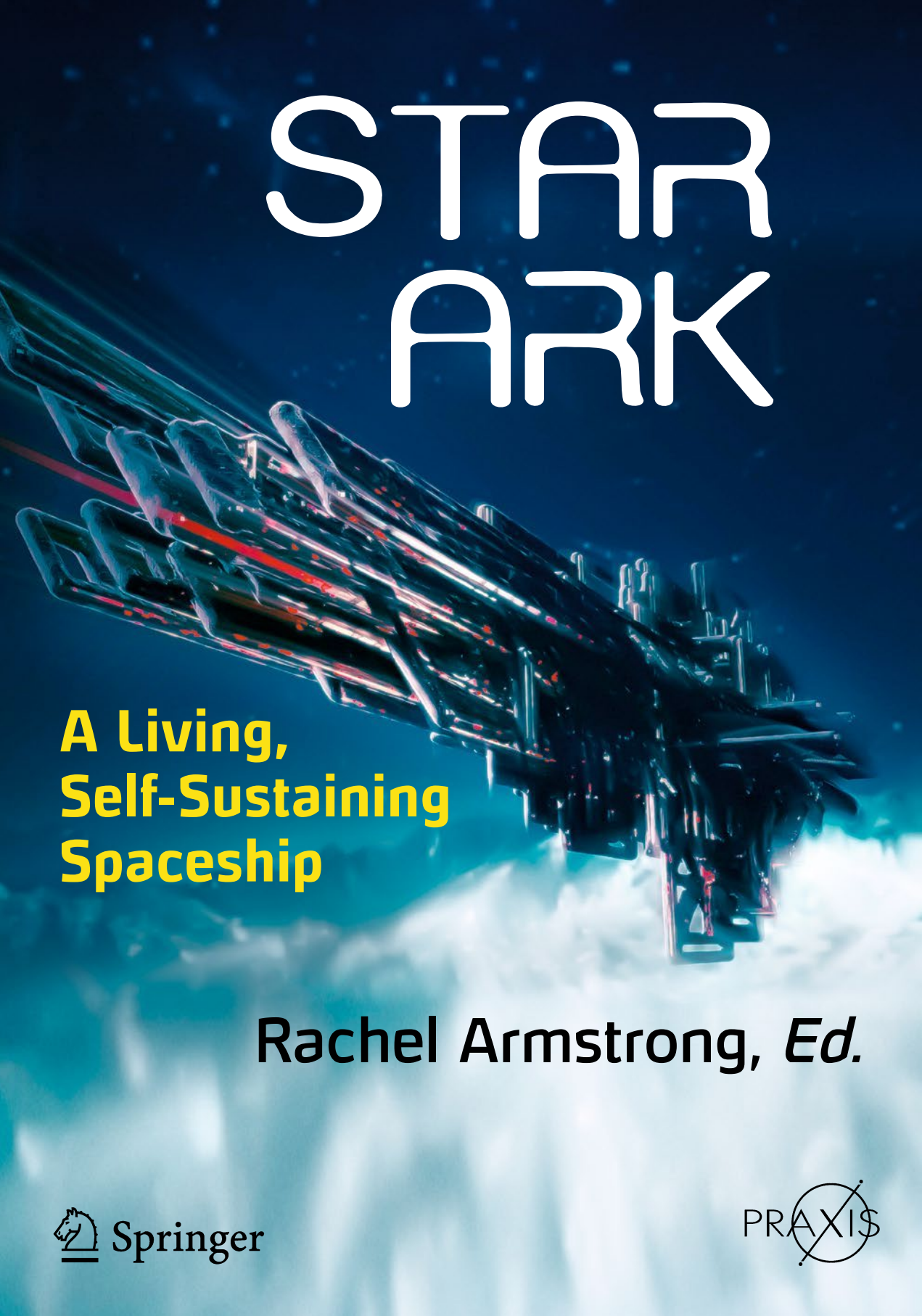
STAR ARK



A Living, Self-Sustaining Spaceship

Rachel Armstrong, *Ed.*

Springer

PRAXIS

Star Ark

A Living, Self-Sustaining Spaceship

Rachel Armstrong (editor)

