Concept Design and Realization Branch—Part II: Guest Editors' Introduction

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ABSTRACT

The Johns Hopkins University Applied Physics Laboratory (APL) Concept Design and Realization Branch offers an array of engineering, design, and fabrication capabilities that support the Laboratory's mission and broad sponsored work. Until 2023, the Johns Hopkins APL Technical Digest had not published a comprehensive review of the branch's work in more than two decades. During those years, manufacturing technologies and the Lab's capabilities have advanced significantly, as has the complexity of the challenges APL seeks to solve. This issue, the final in a series of two, further highlights APL's contributions in hardware design, mechanical and electrical fabrication, systems integration, and pioneering manufacturing science. This work not only benefits the Laboratory's programs and missions of today but also positions APL to contribute to solving the challenges of the future.

INTRODUCTION

The Concept Design and Realization Branch of APL's Research and Exploratory Development Department (REDD) is an enabling partner for diverse projects throughout the Laboratory. From modeling and analyzing multiscale systems to fabricating one-of-a-kind prototype systems and spacecraft, the branch has long been an essential contributor to APL's success and trusted relationships with its sponsors. The branch's more than 200 staff members, ranging from uniquely skilled machine operators and electronics technicians to multidisciplinary engineers and scientists, are embedded within projects across the Lab to develop innovative solutions to extraordinary challenges, fabricate and integrate complex systems, and lead pioneering research in manufacturing science. This issue, the second of two dedicated to showcasing the work of this branch, further explores many of the tools and technologies that make up this unique set of capabilities. In doing so, it highlights examples of the tremendous breadth and depth of contributions of staff members from across the branch. It is this collection of wide-ranging capabilities, exercised in concert with technical sectors focused on developing game-changing solutions to the nation's most pressing challenges, that enables APL to be a leader among its peers.

THE ARTICLES

This issue begins with "Microelectronics Packaging at APL: Delivering Custom Devices for Critical Missions," in which Rojas et al. survey APL's extensive array of microelectronics fabrication, packaging, and assembly capabilities and their multitude of unique applications. Distinctive from the large-scale worldwide industry supporting modern consumer electronics, APL's equipment- and facility-intensive set of laboratories enables highly specialized, one-of-a-kind tasking for Lab projects. In these laboratories, highly skilled staff members prototype and produce a broad range of devices such as sensors, detectors, and communications and computing hardware for projects supporting research and development, defense, near-Earth and deep-space missions, and medicine.

Next, in "Modeling Nonlinear and Dynamic Mechanical Behavior," Shanaman et al. review the state of the art in modeling and analyzing highly dynamic phenomenon, including impacts, blasts, and crashes. Specifically, this article focuses on techniques for achieving models with greater fidelity to real-world situations. Modern, highly specialized software packages running on very high-performance computing clusters enable greater understanding and more accurate characterization of these highly complex scenarios. Nonetheless, deep understanding of the physical mechanics involved, knowledge of the methodologies by which these tools solve for solutions, and the ability to tailor their use based on specific applications is key to superior results. Several case studies demonstrate how APL's expertise in this area contributes to the safety of our nation's warfighters and diplomatic personnel.

Guided by its role as a university-affiliated research center (UARC), APL must often rapidly develop and prototype novel complex systems. To meet the ever-increasing desire for compressed development (and ultimately fielding) schedules while pushing the boundaries of science and technology, the approaches and tools used to execute this work are also rapidly evolving, as described in two articles in this issue. Sharp et al., in "Rapid Prototyping: Accelerating the Design Process," describe several tool sets and methodologies that provide engineers quicker ways to iteratively modify designs of parts and systems with greater precision and at lower cost than ever before. They present three case studies that demonstrate how success is accelerated during the ideation, design, and integration phases of programs. Discussed in this article and also in "From Drafting Boards to Virtual Reality: The Evolution of Mechanical Engineering and Design" by Crane et al. is the role of augmented/virtual reality and how haptic feedback in demonstrations of systems such as future cockpits increasingly allows valuable capture of the human interaction element within systems, a critical component to their operational success. Also explored are related capabilities for reverse engineering from large-scale data, along with some key advanced capabilities embedded in modern computer-aided design tools for packaging complex electromechanical systems and communicating these designs.

The next few articles focus on realizing complex designs for proof of principle, demonstration, and often as a means of further accelerating iterative development. In "Advanced Development and Fabrication at APL: Machines, Components, and Processes," Walters et al. review several examples that illustrate the power of pairing state-of-the-art equipment with knowledgeable manufacturing personnel who directly interact with engineers, designers, and research scientists. As this article explores, the results are frequently groundbreaking, novel, and, in some cases, literally preserve expensive spacecraft missions.

Next, in "Composite Materials: Enabling APL to Meet Complex Requirements for Critical Systems," Quinn explores the role of composite materials in many systems developed by APL. While composites are a long-established material and construction method used widely throughout the aerospace industry, APL uniquely leverages the tailorable properties of these lightweight materials in rapid prototyping applications where the use of expensive tooling with long lead times is not an option. This article also discusses the challenges of engineering composite structures to withstand the extreme environments encountered by spacecraft exploring the solar system. A highly practical example detailed in the article is the development of composite radome covers for a deep-space antenna system situated in the southwestern United States. The material was chosen for its nonmetallic properties and because its thermal characteristics could be tailored to protect system performance, since the system's physical location meant that the antennas would need to survive environmental damage, including hail strikes. The discussion once again highlights the powerful, interdisciplinary nature of APL's manufacturing teams.

This issue closes with "Perspectives on Engineering Design and Fabrication at APL," a reflective discussion by Dr. James Schatz, the head of REDD. He looks back at the branch's first decade and a few of the successes made possible by the visionary strategy to position the design and fabrication capabilities alongside APL's traditional research and development corps, an organizational move that created REDD more than 10 years ago. Schatz highlights some of the emerging trends in fabrication and briefly discusses APL's contributions, including an educational outreach effort with a local skilled training facility. Throughout, he makes the case that the Concept Design and Realization Branch is well equipped to continue pursuing the department's vision of accelerating transformative innovation and inventing the future for APL.

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