Catalog of US Launched Objects for Active Debris Removal

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1. ABSTRACT

The ORBITS Act of 2023 (S.447) [1] which passed the Senate called for the generation and maintenance of a list of debris objects which pose immediate risk to other satellites. We present an updated catalog of such objects that have been launched by the US. We limit the catalog to US launched objects because international treaties from UNOOSA establish that the launching country maintains responsibility for it. Thus, it is simplest for initial Active Debris Removal (ADR) missions from the US to work on such objects. The catalog is a dynamic catalog, requiring regular updates to include new launches and possible disposal of current objects. This presentation updates the catalog of 198 US rocket bodies in LEO with apogees less than 2000 km presented at the IOC 2023 [2] now to include all rocket bodies, payloads, and debris objects with large radar cross sections, and orbital elements current within the last 30 days of the date of analysis. Our analysis now includes the probability of reentry in the next 5-10 years which could present a risk to the ground. Such objects should be priority targets for initial US based ADR missions. We compare the updated catalog with the sample of 50 most dangerous objects in LEO presented by McKnight, *et al.* [3][4].

2. THE ORBITS ACT

The ORBITS Act is a bipartisan effort with the goal of directing resources to specific agencies that will contribute to orbital debris remediation efforts and preserve the space environment. As defined in the Act itself, orbital debris is "any human-made space object orbiting Earth that no longer serves an intended purpose and has reached the end of its mission or is incapable of safe maneuver or operation." [1] More specifically, NASA will be made responsible for maintaining a list of debris that presents the greatest risk to orbital operations, creating a program that allows for demonstration and development of orbital debris remediation technology, and additional R&D for advancing those technologies. This will also give NASA the ability to assign contracts to industry for the remediation of orbital debris. The National Space Council will be responsible for updating the Orbital Debris Mitigation Standard Practices document shortly after bill passage and periodically from that point on. The purpose of this is to keep regulations and guidelines current, while also enabling international discourse on the topic. Lastly, the Department of Commerce would be responsible for developing the standards for directing on-orbit traffic. [5] This bill was originally introduced to the Senate in February 2023, passed the Senate in October 2023, and is now held at the desk of the House awaiting further action. [1]

3. INTERNATIONAL CONSIDERATIONS

In this paper, we limit the data set of objects originating from and launched by the United States of America. The exclusion of other countries is connected to the United Nations Office for Outer Space Affairs (UNOOSA) treaties that were signed between 1967 and 1984 that create the basis for today's interpretation of space law and ownership. In simplest terms, the Liability Convention, adopted in 1972, maintains that the country or countries that launch an object and facilitate that launch are liable for any damage the object causes throughout its life. [6] Liability and ownership in this case are linked, which means that as a US entity, we can only address US objects by these standards. Were we to target an international object without permission, we would not only be taking on ownership of the object, but liability would remain with the originating country. In simplest terms, if we were to remediate an object belonging to someone else, should that object cause damage on reentry, the launching country would remain liable for damages. While there are situations outlined in the Liability Convention that show exclusions for liability, in general, today's space capabilities have outpaced these guidelines.

4. CATALOG GENERATION

On 2024 August 15 the complete satellite catalog (SATCAT) was downloaded from space-track.org. This catalog has 60,371 entries of objects launched since the beginning of the Space Age. In addition, the master Two Line Element (TLE) catalog of objects with updated TLEs within the last 30 days was downloaded. This catalog has 26,203 entries.

Following the procedure outlined in [2], we filtered the SATCAT by selecting:

1. COUNTRY = US, GLOB, ORB, ISS
2. DECAY = blank (has not reentered)
3. COMMENT = blank (not in lunar or heliocentric orbit)
4. APOGEE <= 2000 km
5. RCS = LARGE

The GLOBALSTAR and ORBCOMM satellites are (mostly) launched from the US but have different country codes.

This results in 6,892 objects. Most of these are Starlinks launched in the last 5 years, which we will not include going forward.

For this paper, we only consider objects with LARGE radar cross section, defined as > 1 meter squared or larger. This is not a great measure of size or collisional cross section, but it is all we have for the moment. The intent is to prioritize the sample for objects of maximum size for conjunction and reentry analysis.

