

# Integrated Analysis of Thermal/Structural/Optical Systems

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## ABSTRACT

Productivity bottlenecks for integrated thermal, structural, and optical design activities were identified and systematically eliminated, making possible automated exchange of design information between different engineering specialties.

The problems with prior approaches are summarized, then the implementation of the corresponding solutions is documented. Although the goal of this project was the automated evaluation of coupled thermal/optical/structural designs, significant process improvements were achieved for subset activities such as stand-alone thermal, thermal/structural, and structural/optical design analysis.

## INTRODUCTION: PROBLEM STATEMENT

Structural, thermal, and optical engineers typically work independently of each other using unrelated tools, models, and methods. Without the ability to rapidly exchange design data and predicted performance, and therefore to influence each other's efforts, the prior state-of-the-art for the design of advanced optical systems was inadequate: it has henceforth resisted attempts to achieve the ideals of concurrent engineering. Limited success has been achieved at a very top-level (suitable for conceptual design studies), but only by approximating or neglecting the detailed design tasks that the engineering specialist must perform in later mission phases.

Without the ability to work concurrently, the disciplines of thermal control, structures, and optics levy worst-case performance requirements on each other such that each specialty can contribute to a design independently. The optical engineers dictate distortion limits to the structural engineer, who then dictates limits on temperatures and gradients to the thermal engineer. Requirements are derived, then flowed down. The thermal and structural engineers blindly obey these limits under all operational conditions, thereby satisfying the optical performance requirements.

That approach results in a stack-up of margins and inevitably to over-design, to the point of rendering advanced mis-

sions such as NASA's Next Generation Space Telescope (NGST), with its cryogenic large aperture optics, difficult to achieve without an integrated design approach. For example, temperature gradients in a mirror support structure are inconsequential as long as the required optical performance is achieved, yet derived limits on such gradients often become a design driver for thermal control specialists.

## DESIGN PROCESS INTEGRATION

This paper describes the first step, which was to achieve tighter and smarter communication pathways between existing tools such as ORA's CODE V® optical analyzer, the MSC/NASTRAN® structural analyzer, and C&R's SINDA/FLUINT and Thermal Desktop®. Once this was achieved, the ability to externally drive the design towards an optimum was implemented and tested, as described in Reference 1.

Previous innovations by the development team had eliminated many of the stumbling blocks that had stymied earlier attempts to achieve a tight integration between thermal control, structures, and optics. These prior advances include a finite element-compatible and CAD compatible thermal radiation analyzer (Ref 2), thermal tools compatible with structural programs (Ref 3), optimizing thermal/fluid solvers (Ref 4), and integrated structures/optics design.

The theme of "intelligent integration without sacrificing the tools or methods of each specialty" was carried forward into the idea of providing system-level design optimization tools. In other words, the goal of this development was not merely an integrated tool suite, but also one that can automatically explore the design space to find an optimal design that meets required optical performance under all structural load cases and thermal environments.

As will be seen, however, the end product (OptiOpt™, for "optimized opto-mechanical design") does not have to be applied in its entirety in order to achieve significant improvements over prior design practices. Rather, improvements to the underlying thermal and optical codes and the generation of general purpose model conversion and mapping schemes are useful in and of themselves. In

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## **Table of Contents Integrated Analysis Of Thermal Structural Optical Systems**

1. Understanding the eBook Integrated Analysis Of Thermal Structural Optical Systems
  - The Rise of Digital Reading Integrated Analysis Of Thermal Structural Optical Systems
  - Advantages of eBooks Over Traditional Books
2. Identifying Integrated Analysis Of Thermal Structural Optical Systems
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Integrated Analysis Of Thermal Structural Optical Systems
  - User-Friendly Interface
4. Exploring eBook Recommendations from Integrated Analysis Of Thermal Structural Optical Systems
  - Personalized Recommendations
  - Integrated Analysis Of Thermal Structural Optical Systems User Reviews and Ratings

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- Integrated Analysis Of Thermal Structural Optical Systems and Bestseller Lists
- 5. Accessing Integrated Analysis Of Thermal Structural Optical Systems Free and Paid eBooks
  - Integrated Analysis Of Thermal Structural Optical Systems Public Domain eBooks
  - Integrated Analysis Of Thermal Structural Optical Systems eBook Subscription Services
  - Integrated Analysis Of Thermal Structural Optical Systems Budget-Friendly Options
- 6. Navigating Integrated Analysis Of Thermal Structural Optical Systems eBook Formats
  - ePub, PDF, MOBI, and More
  - Integrated Analysis Of Thermal Structural Optical Systems Compatibility with Devices
  - Integrated Analysis Of Thermal Structural Optical Systems Enhanced eBook Features
- 7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Integrated Analysis Of Thermal Structural Optical Systems
  - Highlighting and Note-Taking Integrated Analysis Of Thermal Structural Optical Systems
  - Interactive Elements Integrated Analysis Of Thermal Structural Optical Systems
- 8. Staying Engaged with Integrated Analysis Of Thermal Structural Optical Systems
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Integrated Analysis Of Thermal Structural Optical Systems
- 9. Balancing eBooks and Physical Books Integrated Analysis Of Thermal Structural Optical Systems
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Integrated Analysis Of Thermal Structural Optical Systems
- 10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
- 11. Cultivating a Reading Routine Integrated Analysis Of Thermal Structural Optical Systems
  - Setting Reading Goals Integrated Analysis Of Thermal Structural Optical Systems
  - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Integrated Analysis Of Thermal Structural Optical Systems
  - Fact-Checking eBook Content of Integrated Analysis Of Thermal Structural Optical Systems
  - Distinguishing Credible Sources

13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
  - Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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