ATOMIC POWER IN SPACE II

A History of Space Nuclear Power and Propulsion in the United States

Idaho National Laboratory

INL/EXT-15-34409

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Prepared by
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Preface

Atomic Power in Space II is a sequel to *Atomic Power in Space* (published by the Department of Energy [DOE] in 1987). Beginning with a brief overview of the programs and systems developed through the late 1970s, *Atomic Power in Space II* traces the development and use of space nuclear power systems, including the missions and programs for which they were developed, to the present day. The history is written largely in nontechnical language so as to be useful to the general reader as well as the seasoned space nuclear professional.

Completion of this book would not have been possible without the help of many dedicated individuals. First and foremost is Steve Johnson, Director of the Idaho National Laboratory (INL) Space Nuclear Power and Isotope Technologies Division (SNPIT), whose vision and confidence were crucial in the undertaking of this assignment and whose balance of competing priorities helped ensure its fruition. Carl Friesen of the DOE-Idaho Operations Office and Wade Carroll of DOE-Headquarters provided many of the resources necessary to complete the project. A draft partial manuscript and resource library, developed by Janine Finnell, Richard Price, Ellen Clark, and their colleagues under another DOE contract prior to INL SNPIT involvement, was made available for use. That information, which included a series of interviews with many individuals who were involved in various aspects of space nuclear power system development over the years, was drawn upon during the research, writing, and development of this history. DOE also coordinated an independent technical review of the draft manuscript, which was provided by Dr. Gary Bennett (DOE/NASA retired), Earl Wahlquist (DOE, retired), John Warren (DOE/NASA), Robert Wiley (DoD/DOE/NASA contractor and DOE, retired), and Robert Carpenter (Orbital Sciences Corporation). Their comments, insight, and suggestions greatly improved the final manuscript. Any factual or technical accuracy errors that remain are my responsibility as the author and technical lead.

Graphics development and layout, technical editing, and other assistance were provided by Kris Burnham, Ann Riedesel, Lori McNamara, Travis Moedl, and Whitney Richardson of North Wind, Inc. Tamera Waldron, Tam Elingford, and Jackie Loop of the INL Technical Library provided invaluable assistance in locating journal articles, technical reports, Congressional hearing manuscripts, and other historical documents. James Werner of the INL SNPIT Program provided insight and perspective pertaining to space nuclear system technologies early in the development process. Several others assisted in the retrieval and provision of historical

photos and images for the book, including Doug Gabriel and Dick Madding at the Mound Museum in Miamisburg, Ohio; Nicholas Natanson of the National Archives and Records Administration; Heidi Palombo of DOE Energy Technology Visuals Collection and Document Imaging; Paul Ostdiek of Johns Hopkins University Applied Physics Laboratory; George Ulrich of the Oak Ridge National Laboratory; Jay Ray of DOE Savannah River; Scott Wold and Chris Morgan at INL; Richard Robinson and Alan Carr at Los Alamos National Laboratory; Ron Lipinski at Sandia National Laboratories; and Dwayne Brown at NASA.

My hope is that this history presents a meaningful and accurate sequel to that which was published almost 30 years ago. I also hope that the reader walks away with a sense of the wonder and amazement that I discovered as I learned about space nuclear power systems and their potential, both realized and unrealized, in the future of space exploration. Finally, for the dedicated individuals who spent countless hours and years laying the foundation of these remarkable systems and continuing the advancement of the technology, I hope the story stirs up memories (mostly fond!) of your labor and service to the U.S. space program, both civilian and defense.

