SUMMARY OF THE IAA POSITION PAPER ON ORBITAL DEBRIS: RECENT EVENTS AND OBSERVATIONS

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Abstract

The orbital debris community rallied under the auspices of the International Academy of Astronautics Committee on Safety, Rescue, and Quality, to compile a position paper on what needs to be done to control the growing space environmental hazard posed by orbital debris. An international team of thirteen experts from six countries summarized their efforts by proposing three families of debris control options. These options were classified by their likelihood of significantly reducing the debris population and the level of technology needed to implement each. A discussion is provided highlighting the necessity to characterize the debris population in a variety of ways (e.g., by object type, by country, by age, etc.) to understand the efficacy of the options recommended by the IAA position paper.

Background

In early 1991, Dr. Hartmut Sax asked for a position paper to be written on orbital debris under the auspices of the Committee on Space Safety, Rescue, and Quality. Within several months, Dr. Walter Flury and I had agreed to act as cochairmen for an ad hoc committee of orbital debris experts from around the world chartered to write the position paper. Figure 1 shows the international nature of the authors of the debris position paper. This effort was chartered specifically to go one step further than previous international reviews of this space environmental problem. More specifically, it was to recommend action and not to merely review the state of the debris environment. The terms of reference agreed upon by the team of 13 specialists read as follows:

"The group shall, in preparing its report, establish and maintain consultation with the International Institute of Space Law as well as with other concerned IAA Committees, such as the Committees on International Space Plans and Policies and on Space Sciences. The report shall be based on consensus within the group and reflect the comments made by other members of the Academy and the aerospace community."

"The members of the IAA committee on Safety and Rescue Studies will be given opportunity to comment on the draft report, then, upon approval by the Committee Co-chairmen, the report will be submitted to the President of the Academy for adoption as a position paper of the Academy according to the rules and procedures of the Academy."

"The effort of the group is to elaborate upon the work in progress and the major status reports issued by ESA and the U.S. Interagency Group but to also focus on why the issue is of immediate significance."

"The objective is to exploit the Academy's status and expertise to establish that there is current urgency to initiate intervention even though the most significant adverse effects may not occur for a long time. The primary goal is therefore to explain and elaborate why action now is necessary to preclude serious ramifications later. The group shall further more give some indication of what classes of action are to be undertaken in order to make progress."

