



## Guest Editors' Introduction

*Ward L. Ebert and Richard W. McEntire*

**T**he 40th Anniversary of the APL Space Department, like any major milestone, is an opportunity to take stock of the past and the present, and to think about the future. Forty years is not a long time in most of mankind's enduring endeavors, but it is almost the entire duration of the space age. In these few decades we have gone from the first infant satellite, beeping at the Earth, to huge fleets of globe-girdling, highly complex applications satellites vital to our economy. From space, man has looked downward on our small, precious world and outward to the outer limits of the solar system and the universe. In all of these endeavors, the Space Department has made important contributions. We were a player on the field in this grand game, and we still are.

The history of the Space Department has been well chronicled, and much of that in previous issues of this publication. For this anniversary issue, we set out to identify and emphasize the major thrusts that are important to the Department, that have evolved through our past to the present, and that will continue into the future. It is our hope that this issue captures this purpose with due respect to the accomplishments of the early days, but emphasizing the Space Department as it is today. Having set that goal, we still find in these articles much reference to our origins with the Navy Navigation Satellite System, because it is impossible without historical reference to describe how and why we do things as we do.

An apology seems in order to those who might look here for a complete description of the many significant accomplishments of the Department's staff over these 40 years. This issue, both by intent and the constraint of space, describes only the major, core capabilities and strengths of the organization and does not attempt to address the myriad inventions, applications, and spin-offs of that core as it evolved over the decades. Fortunately, many of these achievements are already documented elsewhere. We have also largely attempted to avoid stressing individual credit. Although each effort had many leaders and heroes, complex space missions are quintessentially team accomplishments! Every member of the Space Department has contributed to our present and will be responsible for shaping our future. The articles have been grouped to begin with a strategic overview and then present the three major thrusts of our current activity: spacecraft system development, scientific research, and advanced technology

development, with a concluding look at the impact of the Department's accomplishments to date.

In his overview of the Department's first 40 years, Krimigis recounts the history of APL's involvement in the nation's space program and the evolution of the Laboratory's relationships with the defense and civil space communities. The next seven articles explore aspects of space mission development and deployment with an emphasis on current challenges and on APL's ability to support missions "end-to-end," i.e., from problem definition to data understanding, including a top-level look at the development and operation between.

Bostrom describes the relationship of the technical demands the country has faced to the skills and innovation provided by APL, highlighting the characteristics of the organization that have persisted over the decades. Chief among his points is that our reputation has been the source of our continuing involvement in new challenges as they arise. Hoffman and Fountain then discuss the engineering implementation of space missions, describing system engineering and design philosophies that have served well. The article comments on the efficacy of "better, faster, cheaper" and the issue of discipline in managing requirements and risk. Ebert and Hoffman also tackle the "better, faster, cheaper" debate with a description of APL's experience and methods for ensuring reliable spaceflight systems. Their article examines several aspects of space system reliability including radiation hardness, reliability modeling, flight qualification, and process control. Coughlin, Chiu, and Dassoulas give the program manager's perspective on how to get the job done right, quickly, and efficiently. They codify and enumerate the "keys to success" that make the APL approach unique.

Baer et al. explain how mission operations are accomplished and provide insight into the advantages of increased autonomy in future spacecraft and ground systems. Faced with widely varying types of spacecraft and missions, from the intense control and data recovery activities of MSX (the Midcourse Space Experiment) to future interplanetary missions involving highly autonomous spacecraft, they present a spectrum of approaches that are necessary to address these challenges. Malcom and Utterback follow this theme with a discussion of flight software development, where the advances in computer technology have enabled increasingly autonomous behavior. This is an area less mature and more rapidly changing than spaceflight hardware technology, a fact borne out by the number of mission problems attributable to flaws in software development and testing. Last in this group of articles, Nylund and Holland address the challenges of usefully handling and displaying some of the common classes of high-volume digital data obtained from remote and *in situ* spacecraft sensors.

All aspects of mission definition and development, reliability, and operations are ultimately in service of the end mission objectives. For many of the Space Department's past, present, and future missions these objectives involve basic scientific research into our environment, from the Earth's oceans and atmosphere to the Sun and the outer reaches of the solar system. The next six articles describe major basic research areas in the Department—how and why they developed, and how they look toward the future. The first four articles concentrate on space physics, the next two on remote sensing of the Earth's atmosphere and oceans.

Williams et al. present the Department's initial basic research area, the study of energetic particles and magnetic fields in space—to measure and understand the environment in which our satellites had to function and survive. They trace this world-class research effort from initial measurements in low-Earth orbit to APL's present involvement in studies throughout the solar system. Currents driven by changes in the magnetic field, and particles precipitating from space, have significant effects on the upper atmosphere and ionosphere, including creation of the spectacular aurora. Paxton and Meng describe the evolution of our spacecraft studies of the aurora from above. They explore the science and instrumentation of remote sensing in visible and ultraviolet wavelengths of the aurora, and of the aurora's effects on the ionosphere and atmosphere. The ultimate source of the energy that drives all of this is the "solar wind," the supersonic plasma streaming out from the Sun. Rust describes the growing Space Department contributions to research on solar flares and the ejection of plasma from the Sun, as well as attempts to predict the Earth's "space weather." A recent major area of emphasis for Space Department scientists is solar system exploration. Cheng gives a personal account of our exciting entry into this area with the NEAR (the Near Earth Asteroid Rendezvous) mission, and of the challenging missions to come.

The structure and dynamics of the ionosphere and the upper atmosphere both affect, and can be affected by, man's activities, and the Department has a major and long-standing interest in understanding the processes involved. Greenwald et al. discuss progress from the application of a number of our remote sensing techniques (satellite measurements of atmospheric ozone, ground-based radar measurements of global ionospheric potentials, the effect of sunlight on auroras). They show both the importance and the complexity of these measurements. The last basic research article returns to the Department's roots. At our inception, sailors looked upward to APL-designed and built satellites in order to navigate the world's oceans. Gasparovic et al. describe APL's contributions to studies of the oceans, looking downward from space.

Our final series of articles emphasizes recent innovations and future capabilities. It is the nature of instrument development to be always on the cutting edge, because new scientific knowledge often requires the gathering of data beyond yesterday's boundaries of technology. Gold and Jenkins discuss advances in our instrument technology, addressing primarily the scientific instruments that comprise the "payload" carried by most of our recent spacecraft. This is an area that continually advances to keep up with changes in fundamental knowledge, and which in turn drives the definition of new missions. Jenkins then describes the present and future status of miniaturization of spaceflight electronics, and includes a list of "APL Space Firsts" over the four decades of the space age. His main

focus is on the management of technology development to achieve the greatest payoff from limited resources. He addresses specifics of our current thrusts in electronics in response to predicted needs for reusability of design, lighter weight, and greater autonomy. Bostrom and McEntire conclude with a view of the history and future of the APL Space Department from a broader perspective, beyond specific sponsor and mission requirements to the impact on all who have ultimately benefited from our endeavors.

We hope you enjoy these articles and come away with some sense of the essence of the APL Space Department—a uniquely experienced organization that continues to be, as it has been for 40 years, committed to innovation in science and technology in the nation's service.

#### THE AUTHORS



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