Greg Hula
Idaho National Laboratory
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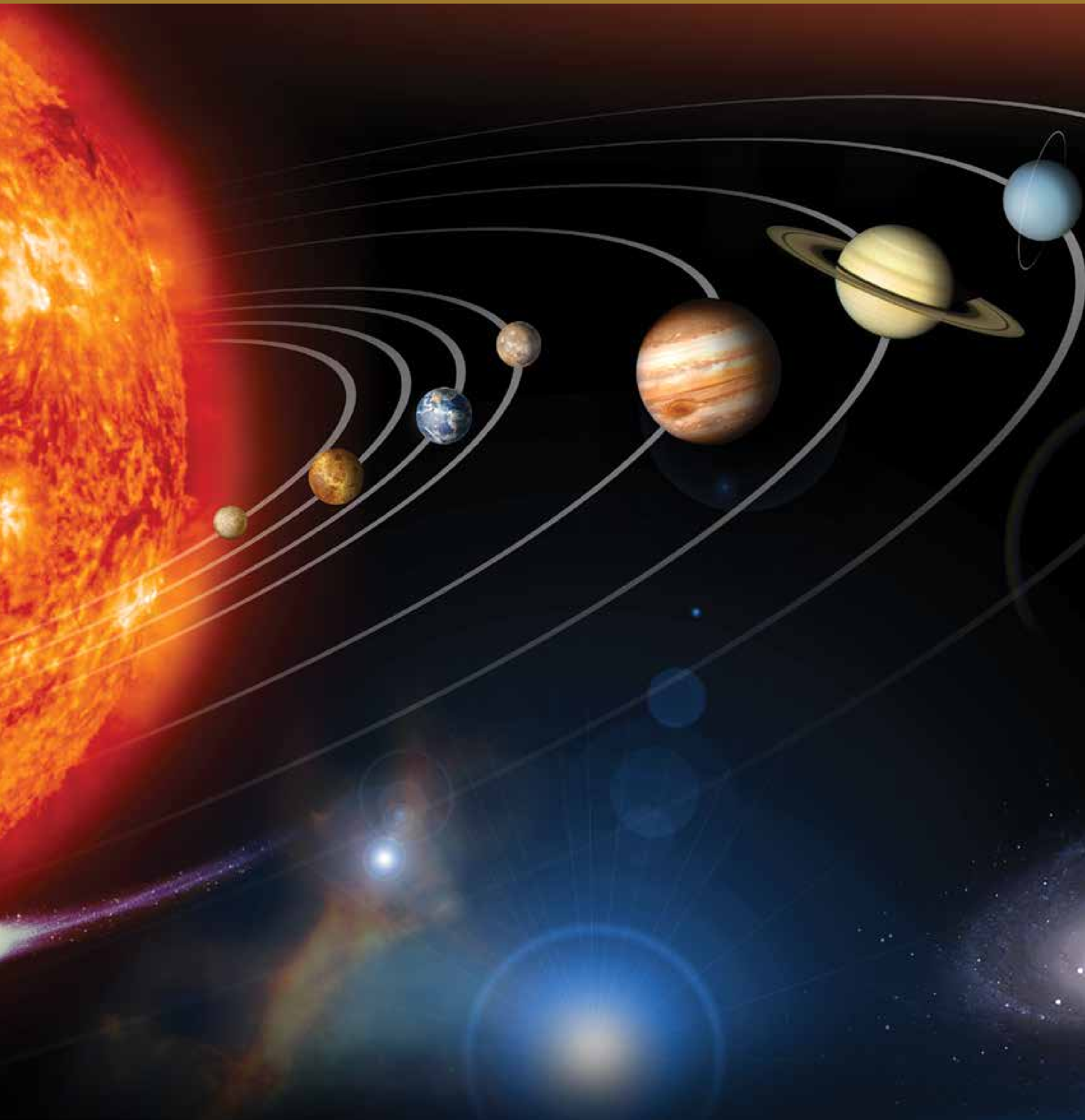
–Alice Caponiti



Foreword
To Know the Unknown

Innate to the human experience is our yearning to explore; to know the unknown; to discover the undiscovered. Humans continue to uncover new things about planet Earth and we routinely interact with satellites that allow us to communicate across the globe, view images of our homes as seen from space, or navigate to unfamiliar locations. Satisfying the urge to explore requires moving ever further from our planet, to the far reaches of our solar system and beyond. But such exploration requires reliable and long-lived power often beyond the capabilities afforded by solar and chemical systems.