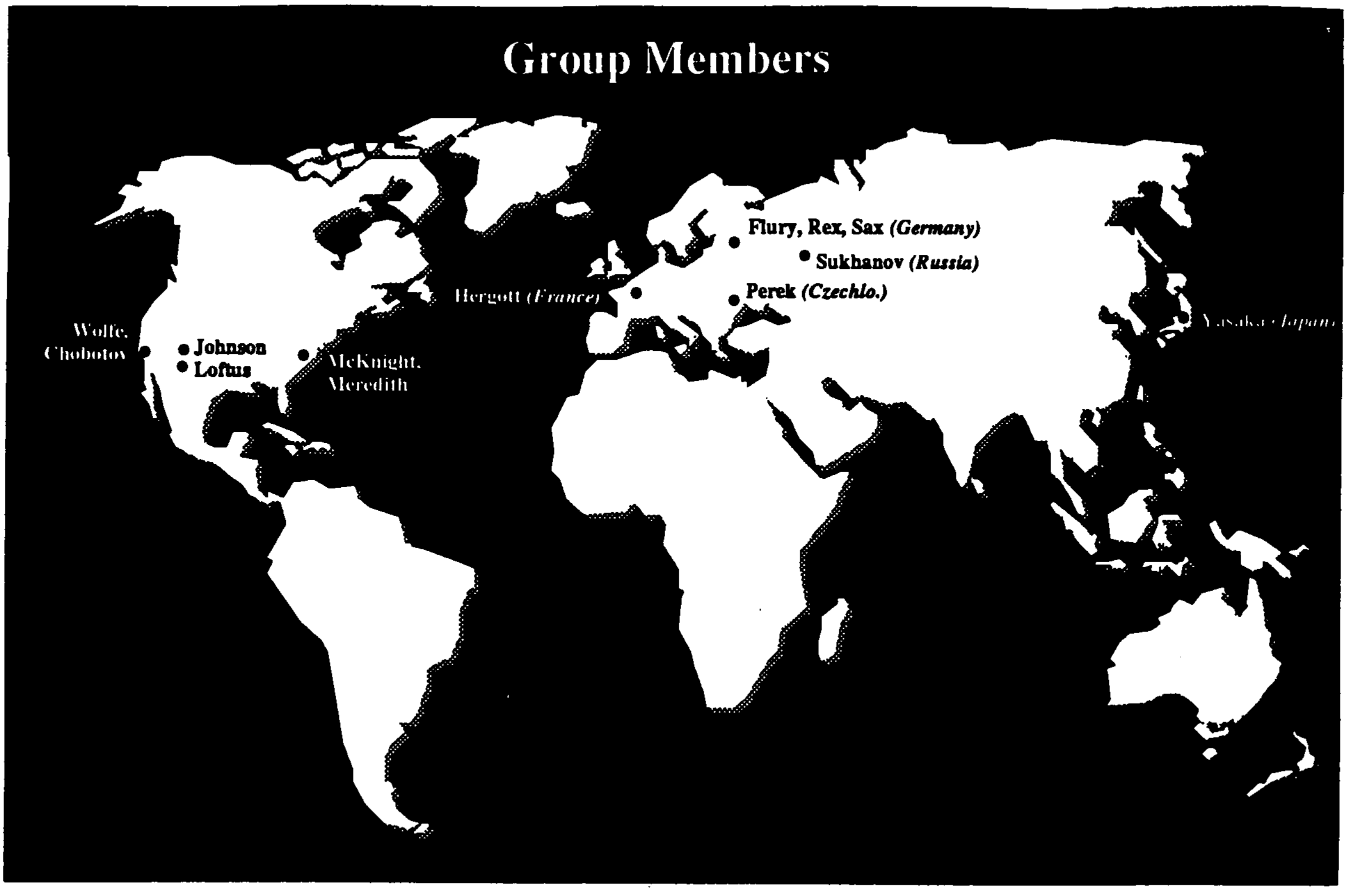

Figure 1. Authors of the Position Paper on Orbital Debris.

"The report of the group should focus on the technical urgency for action and provide some framework for addressing debris control options in the future. It may address particular solutions or measures to be effected if a consensus is reached in this area."

The paper was completed in August 1992 and presented at the World Space Congress in Washington, D.C. in September 1992.[1] After review by several distinguished scientists outside of the original committee, the paper was officially submitted to the IAA President for consideration as a cosmic study of the Academy in March 1993. October 1993 marks the official release of this paper as an IAA-approved position paper.

Specifics of Paper

The paper deals with only one of three families of man-made space debris, Earth orbital, as shown in Figure 2. Earth orbital man-made space debris is simply referred to as orbital debris. The first task of the group was to develop an acceptable definition of orbital debris:

". . . any man-made Earth-orbiting object which is nonfunctional with no reasonable expectation of assuming or resuming its intended function or any other function for which it is or can be expected to be authorized, including fragments and parts thereof."

Categories of orbital debris are reviewed and compared to the natural meteoroid hazard. Figure 3 provides several different views of the cataloged population, with debris as a significant subset.

The position paper briefly reviewed the present status of the orbital debris environment by debris size and orbit type. Spatial density and probability of collision values are reported. The need for action is then shown by examining the concept of critical density: a state at which debris production via collisions will be greater than the loss via atmospheric drag therefore causing an irreversible growth of orbital debris.