The question is how to define an inactive payload. For simplicity, only PAYLOAD type objects at least 24 years old (launched prior to January 1, 2000) will be included, under the major assumption that older payloads are more likely to be inactive. Two objects known to still be active – the International Space Station and the Hubble Space Telescope, were removed. Two online databases of Resident Space Objects (RSOs) [7][8] were accessed for lists of active satellites launched prior to January 1, 2000, which were then removed from the payload list. A full sample of all inactive payloads with any launch date is beyond the scope of this initial study.

The final catalog as of August 15, 2024, has a total of 382 objects: 223 inactive payloads, 132 rocket bodies, and 27 pieces of debris.

This catalog is a dynamic catalog requiring frequent updating. New launches occur, old objects reenter, active payloads fail, and collisions and fragmentations occur.

5. ANALYSIS

The analysis presents the big picture of the catalog: the launch dates of payloads and rocket bodies, the distribution in the inclination-altitude plane, how this catalog compares with the analysis of the 50 most dangerous objects in LEO by McKnight, *et al.* [3][4], and the population of objects that can be expected to reenter in an uncontrolled fashion in the next 5 to 10 years.

For purposes of this study, objects below a current altitude of 500 km can be expected to reenter in an uncontrolled fashion in the next 5 to 10 years. They could present a hazard to structures and people on the ground [9][10].

Fig. 1 and 2 show the launch frequency as a function of year for inactive payloads and rocket bodies. For payloads, over half were launched prior to 1988, and for rocket bodies over half were launched prior to 1980. In both samples, the majority of objects have been in orbit for 30 years or more.

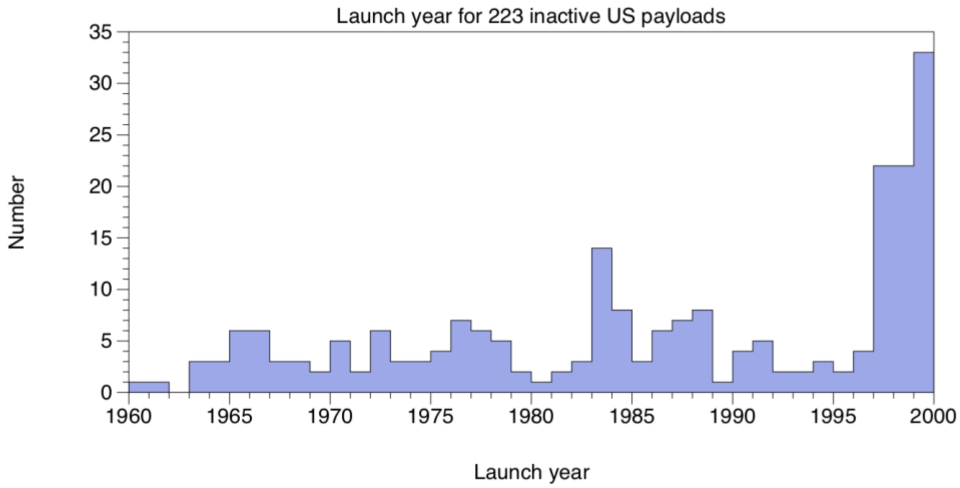

Fig. 1. Distribution of year of launch for 223 inactive US payloads. Over half were launched prior to 1988. The cutoff at 2000 is from the definition of inactive payloads – assumed to be launched prior to January 1, 2000.