Star Ark

A Living, Self-Sustaining Spaceship

Springer

Published in association with
Praxis Publishing
Chichester, UK

PRAXIS

Editor
Rachel Armstrong, PhD.
Professor of Experimental Architecture
Newcastle University
Newcastle-upon-Tyne, UK

SPRINGER-PRAXIS BOOKS IN SPACE EXPLORATION

Springer Praxis Books
ISBN 978-3-319-31040-4 ISBN 978-3-319-31042-8 (eBook)
DOI 10.1007/978-3-319-31042-8

Library of Congress Control Number: 2016952869

Cover design: Jim Wilkie

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG Switzerland

Preface

This anthology examines the Interstellar question – i.e. the idea that we may one day live beyond the world we know and settle distant planets. A challenge on this scale requires not only vision, but multiple voices for the acknowledgment of complexity and contradictions. These are inherent in the quest. Taking a multidisciplinary and cultural view of the challenge, the book accordingly seeks to provide a form of cultural catalysis by which an interstellar culture may be seeded (it is, in other words, emphatically *not* a technical manual seeking to offer formal solutions to particular problems). To address such ambitions, the book has been divided into two main sections – Part I and II – in which differing conventions of writing have been deployed.

Part I, written by Rachel Armstrong, proposes a new age of space exploration based on an ecological perspective of the cosmos. It is this that will create the conditions for inhabiting starships and, ultimately, new worlds. Drawing on her leadership of the Persephone Project, this section adopts an experimental, yet testable, and inclusive approach to constructing a livable and self-sustaining starship. Persephone is part of the Icarus Interstellar group's portfolio of work – an international consortium of aerospace engineers aiming to construct a starship research platform in Earth's orbit within the next hundred years. This means a series of Earth-bound experiments are being detailed through a wide range of laboratory types that inform us about how we live with and design ecosystems on this planet – and beyond.

Part II, which is edited by Rachel Armstrong, introduces other voices to explore the Interstellar Question. The editor's aim here has been to create a productive interplay between differing perspectives and disciplinary backgrounds via themed, multi-author chapters. These are organized into, sections, presenting distinct viewpoints for examining the Interstellar Question. Topics include: the interstellar mission (Andreas C. Tziolas, Nathan Morrison, Esther M. Armstrong), space ecology (Michael N. Mautner, Simon Park), (Barbara Imhof, Peter Weiss, Angelo Vermeulen; Astudio – Emma Flynn, Richard Hyams, Christian Kerrigan, Max Rengifo; Susmita Mohanty, Sue Fairburn), space bodies (Kevin Warwick, Arne Hendriks, Rachel Armstrong, Sarah Jane Pell), connecting with the divine and the sacred and becoming cosmically conscious (Steve Fuller, Roberto Chiotti,

Krists Ernstsons), constructing worlds (Jordan Geiger, Mark Morris) and interstellar research methodologies (Rolf Hughes, Rachel Armstrong). The unconventional structure explores how different perspectives must be brought into a productive dialogue when considering the fundamental principles for inhabiting space. If, as a result, the book resembles a Tower of Babel for the space age, this is a design choice that invites us to address our innate diversity. Readers are invited to reflect on what these different perspectives mean for a coherent approach to settling environments far, far beyond the familiar planet we call (for now) “home”.

Contents

List of Contributors

Esther M. Armstrong is Program Director for Theatre and Screen at Wimbledon College of Arts, University of the Arts, London. She lectures in Critical and Contextual Studies across the design disciplines of theater and screen arts. Her Ph.D. thesis interrogated the relationship between the reading of set design and national identity. She has also worked and trained in technical arts at the Royal Academy of Dramatic Arts and broadcast journalism at the London College of Printing. She has an M.A. from Regents Park College at the University of Oxford.