Space nuclear power systems have the unique capabilities that make them especially well-suited for space exploration; indeed, many of the National Aeronautics and Space Administration's (NASA's) most ambitious missions would not be possible without them. Ironically, the contribution of nuclear power to the success of many iconic space missions has often gone unnoticed by the public, in part due to its track record of safety and quiet reliability. Nuclear power has been utilized for 26 successful American space missions, both in Earth orbit and beyond. Space nuclear power systems have been aboard satellites and facilitated navigation, communication, and weather forecasting. Many have enabled scientific and exploratory missions. The Viking landers sent the first images from the surface of Mars, and the Voyager probes have traveled to the edge of the solar system, with one entering interstellar space, inspiring a generation of scientists. The nuclear-powered rover Curiosity is exploring Mars using sophisticated scientific instruments to search for conditions favorable to life in Mars' past. This year the New Horizons spacecraft completed its nine-year, three-billion-mile trip to the Kuiper belt, and begins a close encounter with Pluto and other objects on its mission of discovery. Mankind's instinct for exploration has naturally led us to look beyond Earth; what we have learned so far has been astounding. Best of all, our journey is still in its infancy.

The U.S. Department of Energy (DOE) has a unique role in the history of American space nuclear power. DOE has been integrally involved in its development and use for both civilian and defense space missions. The Department owns and operates the facilities that are used to produce and handle nuclear fuel as well as the facilities in which fueled components and systems are assembled and tested. These systems have been vital for both NASA and Department of Defense (DoD) mission applications. Aligned

Artist's concept of our solar system and points beyond. (Photo: NASA/JPL)

Alice Caponiti,
U.S. Department of Energy
Director, Space and Defense Power Systems Program

with these two agencies, DOE has overcome numerous hurdles and has been a partner in many successful missions.

Integral to the history of space nuclear power is the theme of safety, which has always been a central consideration for its development and use—from design to fabrication and through launch. Nuclear power systems are safe to build, assemble, and use, and devices are engineered with multiple layers of containment should a mission falter. All nuclear power systems designed for use in space undergo meticulous flight qualification testing that simulates extreme scenarios, and no system is ever used unless it passes mission acceptance requirements.

To that end, *Atomic Power in Space II* presents a history of U.S. space nuclear power during the past 30 years—its development and use, the missions in which it was incorporated, and the research and accomplishments that served to move the technology forward. It is a story of the dedicated professionals from many organizations working together to build amazing and complex systems. It is also a story of struggle with both technical and non-technical issues, of remarkable successes, and of marvelous opportunities within our reach. This book tells the story through 2013; however, this is only an introduction to the possibilities of space exploration that might be enabled in the future by space nuclear power.

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And what does the future hold? The nuclear-powered Galileo and Cassini spacecraft have found evidence of underground oceans on the moons of Jupiter and Saturn. Such oceans have the potential for life but further exploration is required. The planets Uranus and Neptune have only been explored by brief flybys of the Voyager spacecraft, and future missions will likely yield amazing discoveries. Closer to home, further discoveries of our own Moon require an uninterrupted power source to enable work to continue through the long lunar nights. Perhaps most alluring of all is manned exploration beyond Earth, including landing humans on Mars. When and if these missions become a reality remains to be seen, but nuclear power will likely be the means to make them possible.

Alice Caponiti,
U.S. Department of Energy
Director, Space and Defense Power Systems Program, 2015

On June 29, 2011, NASA and the Smithsonian National Air and Space Museum in Washington, D.C. held an event to commemorate both the launch of the first space nuclear power system, and to recognize the several decades of discovery that radioisotope power systems have enabled. Pictured left to right: Peter Lyons, Assistant Secretary for Nuclear Energy, DOE; Roger Launius, Senior Curator, Smithsonian National Air and Space Museum; Don Ofte (Honoree); Pat Rawlings, Space Artist; John Dassoulas (Honoree); Steve Squyres, Cornell University; James Hagan (Honoree); Ralph NcNutt, Applied Physics Laboratory; Paul Dick (Honoree); Chris Scolese, NASA Associate Administrator; and Robert Carpenter (Honoree). (Photo: NASA)