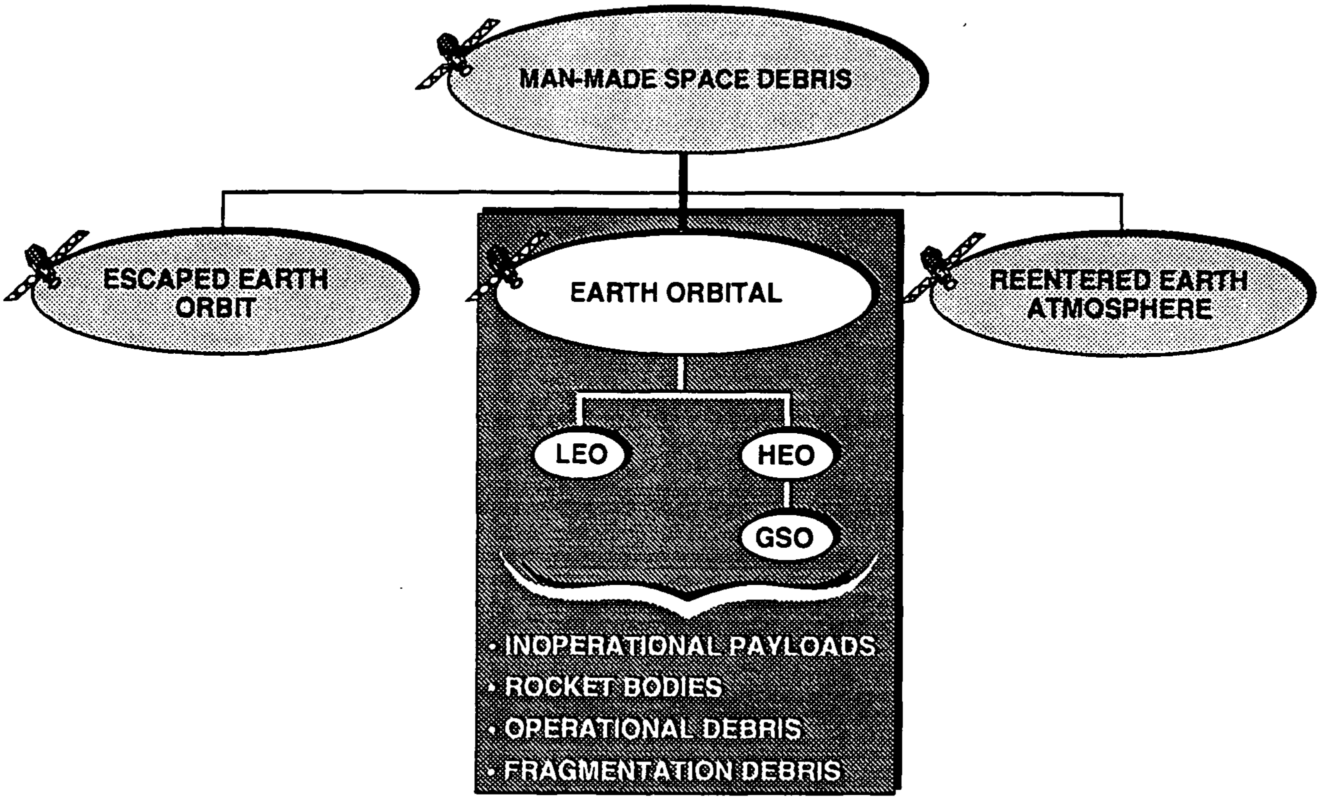

Figure 2. Focus of IAA Position Paper.

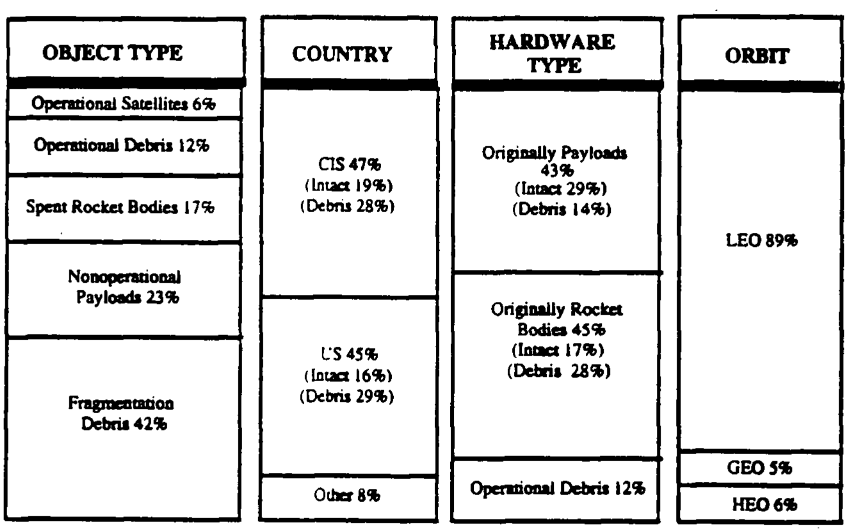

Figure 3. Cataloged population organized by object type, country, hardware type, and orbit..[2,3]

Debris control options are then detailed as either being debris prevention or removal. Table 1 lists the envisioned options within these two categories.

