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Colonizing Space One Module at a Time

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Bigelow Aerospace

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To
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for their invaluable guidance and support
of my academic pursuits

About the Author

Erik Seedhouse is a Norwegian-Canadian suborbital astronaut whose life-long ambition is to work in space. After completing a degree in Sports Science at Northumbria University, he joined the legendary 2nd Battalion the Parachute Regiment. During his time in 2-Para, Erik spent six months in Belize, training in the art of jungle warfare. Later, he spent several months learning the intricacies of desert warfare in Cyprus. He made more than 30 jumps from a C130, performed more than 200 helicopter abseils, and fired more anti-tank weapons than he cares to remember!

Upon returning to the comparatively mundane world of academia, the author embarked upon a master's degree in Medical Science at Sheffield University. He supported his studies by winning prize money in 100-km running races. After placing third in the World 100-km Championships in 1992 and setting the North American 100-km record, the author turned to ultra-distance triathlon, winning the World Endurance Triathlon Championships in 1995 and 1996. For good measure, he won the inaugural World Double Ironman Championships and the Decatriathlon, a diabolical event requiring competitors to swim 38 km, cycle 1,800 km, and run 422 km. Non-stop!

Returning to academia in 1996, Erik pursued his Ph.D. at the German Space Agency's Institute for Space Medicine. While studying, he found time to win Ultraman Hawai'i and the European Ultraman Championships as well as completing Race Across America. As the world's leading ultra-distance triathlete, Erik was featured in dozens of magazines and television interviews. In 1997, *GQ* magazine nominated him the "Fittest Man in the World".

In 1999, Erik retired from being a professional triathlete and started post-doctoral studies at Simon Fraser University. In 2005, he worked as an astronaut training consultant for Bigelow Aerospace and wrote *Tourists in Space*. He is a Fellow of the British Interplanetary Society and a member of the Space Medical Association. In 2009, he was one of the final 30 candidates in the Canadian Space Agency's Astronaut Recruitment Campaign. Erik works as an astronaut instructor with the American Astronautics Institute, triathlon coach, and author. He is Editor-in-Chief of the *Handbook of Life Support Systems for Spacecraft*, a major reference work to be published by Springer in 2016, and is the Training Director for Astronauts for Hire (www.astronauts4hire.org). Between 2008 and 2013, he was director of Canada's manned centrifuge operations.

In addition to being a suborbital astronaut, triathlete, centrifuge operator, pilot, and author, Erik is an avid mountaineer and is pursuing his goal of climbing the Seven Summits. *Bigelow Aerospace* is his 15th book. When not writing, he spends as much time as possible in Kona and at his home in Sandefjord. Erik and his wife, Doina, are owned by three rambunctious cats—Jasper, Mini-Mach, and Lava.