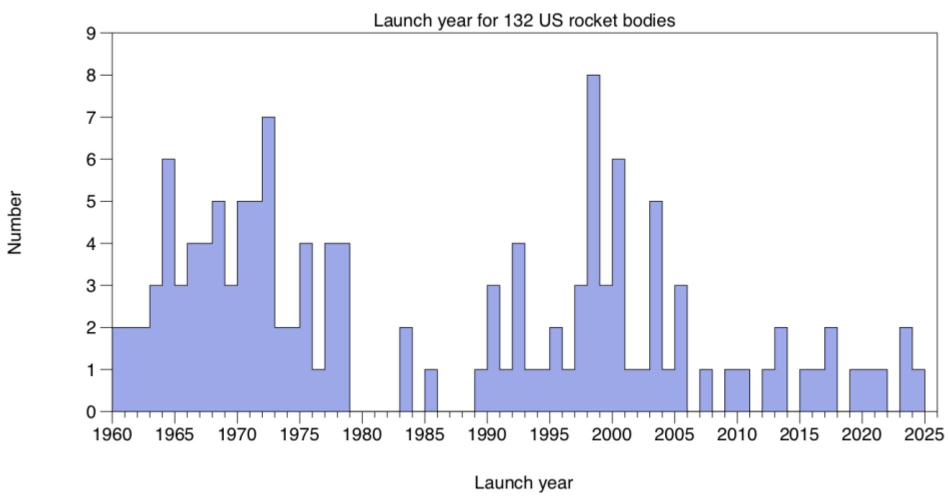

Fig. 2. Distribution of year of launch for 132 US rocket bodies. Over half were launched earlier than 1980.

Fig. 3 and 4. show the distribution of payloads in rocket bodies in the inclination-altitude plane (after [3]). The well populated sun-synchronous orbit regime is the line of objects with an inclination near 98 degrees. The 500 km line is also ahown to indicated objects which have a high probability of reentering in the next 5 to 10 years. There are 5 payloads and 9 rocket bodies which have a current altitude of 500 km or less.

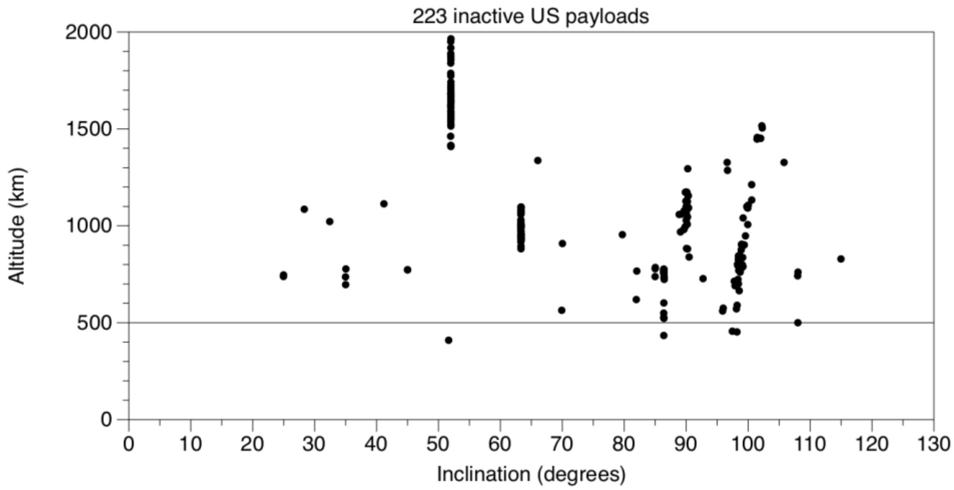

Fig. 3. Inclination versus altitude for 223 inactive US payloads. The sun-synchronous regime is the line of objects near inclination of 98 degrees and altitude 500 km and greater.