Rachel Armstrong is Professor of Experimental Architecture at Newcastle University. She designs lifelike environments for the built environment using technologies that manipulate the building blocks of life such as synthetic biology and smart chemistry. Armstrong trained as a medical doctor, graduating from the University of Cambridge with First-Class Honors and prizes. She completed her clinical training at the John Radcliffe Medical School at the University of Oxford. She also has qualifications in general practice and a Ph.D. funded by the EPSRC in Architecture from the Bartlett School of Architecture, University College London. Armstrong has worked across many disciplines as a multimedia producer, a science fiction author, and an arts collaborator. She is TWOTY Futurist of the Year 2015 and a 2010 Senior TED Fellow. Rachel was named as one of the top 10 UK innovators by *Director Magazine* in 2012 and featured in the top 10 "Big Ideas, 10 Original Thinkers" for *BBC Focus Magazine*. Her TED book on Living Architecture was #1 Bestseller in Biotechnology on Amazon. Her book, *Vibrant Architecture: Matter as CoDesigner of Living Structures*, explores prospects for transformations of matter from inert configuration into lifelike habitable structures, which prompts a reevaluation of how we think about sustainability in our homes and cities.

Roberto Chiotti, B.E.S., B.ARCH., M.T.S., O.A.A., F.R.A.I.C. is Principal at Larkin Architect Limited and Assistant Professor at the Faculty of Design, OCAD University, Toronto, Canada. He obtained his professional architectural degree in 1978 from the University of Waterloo, Canada, and completed a Master of Theological Studies degree at the University of St. Michael's College, University of Toronto, in 1998 with a specialty in

Theology and Ecology obtained through the Elliott Allen Institute for Theology and Ecology at St. Michael's. He is a founding partner of Larkin Architect Limited, a firm specializing in the design of sacred space, and is also currently Assistant Professor within the Department of Environmental Design and the Sustainability Officer for the Faculty of Design at OCAD University. Chiotti brings "big picture" thinking to the topic of sustainability, insisting that his favorite designer is the universe itself, citing many of the major transformations over its 14 billion years of existence and the dynamic laws of cosmogenesis as valuable resources to help address the ecological challenges facing the human community today. He believes that the journey toward sustainability must be grounded in a cosmology that relinquishes the current anthropocentric worldview in favor of one that acknowledges the needs of Earth as primary and those of the human as derivative.

Krists Ernstsons is Architectural Assistant/RIBA Part 2/AA Diploma. He completed his Part I in Architecture at the University of East London and his Part II Diploma in Architecture at the Architectural Association School of Architecture. His thesis project "Virtual Migration to Exoplanets" was nominated for honors and explored the idea of breaking the speed-of-light boundary through quantum entanglement and migrating to Earth-like planets at the macroscale. The key driver for this study was the idea that humanity eventually will grow out of its cradle called the planet Earth. After his Part I, he worked for Foster+Partners in London, where he prototyped a household unit to revolutionize efficiency and functionality of low-income housing. In 2010, he joined Izolyatsia, a platform for Cultural Initiatives in Ukraine, where he worked on master planning, refurbishment, curating a residency program, and executing projects by internationally renowned artists. He recently joined Hawkins\Brown in London, where he works in the infrastructure sector on Crossrail station projects and others.

Susan Fairburn is a Design Educator and Researcher who works between the boundaries of the body and the environment. Her research experience, gained over 20+ years, uses design as knowledge exchange applied to Social Design and Reciprocities in Design for Extremes. She was cofounder of a social enterprise, Design for Development (DFD 2005–2012), which used the design process as a problem-solving and engagement tool in low-income settings. She continues to work in the areas of social innovation and environmental design at Fibre Design Inc. Educated in Canada, Sue holds degrees in Environmental Physiology and Environmental Design.

