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Effectiveness of Satellite Postmission Disposal To Limit Orbital Debris Population Growth in Low Earth Orbit

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Orbital debris mitigation measures have been developed to reduce the growth of the debris population. A major component in debris mitigation is postmission disposal (PMD). The key PMD element for low Earth orbit (LEO – the region below 2000-km altitude) satellites is the 25-year rule. It is intended to limit the long-term presence of rocket bodies (R/Bs) and spacecraft (S/C) as well as mission-related debris in the environment. The effectiveness of PMD has been demonstrated and documented since mitigation measures were developed in the 1990s. This article provides an update, based on the current environment, using the NASA orbital debris evolutionary model – LEGEND (Low Earth orbit-to-Geosynchronous orbit ENvironment Debris model). This model was developed by the NASA Orbital Debris Program Office at JSC, and the PMD study was completed in 2012.

The study focused on the ≥10 cm population in LEO. The historical simulation spanned the years 1957 through 2011 and followed the recorded launches and known breakup events. The simulation was projected 200 years into the future, with launch traffic from a span of 8 years, 2004–2011, repeated during the projection period. An 8-year mission lifetime was assumed for future S/C. No station-keeping or collision-avoidance maneuvers were implemented, and only objects 10 cm and larger were included in collision consideration. Additionally, no explosions were allowed for R/Bs and S/C launched after 2011. The 25-year PMD rule compliance rates were set at 0 percent, 10 percent, 50 percent, 75 percent, and 95 percent, respectively, for the five study scenarios.

Figure 1 shows the effective numbers of objects in LEO, including both the historical and the five future projections. Each projection curve is the average of 100 Monte Carlo (MC) LEGEND runs. As expected, the 0-percent PMD projection follows a rapid and nonlinear increase in the next 200 years. With 50-percent compliance with the 25-year rule, the population growth is reduced by approximately half. However, even with 95-percent compliance with the 25-year rule, the LEO debris population will increase by an average of more than 50 percent in 200 years.

The projected collision activities are shown in figure 2 and summarized in figure 3. A catastrophic collision occurs when the ratio of impact energy to target mass exceeds 40 J/g. The outcome of a catastrophic collision is the total fragmentation of the target, whereas a noncatastrophic collision results only in damage to the target and the generation of a small amount of debris. Even with 95 percent compliance with the 25-year rule, on average, 26 catastrophic and 19 noncatastrophic collisions are expected in the next 200 years.

Predicting the future debris environment is very difficult. The results are always sensitive to key assumptions adopted by the model, including the future launches and solar activity. Nevertheless, one can make reasonable assumptions, define nominal scenarios, and then draw conclusions from the average results for effective environment management. This updated study again illustrates the effectiveness of orbital debris mitigation. It is the first and the most cost-effective defense against future population growth. On the other hand, the study results also show that even with no future explosion and global 95-percent compliance with the 25-year rule, the LEO debris population is expected to increase slowly during the next 200 years. To stabilize the future debris population and reduce collision activities in LEO, more aggressive measures, such as active debris removal, should be considered by the international community.

