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Reliability for relativistic spacecraft

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Abstract

In this paper for the first time it is merged the relativistic interstellar flight theory with the reliability theory. If a spacecraft flies to a far stellar system with velocities not negligible in comparison with the speed of light it has to be taken into account special relativistic effects, in particular for the time depending quantities. But probability density function, reliability, hazard rate, and other linked quantities, in general are time depending then they can be studied under this point of view. In particular the most used distributions in space engineering have been considered, i.e. Weibull, exponential, normal, lognormal, gamma, Gumbel, and they have been studied for three different kinds of space flights: non-relativistic, relativistic uniform linear motion and relativistic hyperbolic motion. In the first kind of flight the coordinate time t coincides with the proper time τ (in relativistic sense) then the proper functions coincide with the coordinate functions. For the other two cases the proper functions are again the classical quantities, instead the main result of this work gives the collection of the corresponding coordinate functions that are the quantities calculated on the Earth, necessary to design and follow the mission at a distance.

Keywords: Reliability; Relativistic reliability; Special relativity; Interstellar flight; Relativistic spacecraft

1. Introduction

If a spacecraft goes out from our solar system toward another star, like Alpha Centauri (4.29 *ly* from the Earth), it needs very advanced and powerful propulsion systems to thrust it to relativistic speeds.

Such a kind of mission it is clearly very different from classical ones, also in terms of probability functions, random variables and their application to the engineering design.

In Sections 2 and 3 it is summarized useful basic concepts of reliability theory and relativistic motion in space. In Section 4 it is shown the way to transform reliability functions, and other connected functions, from the proper form (used aboard a relativistic spacecraft) to the corresponding coordinate form (used on the Earth). Finally, in Sections 5, 6, 7 and 8 it is applied all transformation rules found to the most used continuous reliability functions.

2. Fundamentals of the reliability theory

First of all it is necessary to define the most important quantities utilised in the reliability theory, useful to carry out all other aspects of this research. They are collected in Table 1.

In reliability theory it is important to distinguish between repairable and non-repairable items (Ref. [1]). For a *non-repairable item* (a rocket motor, an unmanned

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