Survival Analysis for Nanosatellites and Picosatellites

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I. Background

This work explores reliability factors associated with fractionated spacecraft architectures (specifically, the Kinetically-Aggregated Infrastructure Revitalization of Spacecraft [KAIROS] concept) by conducting a survival analysis for nanosatellites and picosatellites. Time to failure data is collected for 85 spacecraft in the nano- (1.01 – 10 kg wet mass) and pico- (0.11 – 1 kg wet mass) classes without data censoring. These spacecraft were launched between 2010 and 2019, inclusive, having an internationally diverse set of owners from the sectors of military, government, commercial, and academia. This data is used to build a distribution for the survival analysis of satellites in these classes.

II. Results

Analysis indicated that the two-parameter Weibull distribution may be an adequate fit for the data.

$$f(z) = \frac{e^{-\frac{z^\gamma}{\beta}}}{\beta} \gamma z^{\gamma-1}$$

Fitting the two-parameter Weibull yielded parameter estimates of $\beta = 0.3306607$ and $\gamma = 0.5922925$ which indicates beneficial aging. The figure shows the cumulative distribution function for spacecraft failure with the fitted Weibull.
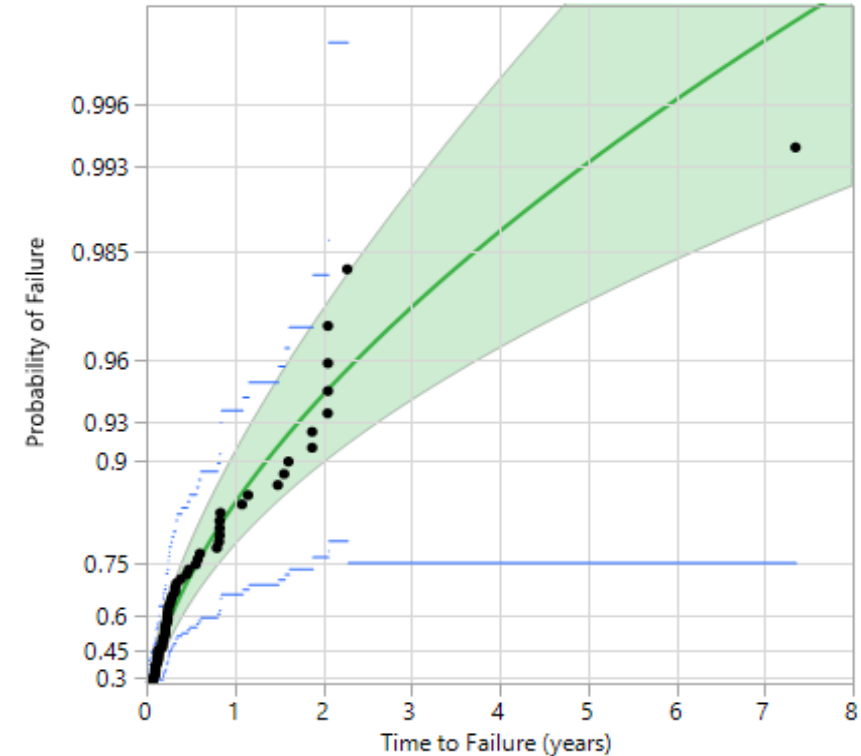
III. Conclusions

Understanding the reliability characteristics of satellites in these classes affords the U.S. Department of Defense the opportunity to increase the efficacy of its acquisition programs. This work strives for the enhancement of the security and prosperity of the U.S. through the advancement of strategic thinking within the space domain.

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