Table 1. Methods to Reduce the Debris Population.

PREVENTION	REMOVAL
Design & operations	Retrieval
Expulsion of residual propellants & pressurants	Propulsive maneuvers (deorbit)
Battery safety (vent or fuse)	Drag augmentation
Retention of covers & separation devices	Solar sail
Propulsive maneuvers (reorbit)	Tether Sweeping Laser

Methods for debris control are then reorganized into three categories as a function of impact on the environment and ease of implementation:

<u>Category I</u>: Have greatest impact on population control and require no technology development;
<u>Category II</u>: Have moderate impact on population control and will require changes to hardware or operational procedures; and
<u>Category III</u>: Require new technology developments to apply.

Specific Recommendations

The position paper concluded with seven recommended immediate actions to control the growth of orbital debris:

1. No deliberate breakups of spacecraft which produce debris in long-lived orbits.
2. Minimization of mission-related debris.
3. Safing procedures for all rocket bodies and spacecraft which remain in orbit after completion of their mission.
4. Selection of transfer orbit parameters to insure the rapid decay of transfer stages.
5. Reorbiting of geostationary satellites at end-of-life (minimum altitude increase 300-400 km).
6. Separated ABMs used for geostationary satellites should be inserted into a disposal orbit at least 300 km above the geostationary orbit.
7. Upper stages used to move geostationary satellites from GTO to GEO should be inserted into a disposal orbit at least 300 km above the geostationary orbit and freed of residual propellant.

As would be expected, these are all Category I control options. The first three apply generally to all space missions, the fourth to geosynchronous transfer orbits (GTO), while the last three pertain directly to geosynchronous (GEO) missions.

Observations

Figure 4 shows the growth of components of the orbital population: fragmentation debris, operational debris, rocket bodies, and payloads. The growth of fragmentation debris is seen as the major contributor to the overall population. The effects of cyclic solar activity is clearly seen, but still much of the debris reside in long-lived orbits. Operational debris is shown to be small in number in comparison to other components. The growth of rocket bodies is the most alarming since they have shown such a propensity to fragment in the past. Figure 5 plots the growth of the number of rocket bodies left in orbit by the U.S. vs the USSR/CIS. The trend is quite obvious showing that the USSR/CIS space program is responsible for almost twice as many on-orbit rocket bodies as the U.S. More generally, considerations for safing rocket bodies must be equally applicable to a variety of technologies (i.e., Russian, American, European, etc.).