Emma Flynn leads Research and Development at Astudio. She is a practicing architect and design researcher, whose work broadly focuses on the future architectural landscape in relation to Nature, exploring environmental responsiveness and resilience in the context of climate change and resource depletion. In 2012, she helped to establish Astudio Research as the separate R&D arm of Astudio in response to the need for increasingly innovative responses to issues of sustainability in the built environment. Existing at the intersection of sustainability, technology, and design, her work is highly collaborative and multidisciplinary, exploring fields such as environmental design, energy management and modeling, emerging technologies, facade system design, modern methods of construction, and future cities. Key research projects include Living Architecture: Demonstrating Resilience to Climate Change and Resource Depletion, Bio-Responsive Facade Systems,

In-Use Environmental Performance Monitoring and Metering Systems, and Waste to Value: Micro Anaerobic Digestion for Urban Communities. She is a tutor in Environmental Design on the B.Sc. Architecture course at the Bartlett School of Architecture, is a module leader of the Adaptive Typologies Think Tank, London School of Architecture, and works with students at Brunel University as part of the EU Co-Innovate program.

Steve Fuller is Auguste Comte Professor of Social Epistemology in the Department of Sociology at the University of Warwick, UK. Originally trained in history and philosophy of science, he is best known for his foundational work in the field of "social epistemology," which is the name of a quarterly journal that he founded in 1987 as well as the first of his more than 20 books. He has recently completed a trilogy relating to the idea of a "post-" or "trans-"human future, all published with Palgrave Macmillan: *Humanity 2.0: What It Means to Be Human Past, Present and Future* (2011), *Preparing for Life in Humanity 2.0* (2012), and (with Veronika Lipinska) *The Proactionary Imperative: A Foundation for Transhumanism* (2014). His latest book is *Knowledge: The Philosophical Quest in History* (Routledge 2015). His works have been translated into over 20 languages. He was awarded a D.Litt. by the University of Warwick in 2007 for sustained lifelong contributions to scholarship. He is also a Fellow of the Royal Society of Arts, the UK Academy of Social Sciences, and the European Academy of Sciences and Arts.

Jordan Geiger is an architect and educator whose work crosses architecture and interaction design, considering implications of human–computer interaction for social and environmental issues. He lectures, exhibits, and publishes internationally on theoretical research and on his projects, which frequently investigate globalization's design problems at many scales. Design research outcomes include buildings, objects, and landscape proposals, but also written and graphic analyses and technological investigations. He is editor of the book *Entr'acte: Performing Publics, Pervasive Media and Architecture*, which explores ephemeral and interstitial formations of publics and of public space with the proliferation of new technologies. Geiger has taught architecture, at the University of Buffalo as member of the department's Center for Architecture and Situated Technologies. He has also taught architecture, urban design, and advanced interdisciplinary studios and seminars at the Academy of Fine Arts in Vienna, at UC Berkeley, and at the California College of the Arts in San Francisco. He holds a Master of Architecture from Columbia University and a Bachelor of Arts in Comparative Literature from UC Berkeley.

Arne Hendriks is an Amsterdam-based artist, exhibition maker, researcher, and historian with a Master of Arts from the University of Amsterdam. He teaches at the Next Nature department of the Technical University in Eindhoven, which is concerned with investigating the implications of nanotechnology. He was the second ambassador of the 13th Dutch Design Week and a curator for the next Alternativa exhibition in Gdansk Poland. His work explores the positive transformative power of creative impulses and the importance of fundamental free scientific research. In his speculative design research, the strange and the familiar continuously swap places to provoke conflicting perspectives, which speak about the radicality of everyday experience and the familiarity of radical interventions. He is a strong believer in the transparency of information and an active participant in the open-design movement. His projects include Instructables Restaurant (the world's first open-source

restaurant), Hacking Ikea, the Repair Manifesto, and the Academy of Work. His most recent projects include *The Incredible Shrinking Man*—downsizing the human species to better fit Earth; Fatberg—constructing a floating island of fat to ask what this substance means to us in an age of excess, obesity, and starvation; and 8 Billion City—one city for all.

