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Systems Engineering for Astronomical Telescopes

Paul A. Lightsey
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Introduction to the Series

Since its inception in 1989, the Tutorial Texts (TT) series has grown to cover many diverse fields of science and engineering. The initial idea for the series was to make material presented in SPIE short courses available to those who could not attend and to provide a reference text for those who could. Thus, many of the texts in this series are generated by augmenting course notes with descriptive text that further illuminates the subject. In this way, the TT becomes an excellent stand-alone reference that finds a much wider audience than only short course attendees.

Tutorial Texts have grown in popularity and in the scope of material covered since 1989. They no longer necessarily stem from short courses; rather, they are often generated independently by experts in the field. They are popular because they provide a ready reference to those wishing to learn about emerging technologies or the latest information within their field. The topics within the series have grown from the initial areas of geometrical optics, optical detectors, and image processing to include the emerging fields of nanotechnology, biomedical optics, fiber optics, and laser technologies. Authors contributing to the TT series are instructed to provide introductory material so that those new to the field may use the book as a starting point to get a basic grasp of the material. It is hoped that some readers may develop sufficient interest to take a short course by the author or pursue further research in more advanced books to delve deeper into the subject.

The books in this series are distinguished from other technical monographs and textbooks in the way in which the material is presented. In keeping with the tutorial nature of the series, there is an emphasis on the use of graphical and illustrative material to better elucidate basic and advanced concepts. There is also heavy use of tabular reference data and numerous examples to further explain the concepts presented. The publishing time for the books is kept to a minimum so that the books will be as timely and up-to-date as possible. Furthermore, these introductory books are competitively priced compared to more traditional books on the same subject.

When a proposal for a text is received, each proposal is evaluated to determine the relevance of the proposed topic. This initial reviewing process has been very helpful to authors in identifying, early in the writing process, the need for additional material or other changes in approach that would serve to strengthen the text. Once a manuscript is completed, it is peer reviewed to ensure that chapters communicate accurately the essential ingredients of the science and technologies under discussion.

It is my goal to maintain the style and quality of books in the series and to further expand the topic areas to include new emerging fields as they become of interest to our reading audience.

James A. Harrington
Rutgers University
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Preface

The discipline of systems engineering has been emerging since the 1940s. With the development of large ground-based telescopes, such as the Keck, Gemini, and the Very Large Telescope, and space telescopes, such as the Hubble Space Telescope, Chandra X-ray Observatory, and the Spitzer Infrared Telescope, the role of systems engineering for astronomical telescopes has come to the forefront. As we move forward into the next decade, there are numerous opportunities and a need for systems engineering to play a role for future observatories. The purpose of this book is to provide an overview of systems engineering as it applies to large astronomical telescopes, with an emphasis on space telescopes, and the tools for supporting the development and management of future programs. Examples from previous programs are used to illustrate the concepts and processes. The important personality and behavioral aspects of good systems engineers are mentioned. The book is intended for aspiring new systems engineers and as a refresher or reference for current practitioners. It is also useful for engineers in other disciplines to better understand and guide their participation in the larger system endeavor. To paraphrase an old bumper sticker from years ago: Think globally, systems, act locally.

The stimulus to develop this book has evolved over time. The initial impetus for Paul Lightsey was a suggestion from Phil Stahl following a briefing of the results of the pre-Phase-A architecture study for the Next-Generation Space Telescope (which later became the James Webb Space Telescope, or JWST). Stahl suggested that Lightsey offer a short course on systems engineering and architecture development for SPIE. The seed was planted but took time to germinate. In the interim, Lightsey was an adjunct lecturer for the Johns Hopkins Masters in Space Systems Engineering program offered at Ball Aerospace, and also developed and taught an internal training course at Ball on architectural concept development. A few years later, Stahl invited Jonathan Arenberg and Lightsey to collaborate on status updates on the progress of the JWST program at a Mirror Technologies Meeting. A few years later, Arenberg was invited to develop a short course on systems engineering for SPIE. He agreed on the condition that he and Lightsey could co-develop the course. The course relied on the combined experience of the authors having
worked on the Great Observatories Hubble Space Telescope, Chandra X-ray Observatory, and the Spitzer Infrared Telescope Facility, along with diverse experience from a multitude of other aerospace programs. The course was first presented at the SPIE International Conference on Astronomical Telescopes and Instruments at Montreal in 2014. At that time, the authors were invited to develop a text based on the course. The progress was slow, with a preliminary draft ready at the time of the SPIE International Conference on Astronomical Telescopes and Instruments at Edinburgh in 2016. The SPIE editors solicited reviews, which have been used to update the book, from colleagues and feedback from the short-course students. So now as we approach the imminent launch of the JWST and the reports from the studies for missions to be presented for the 2020 Decadal survey, we offer this book and hope that readers find it useful.

We wish to thank the many colleagues and students, past and present, from whom we have learned much. We would like to dedicate this book to our wives, who tolerated the long hours we have put into our profession and into the preparation of this book.

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