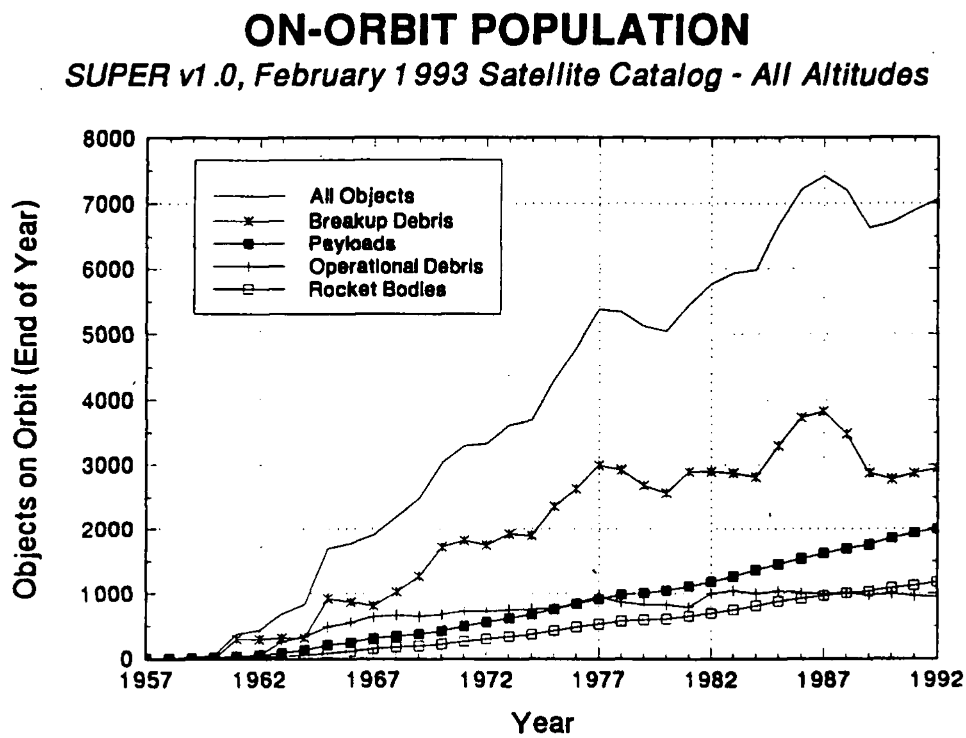

Figure 4. Growth Rate of Components of the Trackable Orbital Population.[4]

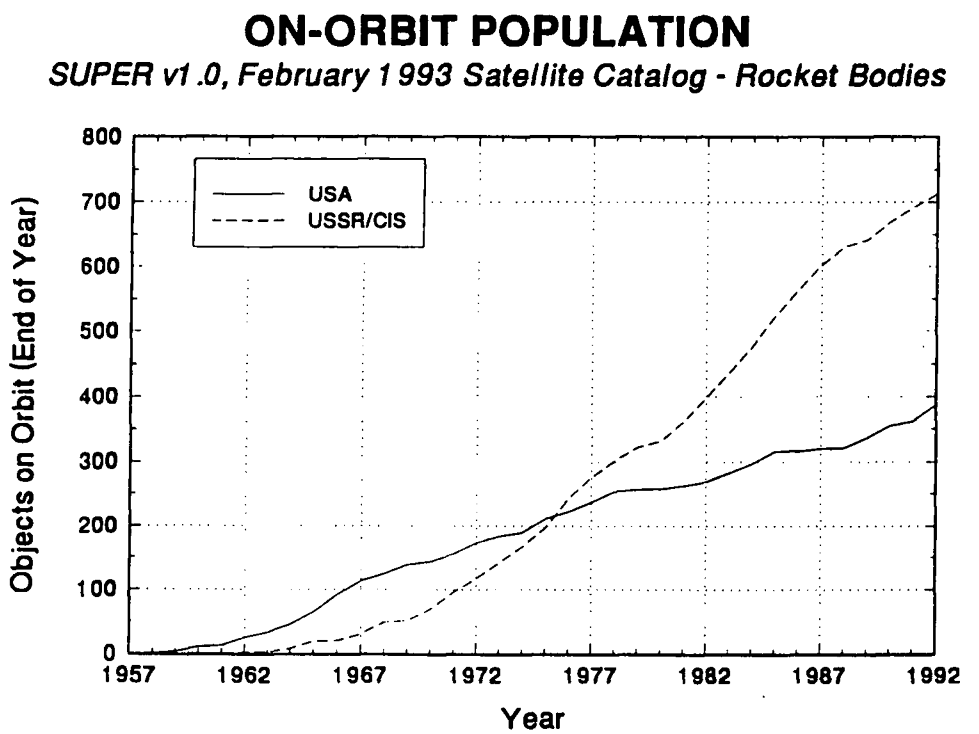

Figure 5. Rocket Body Growth Rates for U.S. and CIS/USSR.[4]

The concern about the GEO regime is largely due to the international nature of the satellites deployed there but also since atmospheric drag does not reduce any objects' lifetimes. Figure 6 plots the growth of the orbital population in GEO, with GEO defined as +/-1000 km of GEO. Note the steep growth of the GEO catalog with no operational or fragmentation debris due to resolution constraints.

Dividing the GEO regime, as previously defined, into two regions provides a greater insight into GEO growth. GEO1 represents all objects within +/-100 km of GEO and less than 7 degrees inclination. GEO2 contains all the objects of GEO not contained in GEO1 (i.e., GEO1 + GEO2 = GEO). GEO1 may be thought of loosely as geostationary satellites, while GEO2 represents largely old, abandoned objects. Figures 7 and 8 are the growth curves for GEO1 and GEO2, respectively.