Rolf Hughes Professor of Artistic Research and former Head of Research at Stockholm University of the Arts (inaugurated 2014). He is a prose poet and disciplinary nomad, actively promoting innovative forms of artistic and transdisciplinary research over the past 20 years. He has been expert advisor for artistic research at the Swedish Research Council, the Norwegian Artistic Research Programme, and the Austrian Programme for Arts-based Research (PEEK); Guest Professor in Design Theory and Practice-Based Research at Konstfack University College of Arts, Crafts and Design (2006–2014); and Senior Professor in Research Design at Sint-Lucas School of Architecture (KU-Leuven, Belgium), where he helped create and develop an international, design-led Ph.D. program (2007–2013). He has also served two terms as Vice President of the international Society for Artistic Research (elected by the SAR membership 2011–2013, unanimously re-elected 2013–2015). Hughes holds a First-Class degree in English and Related Literature (University of York), an M.A. (with Distinction) in Creative Writing, and the first ever Ph.D. in Creative and Critical Writing funded by the British Academy from the University of East Anglia, UK. He is currently exploring the potential contribution of magic and the circus arts to the conception and design of a third-millennium experimental research laboratory. Writing and performing arts remain central to his endeavor to link diverse forms of experience, expertise, and knowledge.

Richard Hyams is a Director of Astudio, whose purpose is to leave the planet better than we found it. He is an architect who focuses on Research and Innovation. Motivated by unique design challenges, he enjoys leading design at and beyond the industry boundaries. Blending high-quality design with research, he challenges the professional status quo and leads teams to deliver highly individual buildings that inspire and delight. His pragmatism for understanding a complex brief and finding elegant yet simple solutions has placed Astudio as one of the most successful rising practices. Hyams has encouraged this approach throughout Astudio, and the practice's innovative lateral thinking often surprises clients. This is adopted on all projects to deliver buildings and spaces which are not thought possible in the tight constraints which project briefs often demand. Astudio was awarded Architectural Practice of the Year after just 6 years in practice.

Barbara Imhof is a space architect, design researcher, and lecturer. She cofounded LIQUIFER Systems Group in 2004, a platform of experts comprising different experts from the field of engineering, science, architecture, and design collaborating on R&D projects. She has a background in architecture, having studied at the Bartlett School UCL, London, and graduated from the University of Applied Arts (Studio Wolf D. Prix). She additionally holds a Master of Science from the International Space University in Strasbourg, France, and a Ph.D. from the Vienna University of Technology (VUT). She taught at the VUT (assistant professor for 8 years), the ETH Zürich, and among others at the Chalmers University in Gothenburg. Barbara combines artistic with scientific education.

She has more than 10 years of experience in project lead functions with EU framework programs, the Austrian Science Fund, and contracts for the European Space Agency. She has been the project leader of architectural projects and academic teaching projects that include the first European habitat simulator, SHEE (Self-deployable Habitat for Extreme Environments), and the biomimetics project GrAB (Growing As Building), translating growth principles from Nature into proto-architecture. Currently, Barbara develops RegoLight, a H2020 EU solar sintering project developing building elements for 3D printed habitats on the Moon.

Christian Kerrigan is an architect at Astudio. He studied architectural technology at Dublin Institute of Technology, architecture at Edinburgh College of Art, and completed his M.Arch. with Distinction at the Bartlett School of Architecture in 2007. He enjoys growing strong links in a variety of industries to push beyond the expectations of architecture. Working through concept computer drawings, installations, R&D, and architectural technology, he has informed the design and realization of a number of projects including Avon & Somerset Constabulary, CI Tower New Malden, RIBA Pylon Competition, Raine's Foundation School, and Skyline of London a future vision. Recently, he has been responsible for the team delivery of a commercial office development for Stanhope at 70 Wilson Street. He is project leader in the design of an amphitheater and Memory Stones project on the Isle of Portland. Kerrigan's research explores the 200 Year Continuum that draws from Nature to innovate across disciplines, which began during his thesis year at the Bartlett School of Architecture, UCL. In 2010, he collaborated with chemist Martin Hanczyc to make the world's first synthetic biology drawing, programming ink to move by itself. He has exhibited his work in the USA, Europe, and the UK, and, in 2010, he was awarded the first digital artist in residence at the Victoria & Albert Museum. He has lectured for Astudio at the Aarhus School of Architecture Master's program and tutored at Chelsea College of Art and Greenwich University. He has spoken at numerous conferences such as Leonardo ISSAT Art papers SIGGRAPH, New Orleans; Generative Art International, Milan; GSK New Contemporary Art season at the Royal Academy of Arts; and First To Bloom, Last To Leave as part of the Human–Nature series at Siobhan Davies Dance studio. Christian's work has also been featured on TED collaborating with Dr. Rachel Armstrong on "Architecture that repairs itself."

