



## Safe Onboard Guidance and Control Under Probabilistic Uncertainty

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An algorithm was developed that determines the fuel-optimal spacecraft guidance trajectory that takes into account uncertainty, in order to guarantee that mission safety constraints are satisfied with the required probability. The algorithm uses convex optimization to solve for the optimal trajectory. Convex optimization is amenable to onboard so-

lution due to its excellent convergence properties.

The algorithm is novel because, unlike prior approaches, it does not require time-consuming evaluation of multivariate probability densities. Instead, it uses a new mathematical bounding approach to ensure that probability constraints are satisfied, and it is shown that the result-

ing optimization is convex. Empirical results show that the approach is many orders of magnitude less conservative than existing set conversion techniques, for a small penalty in computation time.

*This work was done by Lars James Blackmore of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-46155*

## General Tool for Evaluating High-Contrast Coronagraphic Telescope Performance Error Budgets

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The Coronagraph Performance Error Budget (CPEB) tool automates many of the key steps required to evaluate the scattered starlight contrast in the dark hole of a space-based coronagraph. The tool uses a Code V prescription of the optical train, and uses MATLAB programs to call ray-trace code that generates linear beam-walk and aberration sensitivity matrices for motions of the optical elements and line-of-sight pointing, with and without controlled fine-steering mirrors (FSMs). The sensitivity matrices are imported by macros into Excel 2007, where the error budget is evaluated. The user specifies the particular optics of interest, and chooses the quality of each optic from a predefined set of PSDs. The spreadsheet creates a nominal set of thermal and jitter motions, and combines that with the sensitivity matrices to generate an error budget for the system.

CPEB also contains a combination of form and ActiveX controls with Visual Basic for Applications code to allow for user interaction in which the user can perform trade studies such as changing engineering requirements, and identifying and isolating stringent requirements. It contains summary tables and graphics that can be instantly used for reporting results in view graphs.

The entire process to obtain a coronagraphic telescope performance error budget has been automated into three stages: conversion of optical prescription from Zemax or Code V to MACOS (in-house optical modeling and analysis tool), a linear models process, and an error budget tool process. The first process was improved by developing a MATLAB package based on the Class Constructor Method with a number of user-defined functions that allow the user to modify the MACOS optical pre-

scription. The second process was modified by creating a MATLAB package that contains user-defined functions that automate the process. The user interfaces with the process by utilizing an initialization file where the user defines the parameters of the linear model computations. Other than this, the process is fully automated. The third process was developed based on the Terrestrial Planet Finder coronagraph Error Budget Tool, but was fully automated by using VBA code, form, and ActiveX controls.

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*This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at [danielb@caltech.edu](mailto:danielb@caltech.edu). Refer to NPO-47220.*

## Hidden Statistics of Schrödinger Equation

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Work was carried out in determination of the mathematical origin of randomness in quantum mechanics and creating a hidden statistics of Schrödinger equation; i.e., to expose the transitional sto-

chastic process as a "bridge" to the quantum world. The governing equations of hidden statistics would preserve such properties of quantum physics as superposition, entanglement, and direct-pro-

duct decomposability while allowing one to measure its state variables using classical methods. In other words, such a system would reinforce the advantages and minimize the limitations of both quan-