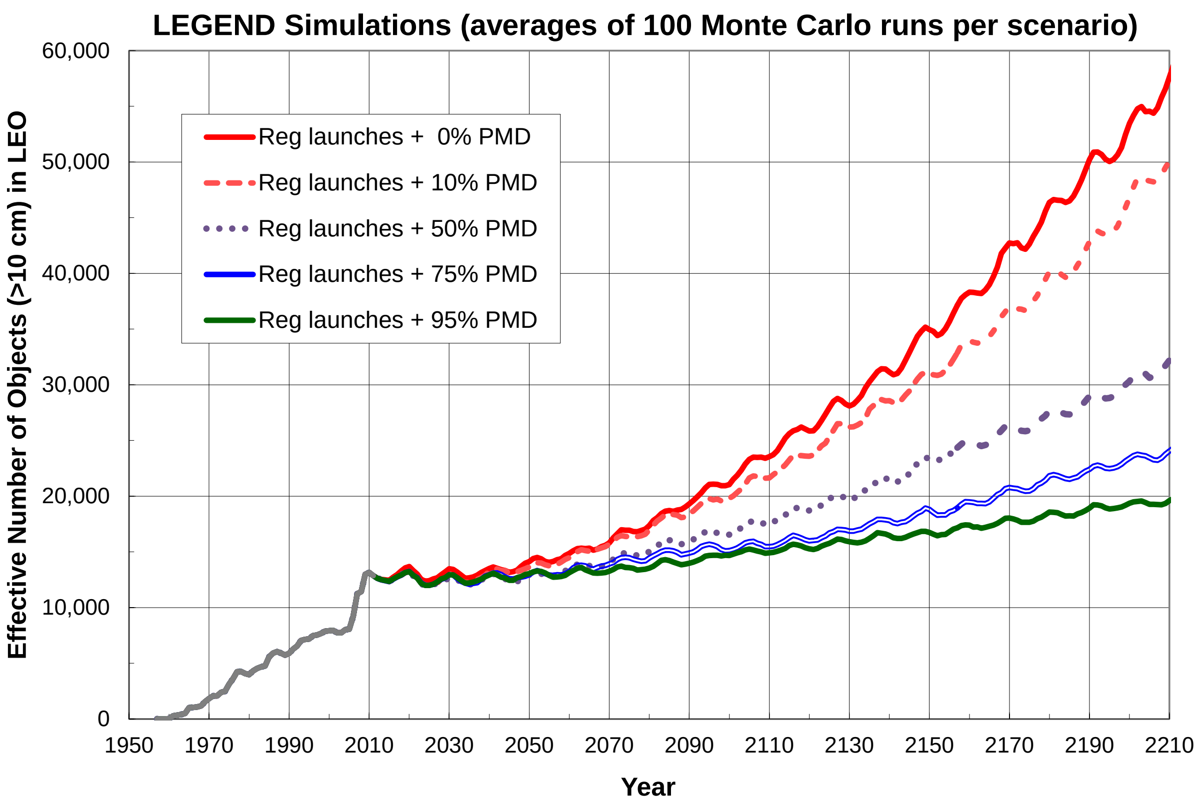

Figure 1.– Effective numbers of the 10-cm and larger objects in LEO. The effective number is defined as the fractional time, per orbital period, an object spends below 2000-km altitude. The simulations assumed no explosions for S/C and R/Bs launched after 2011.

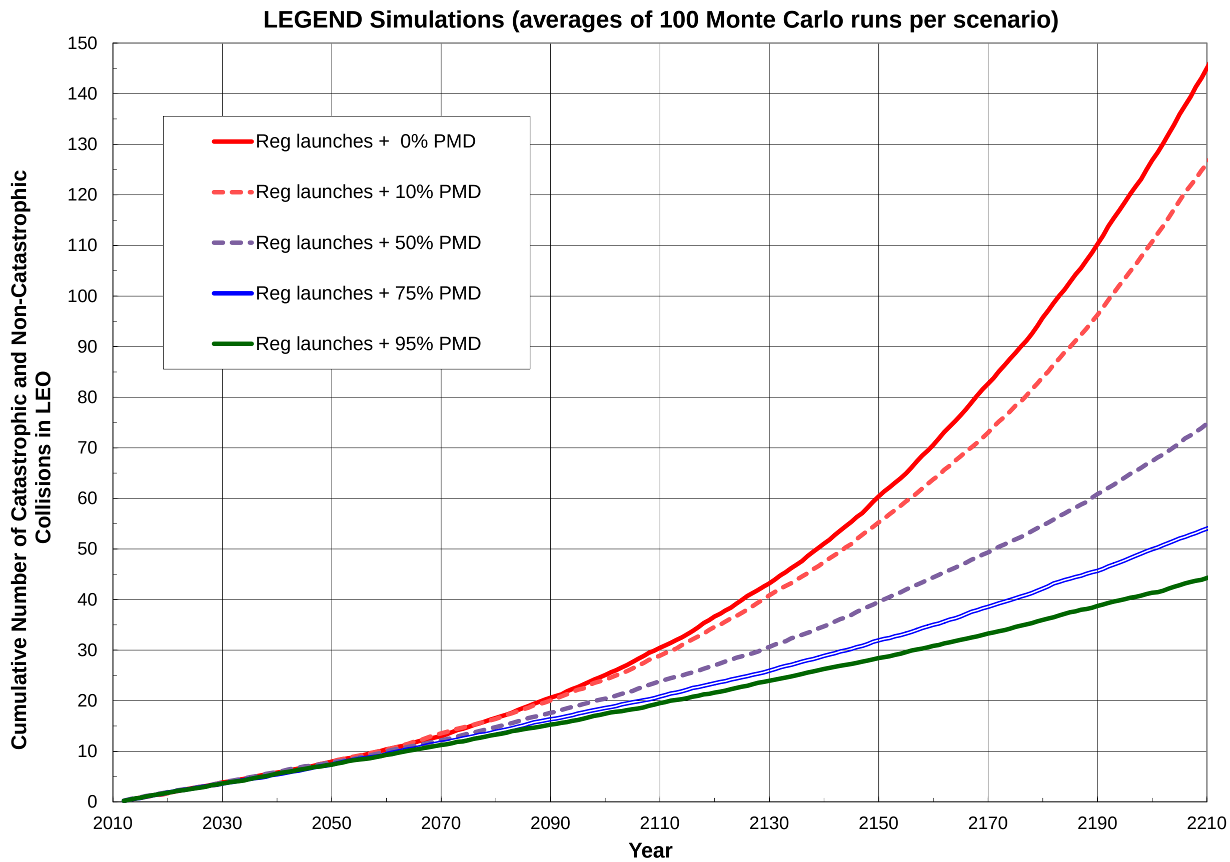

Figure 2.– Cumulative numbers of catastrophic collisions predicted by the five-projection scenario. Each curve represents the average of 100 Monte Carlo runs.

	0% PMD	10% PMD	50% PMD	75% PMD	95% PMD
Cat. Collisions	71	63	39	30	26
Non-cat. Collisions	76	65	37	24	19
Total Collisions	147	128	76	54	45

Figure 3.– Projected collision activities for the next 200 years in LEO. All collisions are for objects 10 cm and larger. The numbers are averages of 100 Monte Carlo runs.