As expected, GEO1 consists almost totally of payloads, while GEO2 has a nearly equal number of payloads and rocket bodies while they are growing at nearly equal rates. GEO1 and GEO2 regions contain almost equal number of trackable objects.

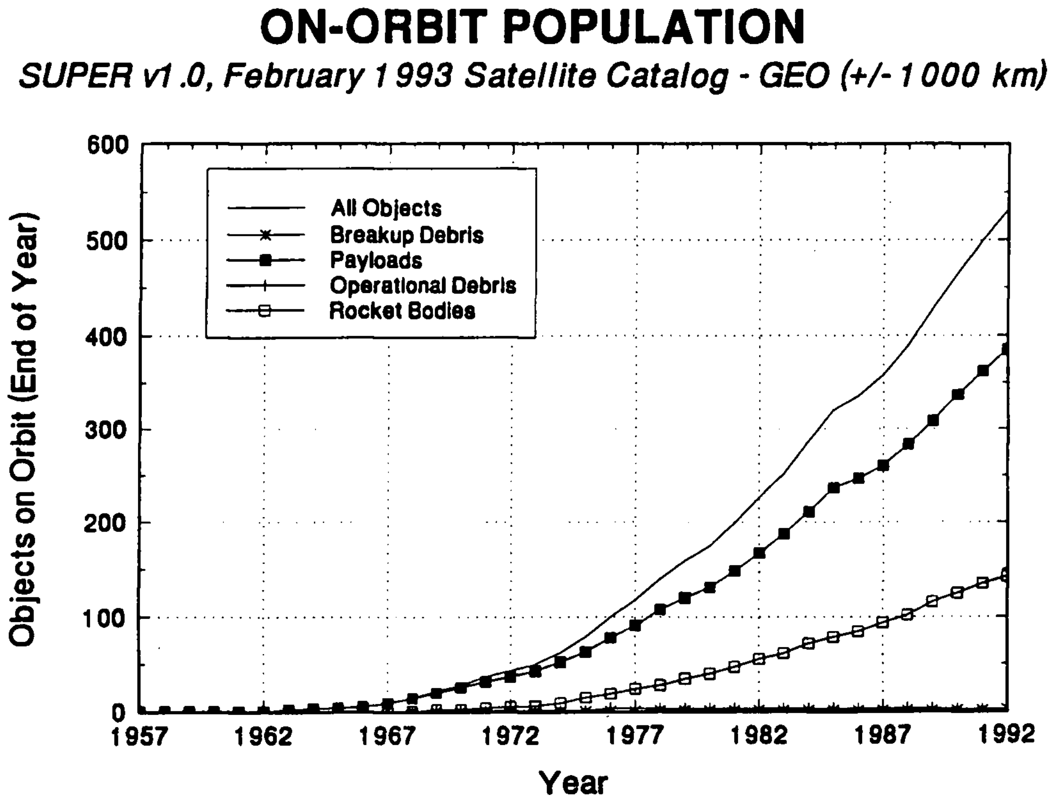

Figure 6. Growth Rate of GEO Population.[4]

