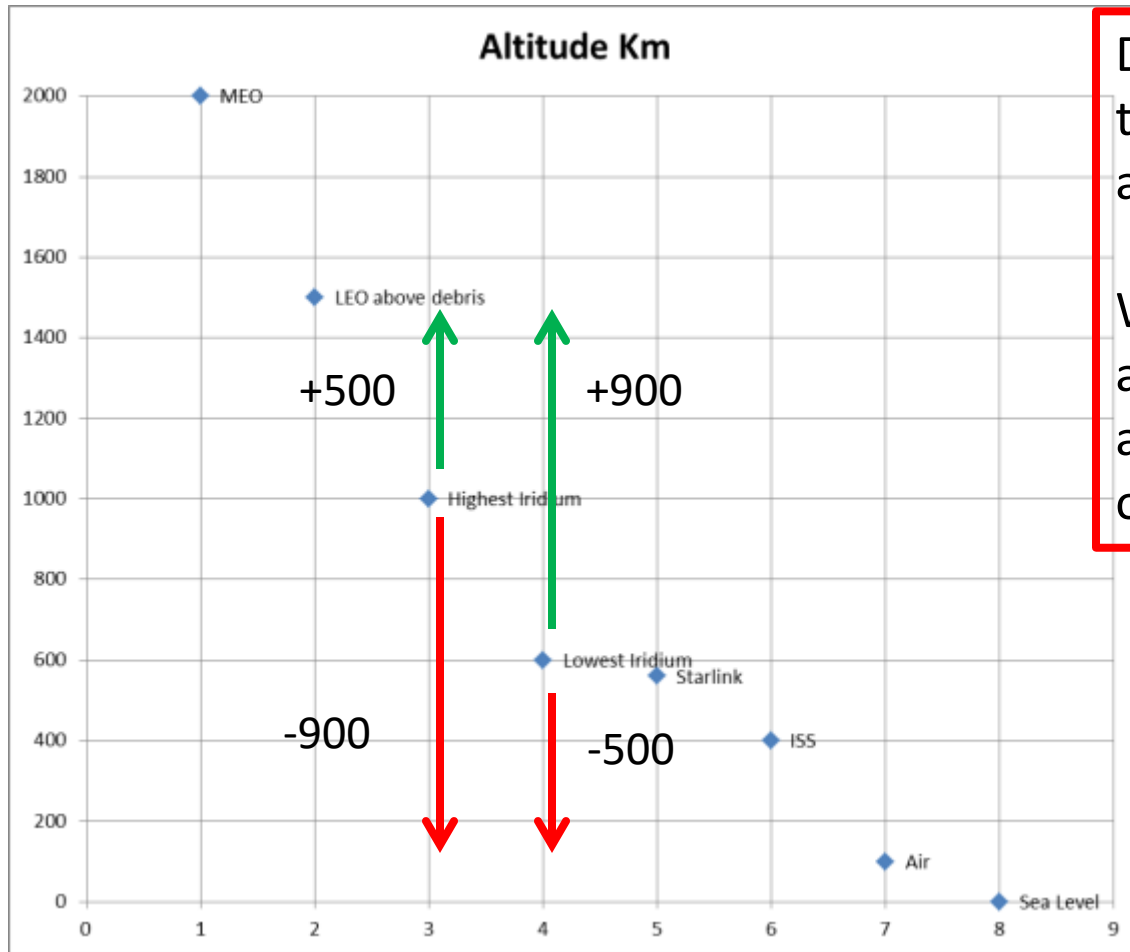
Above ISS and other active satellites means it must drift through all of those orbits

It would also increase the density of objects to fly through on the way up

Its safest to decelerate all the way down to 100km

Is dumping down to the air and sea the only option?

Moving the Iridium Derelicts



Decelerating a mass takes the same energy as accelerating

Whatever budget is available to dump into the air can be spent to raise the orbit instead

How can keeping it in space be as safe?