Michael Noah Mautner is Research Professor at Virginia Commonwealth University. Born in 1942 in Budapest, Hungary, he was saved from the Holocaust by a courageous woman, Irene Gigor-Horvath. He obtained a B.Sc. from the Hebrew University, an M.Sc. from Georgetown University, and a Ph.D. in Physical Chemistry from Rockefeller University. He is the author of over 180 research papers and book chapters on ion chemistry (also under Meot-Ner) and in astrobiology and space science. He served as Associate Professor at Rockefeller University and as a Research Scientist at the National Institute of Standards and Technology. His research interests in chemistry include ion chemistry with applications to astrochemistry and biophysics; space science, astroecology, and the soil fertilities of asteroid/meteorite materials as biological resources; prospects for human populations in the Solar System; and directed panspermia for seeding new solar systems to secure and expand life. His early experiences showed the value of life, especially when we can either destroy our species or perpetuate life for innumerable eons. This led to the

principles of life-centered biotic ethics that value life itself and panbiotic ethics that can motivate us to seed new solar systems with our family of organic gene/protein life (see www.astro-ecology.com, www.panspermia-society.com).

Susmita Mohanty is a spaceship designer and aerospace entrepreneur who lives a renaissance life without boundaries. She was a member of an international crew that lived in isolation on a simulated Martian outpost in the Utah desert (2004). She is the CEO of Earth2Orbit, India's first private start-up and her third venture. Prior to turning entrepreneur, she worked for the Space Station Program at Boeing in California and for a brief period at NASA Johnson. Educated in India, France, and Sweden, Mohanty holds multiple degrees including a Ph.D.

Mark Morris teaches architectural design, history, and theory at Cornell University. He is the winner of an AIA Medal for Excellence in the Study of Architecture. Morris has taught at The Bartlett, University College London, The Architectural Association School of Architecture, and the University of North Carolina–Charlotte. Morris studied architecture at Ohio State University and received his Ph.D. at the Consortium Doctoral Program, University of London, supported by a Royal Institute of British Architects grant. His studios focus on modeling techniques, reflexive composition, and craft. Morris's essays have been featured in *Frieze*, *Contemporary*, *Cabinet*, *AD*, and *Domus*. He is the author of two books: *Models: Architecture and the Miniature* and *Automatic Architecture: Designs from the Fourth Dimension*. Host of the iTunes podcast series "Architecture on Air," Morris co-organized the Preston Thomas Memorial symposium "Architecture of Disbelief." His research focuses on architectural models, scale, and questions of representation. Morris has previously served as coordinator of post-professional programs and director of graduate studies in the field of architecture.

Nathan Morrison is the Chief Executive Officer and Director of Research and Development for Sustainable Now Technologies, Inc. (SNT), a biotech firm located in Southern California that he cofounded in 2009. Nathan additionally designs living interiors for the Icarus Interstellar Project Persephone. His work primarily centers on closing the cycle of human respiration. Nathan is a published author, public speaker, and a strong advocate for carbon capture implementation strategies. He has spent most of the last decade developing innovative bioreactor technologies that utilize algae as a living internal component to capture carbon and produce sustainable hydrocarbons as organic biomass. Examples of his work include the development of the Helix BioReactor in collaboration with the late inventor Steven Shigematsu, the Algae Research Module for the University of Greenwich's School of Architecture and Landscape in London, and SNT's Mark IX BioReactor modules. These bioreactors are now entering the market in the UK to enable academic institutions and new construction projects to comply with the Climate Change Act implemented by Parliament in 2008.