ON-ORBIT POPULATION

SUPER v1.0, February 1993 Satellite Catalog - GEO1

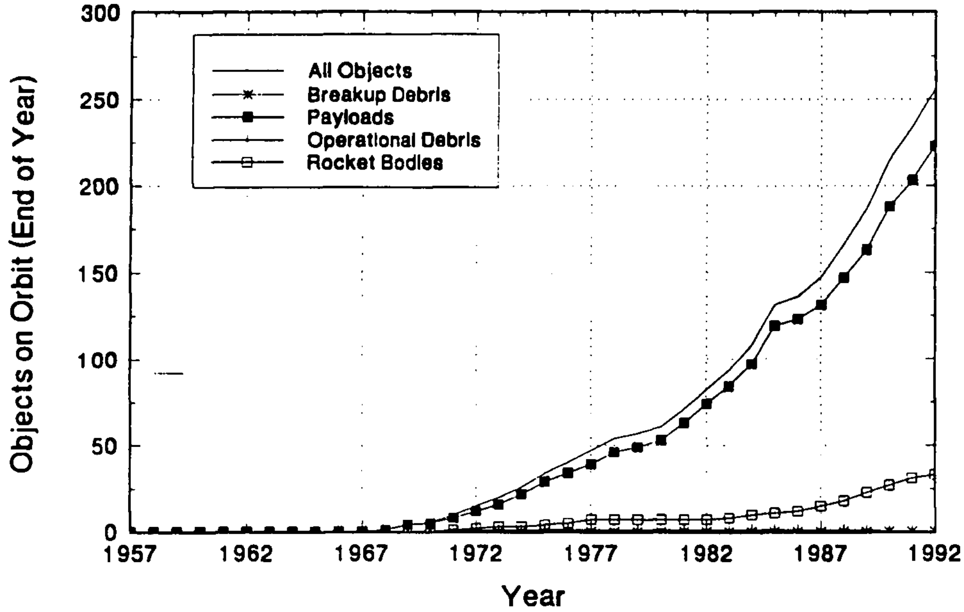

Figure 7. GEO1 Growth Curve.[4]

ON-ORBIT POPULATION

SUPER v1.0, February 1993 Satellite Catalog - GEO2

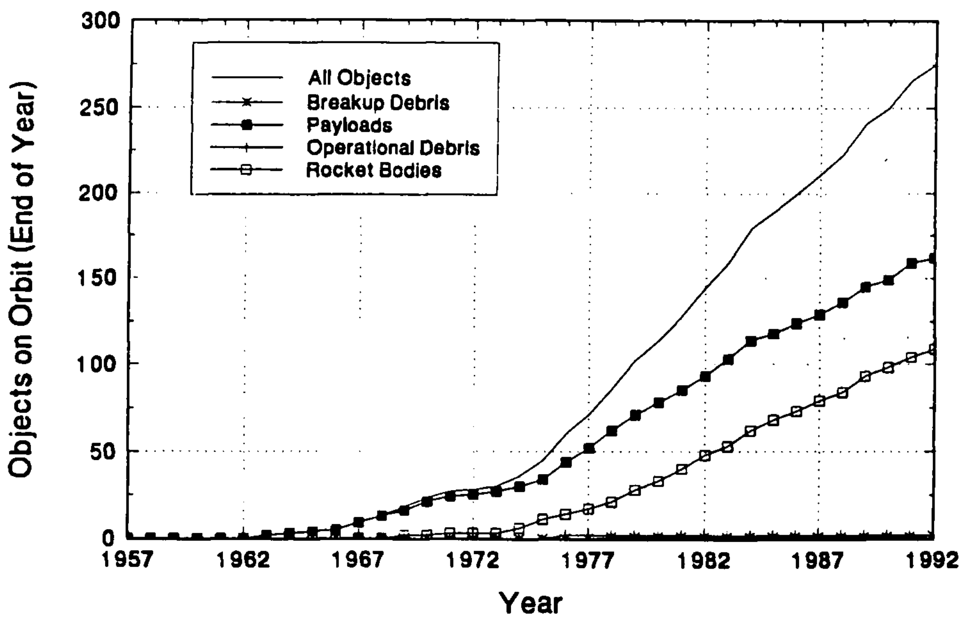

Figure 8. GEO2 Growth Curve.[4]

Recent Events

Since the position paper was initiated (Jan 1991), there have been 14 satellite breakups and the catalog population has increased from 6745 to 7435 (+10%).[5] These rates of 5 breakups/year and 3.6% annual catalog growth are fairly consistent with the past twenty years. Alternatively, the cause for a series of major satellite breakup events (SL-12 Proton kick stages) was determined through a Russian-American investigation.[6] More joint efforts of this type will hopefully continue to shed light on the nearly 30 breakups of unknown cause.

Even as the position paper on orbital debris is just being approved as an official IAA position paper, a new international effort is being initiated.

"The National Research Council (NRC) study on space debris was created at the request of the National Aeronautics and Space Administration (NASA) to assess the nature of the orbital debris problem and recommend technical means for its mitigation. An important objective of the study is to work toward building an international consensus on the need for and technical means to implement debris mitigation efforts; the study's findings and recommendations will be presented as a report to the space agencies of the space-faring world and other concerned parties."

Acknowledgments

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