Author (left) holding the Subida Veleta 50 kilometer trophy

Acronyms

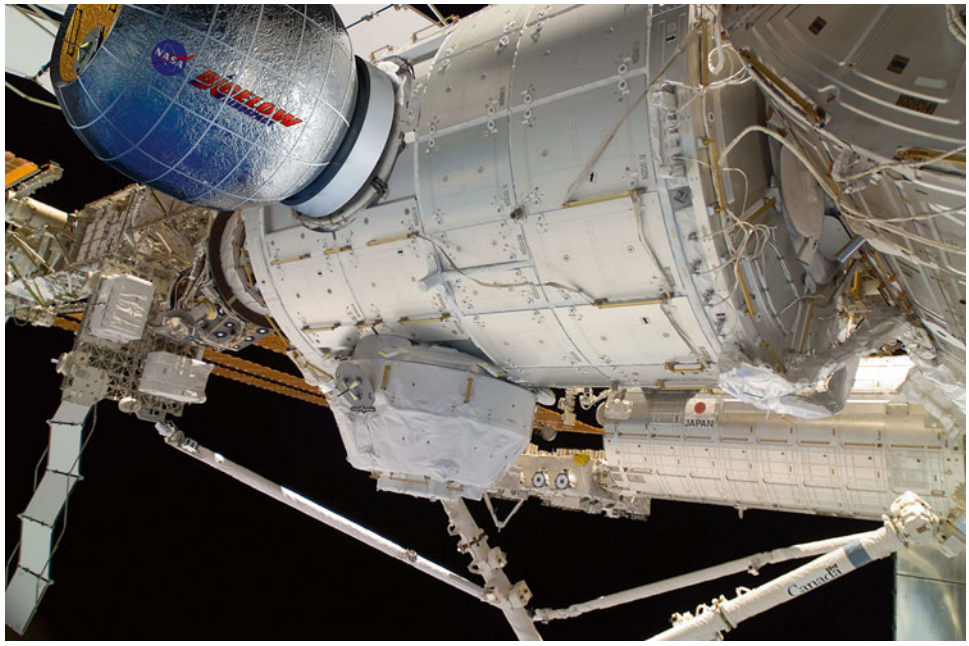
ACS	Attitude Control System
AES	Advanced Equipment System
AMIS	Advanced Man In Space
ARRA	American Recovery and Reinvestment Act
ATV	Automated Transfer Vehicle
BAASS	Bigelow Aerospace Advanced Space Studies
BEAM	Bigelow Expandable Activity Module
CAM	Centrifuge Accommodation Module
CAN	Controller Area Network
CBM	Common Berthing Module
CCDev	Commercial Crew Development
CCiCap	Commercial Crew Integrated Capability
CCP	Commercial Crew Program
CDR	Critical Design Review
CHeCS	Crew Health Care System
CMS	Case Management System
COTS	Commercial Orbital Transportation System
CQ	Crew Quarters
CRS	Crew Resupply Services
DTC	Defence Trade Control
DTSA	Defense Technology Security Administration
ECLSS	Environmental Controlled Life-Support System
ESA	European Space Agency
EVA	Extravehicular Activity
FAA	Federal Aviation Administration
GTO	Geostationary Transfer Orbit
HEDS	Human Exploration and Development of Space
HSP	Habitation System Project
ICBM	Intercontinental Ballistic Missile
IRDT	Inflatable Re-entry Development Technology

ISF	Industrial Space Facility
ISPCS	International Symposium for Personal and Commercial Spaceflight
ISS	International Space Station
ITAR	International Trade on Arms Regulations
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
LBSS	Lunar Base Systems Studies
LEO	Low Earth Orbit
MISSE	Materials on International Space Station Equipment
MMOD	Micrometeoroid Orbital Debris
MMSEV	Multi Mission Space Exploration Vehicle
MUFON	Mutual UFO Network
NACA	National Advisory Committee on Aeronautics
NAUTILUS	Non-Atmospheric Universal Transport Intended for Lengthy US Xploration
NEO	Near Earth Object
NIDS	National Institute for Discovery Science
OSC	Orbital Sciences Corporation
OST	Outer Space Treaty
PBO	Poly Phenylene
PCBM	Passive Common Berthing Mechanism
PET	Polyethylene Terephthalate
PVC	Polyvinyl Chloride
SAA	Space Act Agreement
SDU	Shell Development Unit
SEIM	Surface Endoskeletal Inflatable Module
SLS	Space Launch System
SMAC	Spacecraft Maximum Allowed Concentration
TAAT	Technology Applications Assessment Team
UHMWPE	Ultra High-Molecular-Weight Polyethylene
ULA	United Launch Alliance
WSTF	White Sands Test Facility

Author Note

Since the founding of Bigelow Aerospace, there has always been a degree of mystique surrounding the company. While located in Las Vegas, a city known for flashy spectacle and over exuberance, Bigelow Aerospace has kept a low profile. A very low profile. For many years, people in the spaceflight industry knew Bigelow was working on something that involved the inflatable habitat technology, but there was little publicity. Shying from media attention, the lone-wolf visionary refused to have photos taken by or for the press, and denied television interview requests. The shyness was interpreted by some in the media as a sign of secrecy, and (completely unsubstantiated) claims were made that Bigelow was associated with intelligence agencies. Given the company's secret-squirrel profile and given that the company founder owned the Budget Suites of America hotel chain, it was inevitable that some media outlets suggested Bigelow was in the business of building space hotels. The reality, as you will read in this book, is very different. One of the challenges of writing a book about a company that maintains such a low profile is access to information. You will notice that none of the images in this book is a Bigelow image. Requests were made to the company asking permission to use images, as were fact-checking requests, but no response was received, which means the book you are reading is an independent account of Bigelow Aerospace.