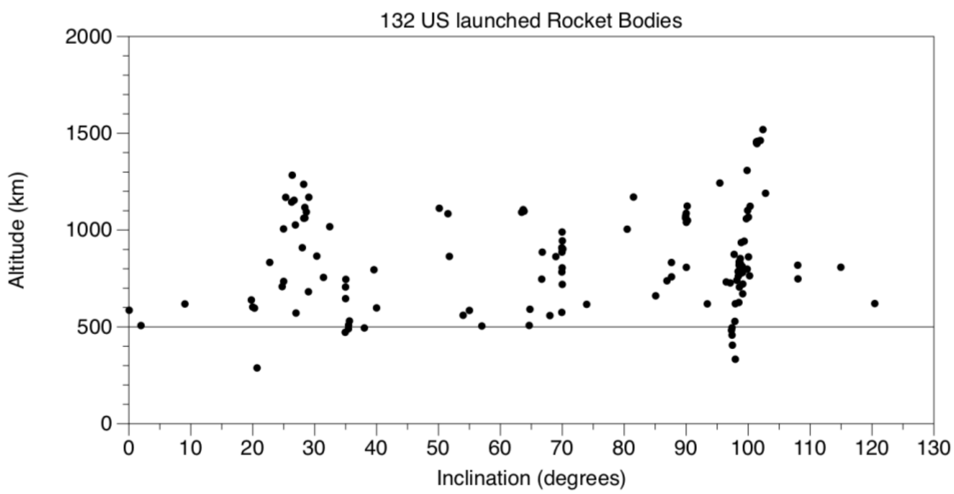

Fig. 4. Inclination versus altitude for 132 US rocket bodies. The sun-synchronous regime is the line of objects near inclination of 98 degrees and altitude 500 km and greater

The distribution of the 27 pieces of debris with large radar cross section is shown in Fig. 5. A substantial fraction is in sun-sync orbits. None have altitudes lower than 500 km, and thus should have reentry times greater than 5 to 10 years.

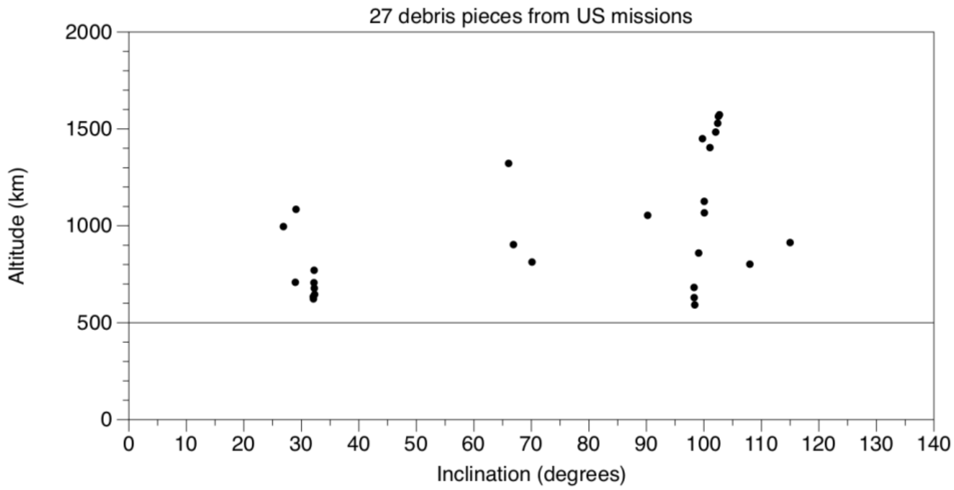

Fig. 5. Inclination versus altitude distribution for the 27 pieces of debris in the catalog.

How does this catalog compare with the 50 most dangerous objects in LEO defined by McKnight, *et al.*[3][4]. In the first study [3], there were no US objects, while in the second [4], there were a few. Fig. 6. and 7 show this catalog in the same limits as [3] and [4]. As was found in an earlier US only catalog [2] there is overlap only in the sun-sync orbital regime marked as M2 in Fig. 6 and 7. In the two other orbital regimes (marked as M1 and M3) there is absolutely no overlap. With the exception of the sun-sync regime, there is no overlap!