US SF SMARG

Space Maintenance And Regeneration Group

- [https://en.wikipedia.org/wiki/309th Aerospace Maintenance and Regeneration Group](https://en.wikipedia.org/wiki/309th_Aerospace_Maintenance_and_Regeneration_Group)
 - Create SMARG for the Space Force to keep weapons and derelicts still classified
 - Perhaps remove sensitive portions to allow the rest to be auctioned, put in a museum, reused, or recycled
 - Before starlink were the majority of satellites classified?
 - Study the root causes of failures to inform future designs

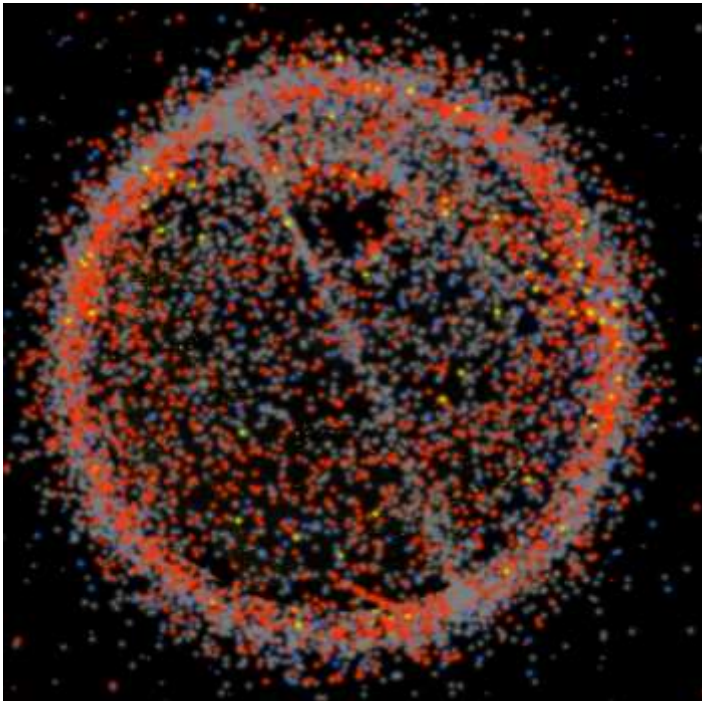
Reduce risk 3 ways

1. Uncontrolled to controlled
 - When 2 active satellites might collide either or both can be moved. 2 derelicts might become a debris field
 - Keep the MEO museum and junk yards under control
2. From most crowded to least crowded volume
 - 100-500Km is the most crowded
 - 1500Km-2000Km is 20% more area and far less crowded part of LEO
3. Scattered to centered
 - Its harder to dodge many small things than a few large ones
 - 1 MEO Museum that grows over time as historic items are added
 - A few junk yards that may shrink over time from reuse and recycling

Make a place for everything and put it there

Conclusion

Before



- N Junk \sim x kg
- M debris
- Most plans to dump it into the air and sea

After



- MEO Museum and gift shop
- Several Propulsion Power Satellites
- Active Scrap yards reuse and recycle
- Example collision reconstructed on earth
- No harm to our air or ocean
- Lower LEO only active satellites

Demonstrations

Financial

- Humanities early objects in space are scarce and valuable
- Investors will buy and loan historic objects to a museum they may or may not visit
- Moving things with recovered fuel and solar panels reduces the launch weight and costs
- Establish removing debris has a cost that can be avoided or insured

