Foreword

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The Interstellar Boundary Explorer (IBEX) is a remarkable mission of exploration and discovery. IBEX is currently producing the first global images of the heliosphere's interaction with the local interstellar medium—these images provide an entirely new framework for understanding the relationship between our heliosphere and the galactic environment. IBEX achieves this by making observations of the energetic neutral atoms (ENAs) produced at the edge of the heliosphere via charge exchange between the solar wind and embedded pickup ions with the cold neutral atoms drifting in from the local interstellar medium. IBEX measures ENAs using two independent single pixel cameras: IBEX-Lo, which measures ENAs from ~ 10 eV and ~ 2 keV, and IBEX-Hi, which measures them from ~ 300 eV to ~ 6 keV. The combination of extremely high sensitivity, excellent spatial resolution (~ 1800 , 6° pixels covering the sky), energy spectral information across a very broad energy range, and simultaneous and independent measurements over the most crucial energy range, makes IBEX ideally suited to provide these unique, new observations. Finally, IBEX also directly measures the interstellar neutral atoms drifting in from the interstellar medium—these include not just the previously observed interstellar He, but also the first direct observations of interstellar H and O as well as the first observations of both the primary and secondary populations of these neutrals.

The IBEX mission grew out of a community consensus about the critical importance of outer heliospheric physics and a call for a mission to somehow provide the global picture of the heliosphere's interaction with the local interstellar medium. For example, the National Academy of Science's 2002 "Decadal Survey" entitled *The Sun to the Earth—and Beyond: A Decadal Research Strategy in Solar and Space Physics*, pointed out that "The boundary between the solar wind and the local interstellar medium (LISM) is one of the last unexplored regions of the heliosphere. Very little is currently known about this boundary or the nature of the LISM that lies beyond it. . . . certain aspects of these regions can be studied by a combination of remote sensing and in situ sampling techniques. This investigation could

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be accomplished by a mission ... to obtain energetic neutral atom images ... of the heliospheric boundary. Such a mission is gauged to be feasible within the resource limits of the Explorer program ...” Similarly, NASA’s *Sun–Earth Connection Roadmap 2003–2028: Understand how the Sun, Heliosphere, and the Planetary Environments are Connected in a Single System* (January 2003) argued that “An entirely new level of information on the interface between the heliosphere and the LISM is required. ... Imaging of the outer boundaries ~ 100 AU away can also be done from orbits near 1 AU. ... Remote-sensing techniques such as energetic neutral atom (ENA) imaging of energetic protons ... near the termination shock and in the heliosheath should provide additional diagnostics of the interfaces with the galaxy.” Finally, even the top-level *National Aeronautics and Space Administration 2003 Strategic Plan* included the comment that “Even the interstellar gas that enters the solar system can be analyzed using remote sensing.”

Unfortunately, it was clear from two previous proposals for larger Mid-sized Explorer (MIDEX) missions, which received excellent reviews and ratings but no funding, that NASA was not able to support such an expensive mission as a MIDEX for this work. Thus it was early in 2002 when we contacted Orbital Sciences Corporation (Orbital) to see if there was some way to design and launch a very small (~ 100 kg) spacecraft into an orbit that would reach far outside the Earth’s magnetosphere from the low Earth orbit launcher typically provided by NASA for SMEX missions—a Pegasus launch vehicle. Several of the engineers from Orbital jumped at the opportunity to help develop something so revolutionary and, along with others at Southwest Research Institute (SwRI), we collectively came up with a detailed plan to add our own Solid Rocket Motor (SRM) to the top of the Pegasus, effectively making it an air-launched, four-stage rocket for the first time.

In parallel with the rocketry work, I assembled a team of the world’s experts in the science of the outer heliosphere and the interstellar interaction, as well as in the development of highly specialized ENA imaging instrumentation. This outstanding group pulled together into a single, seamless team, sharing ideas and optimizing the mission concept as a single collective effort in a way that I have never seen in any other space mission. This effort led to the IBEX proposal in response to NASA’s 2003 Small Explorer (SMEX) Announcement of Opportunity.

After initial selection and a detailed Phase A study, we were finally told in January 2005 that IBEX was selected for development and flight. IBEX has been on the fast track ever since selection with Mission Preliminary Design Review (PDR) in January 2006, Mission Critical Design Review (CDR) in September 2006, and Payload delivery to the spacecraft in September 2007. Delivery to the Vandenberg Air Force Base was scheduled for March 2008 and the entire spacecraft and payload were ready when the IBEX team learned about a new problem with excessive vibration loads from the Pegasus launch vehicle. We ended up having to put our spacecraft in storage for four months and run a crash program to build a shock-absorbing ring, which acted as the interface between our flight hardware and the Pegasus, effectively reducing its vibration loads. In July 2008, after just four quick months, our interface ring was designed, built, tested, and installed in the flight stack and we were out at Vandenberg preparing for launch.

With integration complete, IBEX and the Pegasus rocket were loaded onto the bottom of the L1011 airplane and ferried out to Kwajalein Atoll in the south Pacific where, near the equator, the rotation of the Earth provided additional energy for our launch. On 19 October 2008, IBEX was successfully launched. Our SRM and spacecraft’s internal hydrazine propulsion system worked perfectly and ultimately delivered the IBEX spacecraft from the ~ 200 km, low Earth orbit that Pegasus provided into a highly elliptical orbit that extends out to $\sim 300,000$ km, roughly 80% of the way to the Moon. The orbit raising and spacecraft commissioning took up the remainder of 2008 and in January 2009, we transitioned

over to nominal operations and began making our groundbreaking science observations. Remarkably, the IBEX project was able to do all this work including developing an entirely new launch capability, building and flying a unique and highly specialized spacecraft and instrument suite, and maintaining full funding for our Education and Public Outreach and Phase E science activities, while still under-running our original cost cap (as modified by NASA-directed changes), by roughly three-quarters of a million dollars.

This book comprises a set of papers that describe the IBEX science, instruments, and mission and put these in the context of the existing knowledge of the interstellar interaction at the time of the launch. The book sets the stage for research that will be based on data from the IBEX mission. We sincerely hope that future researchers, authors and students will use this information to help in their studies. Chapter 1 [McComas et al.] provides an overview of the entire IBEX program including the IBEX science, hardware, and mission. Chapter 2 describes the IBEX spacecraft and flight system [Scherrer et al.]. Chapters 3–4 provide the details of the IBEX-Hi instrument [Funsten et al.] and background monitor that is built into it [Allegri et al.], while Chapters 5–7 describe the IBEX-Lo instrument [Fuselier et al.], how IBEX-Lo can measure the interstellar neutrals directly entering the heliosphere [Möbius et al.] and the backgrounds and signal-to-noise ratios expected for IBEX prior to launch [Wurz et al.]. The IBEX Science Operations Center (ISOC) is described in Chapter 8 [Schwadron et al.], which includes how we get data from the IBEX spacecraft and how it will be made available to the science community. Chapters 9–12 summarize the current knowledge of the local galactic environment [Frisch et al.] and various perspectives on the pre-IBEX theory of the interstellar interaction [Lee et al.; Zank et al.; and Izmodenov et al.]. Finally, Chapter 13 describes IBEX's extensive Education and Public Outreach program [Bartolone et al.].

The team of truly outstanding men and women who made the IBEX mission such a great success is given in the following (Acknowledgements) section; this volume is dedicated to every one of them with my sincerest thanks!

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