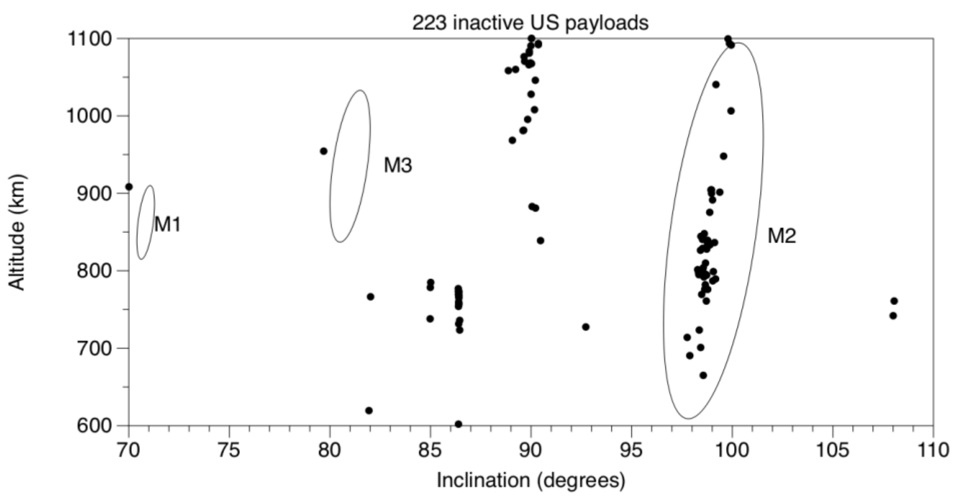

Fig 6. Inclination versus altitude for the 223 inactive US payloads in this catalog at the same limits as the McKnight, *et al.* [3][4] studies. M1, M2, and M3 are the regions of greatest danger in those studies.

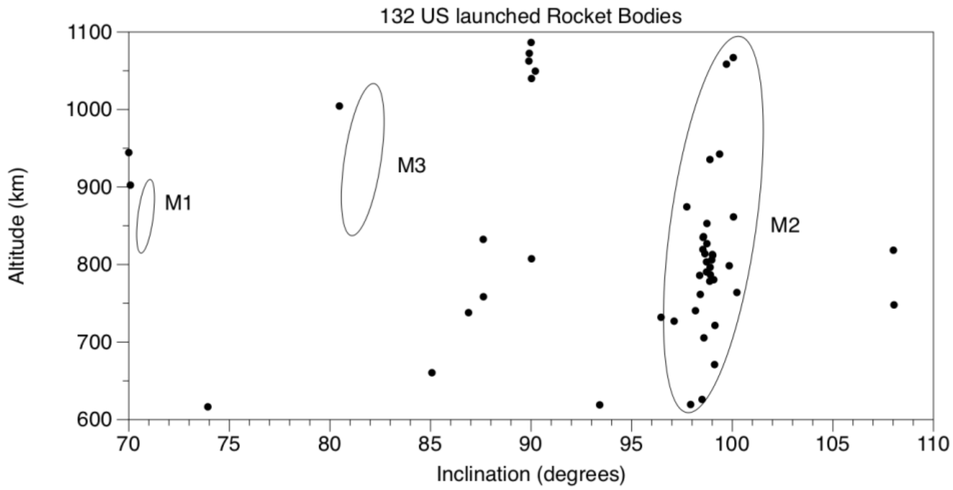

Fig 7. Inclination versus altitude for the 132 US rocket bodies in this catalog at the same limits as the McKnight, *et al.* [3][4] studies. M1, M2, and M3 are the regions of greatest danger in those studies.

Why is the overlap between the M50 sample and the US sample so limited? The selection criteria for the M50 sample and the sample presented here are completely different. M50 analyzes objects of all countries and considers dynamical risk factors for inclusion. Our sample considers only US launched objects without any dynamical considerations. For the sun-sync regime, the addition of US rocket bodies and inactive payloads to a significant non-US population increases the risk in this regime, and the urgency of conducting active debris removal missions here.

6. CONCLUSIONS

This paper presents a catalog of 382 US launched objects with large radar cross section: 223 inactive payloads, 132 rocket bodies, and 27 pieces of debris, for which the US retains responsibility. Fourteen of these objects (5 payloads and 9 rocket bodies) can be expected to reenter uncontrollably in the next 5 to 10 years. Most of the US launched objects have been in orbit for 30 years or more. With the exception of the sun-sync regime, there is no overlap with high-risk clumps in the McKnight, *et al.* studies [3][4].

This catalog is of a changing population and thus requires frequent updating.

The catalog is available in electronic form from the authors.

7. ACKNOWLEDGMENTS

This paper relies extensively on data from the web site space-track.org, run by the 18th and 19th Space Defense Squadrons. It would have been impossible without the efforts of a large number of individuals and organizations over many years to maintain the catalog of objects on space-track.org and make the data available to the public. We cannot thank these individuals and organizations enough for their efforts at spaceflight safety.

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8. REFERENCES

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