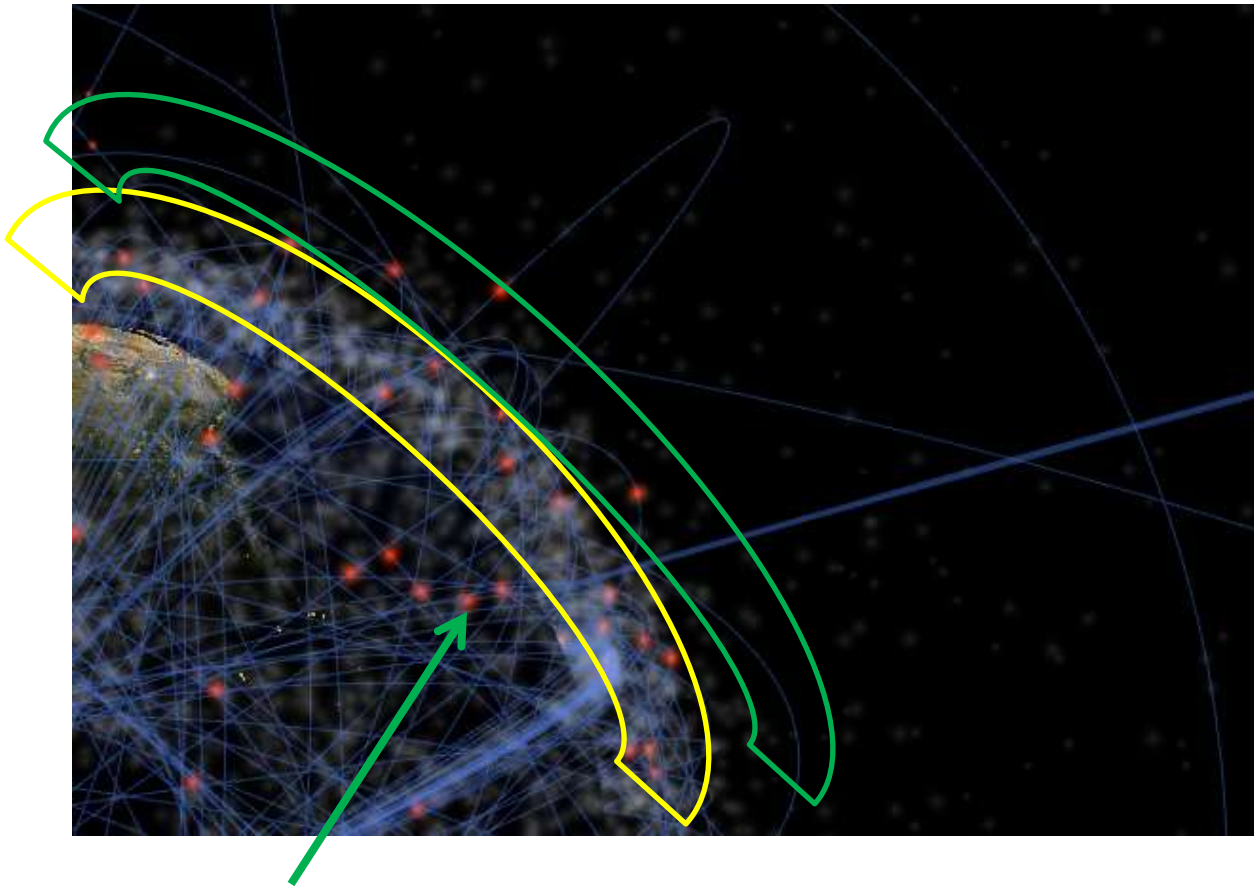
Technical

- Recover fuel to move things
- Recover solar power systems for reuse
- Recover debris from a crash site
- Deliver an entire derelict to earth
- Deliver a crash debris field to earth

This is complimentary to other efforts and more of a shift in focus from minimizing costs to maximizing value

EXTRA CONTENT

Higher orbits = more room



100-600 Km area and 1500-2000km
areas are both 500km wide

1500-2000 KM Area is a larger circle with
20% more volume and far fewer objects.

Questions

- Could Russia pay for the debris collection from the Iridium 33 collision?
 - This would help accelerate clearing it
 - This would set a precedent that Russia may benefit from by establishing there is a cost for abandoning derelicts
 - With an established cost the risk can be balanced with the budget to prevent them. Right now it's 0 or a vague cost easy for managers to ignore
 - , perhaps insured and any future incidents have