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Quality and Safety, a challenge for all in Space (1)

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ACHIEVING HIGH RELIABILITY WITH HIGH CONFIDENCE FOR DEEP SPACE SYSTEMS

Abstract

Future human space missions will explore far beyond Earth orbit and the Earth-moon system, reaching the planets and asteroids in deep space. The propulsion, life support, and other spacecraft systems should be developed to have high reliability with high confidence. The first step is to design, test, and redesign the systems to achieve their highest feasible intrinsic reliability. The second step, if the individual system reliability is less than required, is to provide sufficient spares so that the probability that not all will fail is high enough to meet the mission reliability requirement. Having sufficient spares is necessary but not sufficient to achieve high reliability with high confidence, since there are failure causes that cannot be repaired using spares, such as system level interactions, external impacts, common cause failures, and operator error. The number of spares needed to achieve the required reliability using redundancy can be computed using the cumulative Poisson distribution with a mean equal to the estimated single unit failure rate. The confidence that this reliability will be achieved can be computed using the cumulative Poisson distribution or the chi-square distribution. Since the experienced single unit failure rate on the mission is a probabilistic variable, the confidence that the actual mission unit failure rate is not higher than estimated and the reliability is not overestimated is about 50The single unit failure rate is determined by initial reliability growth testing and removing design errors and later long duration testing to better measure the final constant failure rate. Reducing the failure rate and reducing its variance both reduce the number of redundant units needed for the required reliability and confidence. Since the cost for the required reliability is the sum of the costs of the redundant systems and of the reliability growth and life testing, there is an optimum test duration that produces the minimum total cost.