Foreword



"NASA Awards $17.8 Million for an Inflatable Addition to the ISS"

That was the headline posted in January 2013 after Bigelow Aerospace landed its first major deal with NASA and a chance to prove that the future of human space exploration is inflatable (the company prefers the term "expandable"). Whilst SpaceX might be the toast of the commercial spaceflight—NewSpace—industry thanks to their bold achievements and lofty goals, Elon Musk's operation is far from the only player in the game.

While SpaceX is in the business of getting cargo and crew into orbit, keeping them there is someone else's job, and that someone happens to be Bigelow Aerospace. Unlike most NewSpace companies that are focusing on the launch side of the equation, Bigelow is focusing solely on the "staying up there" part. To that end, he is developing technology for a revolutionary kind of space station that promises to deliver much larger volumes at a fraction of the cost of traditional space station modules. NASA's 2013 contract with Bigelow is proof that the nascent space company is now at the point where its technology is ready for prime time.

Bigelow Aerospace has been trying to get the world to take its expandable space habitats seriously for years and, while some have regarded the Vegas-based firm's habitats with skepticism, NASA has always been willing to listen to Bigelow's ideas. And now the space agency is investing in them. NASA has awarded the private space contractor a US$17.8 million contract to develop a new addition to be berthed with the International Space Station (ISS) in 2015. This is big news for NASA and Bigelow, who has been working for years to create space habitats for corporate clients and government space agencies, going so far as to propose concepts for inflatable Moon bases. The company has already launched two orbiting prototypes—*Genesis I* and *Genesis II*—but, until the NASA deal came along, no government or corporate entity had bought Bigelow's technology. NASA, for its part, is looking for inexpensive and proven ways to expand the space aboard the ISS, and a Bigelow Expandable Activity Module (BEAM) could do exactly that.

Here for the first time, in *Bigelow Aerospace*, you can read how a space technology start-up company is pioneering work on expandable space station modules. Here you will learn how Bigelow Aerospace was founded and how it is funded in large part by the fortune Bigelow amassed through his ownership of Budget Suites of America. This book explains how Bigelow originally licensed the multilayer, expandable space module technology from NASA after Congress canceled the ISS TransHab project following delays and budget constraints. It explains how the entrepreneur continued to develop the technology for a decade, redesigning the module's fabric layers—including adding proprietary extensions of Vectran shield fabric, "a double-strength variant of Kevlar"—and developing a family of uncrewed and crewed expandable spacecraft in a variety of sizes. Here, in *Bigelow Aerospace*, you can read how NASA came full circle to once again consider connecting a Bigelow expandable craft to the ISS for safety, life support, radiation shielding, thermal control, and communications verification testing. Also described is Bigelow's unique business model that involves leasing out voluminous space stations to research communities or corporations—in October 2010, Bigelow announced it had agreements with six sovereign nations to utilize on-orbit facilities of its commercial space station: the UK, The Netherlands, Australia, Singapore, Japan, and Sweden. And at the core of the plan are the inflatable modules. In this book, you can read how these modules are actually tougher and more durable than rigid modules, thanks to the company's use of several layers of Vectran, a material twice as strong as Kevlar, and also because, in theory, flexible walls are able to sustain micrometeoroid impacts better than rigid walls.

Also described is how the link between Bigelow Aerospace, NASA, and dozens of private companies can lead to the creation of a new economy—a space economy. It describes the wait for launch capabilities and Bigelow's plans for a commercial space

station—the Bigelow Next-Generation Commercial Space Station, a private orbital space complex under development. Finally, Chapter 8 describes the company's aspirations beyond LEO and how Bigelow aims to look at ways for private ventures to contribute to human exploration missions, some of which may include establishing bases on the Moon and beyond.