Simon Park is a senior lecturer in the Faculty of Health and Medical Sciences at the University of Surrey, where he teaches Bacteriology and Molecular Biology. As an internationally recognized molecular bacteriologist, he has published over 60 papers in international refereed journals, books, and other periodicals. His wider activities, and practice, are driven by the common misconception that microbiological life is primitive and always

detrimental and that through collaborations with artists the real nature of the microbiological world can be revealed. In this context, he has been widely involved in many innovative collaborative projects with artists. Funded collaborations include "Sixty Days of Goodbye Poems of Ophelia" with artist JoWonder (funded by The Wellcome Trust), "Exploring the Invisible" with artist Anne Brodie (funded by the Wellcome Trust), and "Communicating Bacteria" with artist Anna Dumitriu (funded by the Wellcome Trust).

Sarah Jane Pell is an artist-astronaut and Australia Council Fellow (AU), TED Fellow (USA), and Scientist-Astronaut (PoSSUM Class 1601) for the NASA Flight Opportunities Program Experiment 46-S, Noctilucent Cloud Imagery and Tomography Experiment, she has an extensive exhibition and publication record. She incorporates themes of human-aquatic adaptation to other worlds and other extreme-performance interfaces in her work. She established the Aquabatics Research Team initiative (ARTi) 2002–2012 for developing aquatic performance and related underwater technologies. In support of her research, she logged 500+ Occupational Dives and demonstrated prototype re-breather systems. Leonardo LABS awarded her Best PhD "Art & Science," MIT 2007, and she was made Official Aquanaut of the Atlantica Expeditions subsea habitat mission. In 2006, she graduated from the International Space University to lead the NASA-sponsored project "Luna Gaia: Closed Loop Habitat for the Moon." At Singularity University, in 2010, she codeveloped exponential technology pathways for NASA to "Boldly Stay" in space. Appointed Cochair of the European Space Agency Topical Team Art Science (ETTAS) 2011–2014, she published the ESA Arts Initiative as the first author. In April 2015, Pell reached Everest Base Camp (5,364 m) and survived the Nepal earthquakes. She was attempting an independent arts-led expedition to summit Mt. Everest as an experiment in space analog training and communications. She currently works as Simulation Astronaut for Project Moonwalk, EU Undersea Lunar Analogue EVA Simulation Trials, and is Prime Crew for the Project Poseidon: 100-day Undersea Habitat Mission, US.

Max Rengifo is a Director of Astudio who uses a range of techniques, from sketches to advanced 3D tools, that brings depth to every project. By leading design reviews, he is able to guide projects, making sure that a clear design response is achieved from its brief response to its material language. Rengifo led the award-winning Wigan Life Centre scheme, which is recognized as an exemplar urban regeneration project. He has also been responsible for TOKKO MyPlace Youth Space in Luton, working and mentoring a group of young clients during the design process. Prior to this, he was a founding Director of CPR Arquitectos, where his work was recognized internationally for the National Health Institute of Venezuela—Production Laboratories and Administrative buildings project. He is also an invited critic and university lecturer in South America and Europe.

Andreas Tziolas is a cofounder and the President of Icarus Interstellar. He has served as Project Icarus Leader (fusion-based starship study) and is currently Project Lead for Project TinTin (interstellar nanosat mission development team). He holds the positions of Chairman for Research and Chairman for Education at Icarus Interstellar. Tziolas completed his Ph.D. in Gravitation and Cosmology at Baylor University in 2009. His dissertation "Colliding Branes and Formation of Spacetime Singularities in Superstring Theory" has implications for the study of black holes in extra dimensions. He holds an M.Phys.

degree in Physics with Space Sciences and Technology from Leicester University, where he worked on the Life Detection Module aboard the Mars Express/Beagle-2 mission to Mars. Tziolas has also held a variety of research positions including two summer research fellowships at JPL/NASA, where he worked with the Outer Planetary Atmosphere's Group, supporting the Galileo mission to Jupiter as part of the Hubble Wide Fields and Planetary Camera team. He was a Graduate Technologist working on the Large Interferometric Space Antenna (LISA) mission development team at the University of Birmingham in the UK. He currently resides in Anchorage, Alaska, where he has held the position of Chief Scientist for Variance Dynamical Corp., developing next-generation analog electronic sensors for use in real-time spectrometers and high-radiation environments. He is the founder and President of the Anchorage Makerspace and currently a Project Manager at one of Alaska's largest nonprofit foundations.

Angelo Vermeulen is a space systems researcher, biologist, artist, and community architect at the Participatory Systems Initiative, Delft University of Technology. He therefore collaborates as easily with practicing scientists as he is comfortable constructing multimedia installations in galleries or building communities through design and co-creation. In 2009, he initiated SEAD (Space Ecologies Art and Design), an international network of creatives working in art, science, engineering, and advocacy. Its goal is to reshape the future through critical reflection and hands-on experimentation. To achieve this, SEAD develops paradigm-shifting projects in which ecology, technology, and community are integrated in synergistic ways. Biomodd and Seeker are the two most well-known SEAD projects. From 2011 to 2012, Vermeulen was a member of the European Space Agency Topical Team Arts & Science (ETTAS), and, in 2013, he was Crew Commander of the NASA-funded HI-SEAS Mars simulation in Hawaii. His space-related work led him to start research at Delft University of Technology, creating new concepts for starship development. He has been faculty at LUCA School of Visual Arts in Ghent, the University of Applied Arts in Vienna, Parsons, the New School for Design in New York, and the University of the Philippines Open University in Los Baños. In 2012, he was a Michael Kalil Endowment for Smart Design Fellow at Parsons, and, in 2013, he became TED Senior Fellow.

Kevin Warwick is Deputy Vice Chancellor (Research) at Coventry University, England. His main research areas are artificial intelligence, biomedical systems, robotics, and cyborgs. Due to his reputation as a self-experimenter, he is frequently referred to as the world's first Cyborg. He was born in Coventry, UK, and left school to join British Telecom. He took his first degree at Aston University, followed by a Ph.D. and research post at Imperial College London. He held positions at Oxford, Newcastle, Warwick, and Reading Universities before joining Coventry. Warwick is a Chartered Engineer who has published over 600 research papers. His experiments into implant technology led to his being featured as the cover story on the US magazine *Wired*. He achieved the world's first direct electronic communication between two human nervous systems, the basis for thought communication. Another project extended human sensory input to include ultrasonics. He also linked his nervous system with the Internet in order to control a robot hand directly from his neural signals, across the Atlantic Ocean. He has been awarded higher doctorates (D.Sc.) by Imperial College and the Czech Academy of Sciences, Prague. Warwick has

been awarded Honorary Doctorates by eight UK universities and from Saints Cyril & Methodius University, Skopje. He received the IEE Senior Achievement Medal, the IET Mountbatten Medal, and the Ellison-Cliffe Medal from the Royal Society of Medicine. In 2000, he presented the Royal Institution Christmas Lectures.

Peter Weiss is the Head of the Space and Innovations Department at COMEX. He has 15 years of experience in the management of industrial and research projects in the field of deep sea and space robotics and EVA simulations. He is Technical Coordinator of the FP7 project MOONWALK and Manager at COMEX for the SHEE project on a novel space habitat design. Weiss earned a B.Sc. (FH München, Germany) in Mechatronics, a M.Sc. (EPF Paris, France) in Robotics, and a Ph.D. on kinetic impactor sampling probes (Hong Kong Polytechnic University, China). Peter worked at the DLR (Oberpfaffenhofen, Germany) on a motor drive of a lightweight robot arm, at the Massachusetts Institute of Technology (Boston, USA) on the development of artificial muscles for self-transforming robotic planetary explorers, at Cybernetix (Marseilles, France) as Project Manager for several European Commission Projects and industrial projects, and at the Hong Kong Polytechnic University on a robotic microgravity sampling device for the PHOBOS-GRUNT mission. During his studies in Hong Kong, he led a team of researchers in the frame of the APOPHIS MISSION DESIGN COMPETITION (Planetary Society, NASA, ESA, ASE, AIAA, USRA), where his team won a prize for their innovative proposal.

Part I
An Ecological View of the Interstellar Question

1

The Interstellar Question: an ecological view

Rachel Armstrong

This chapter discusses a vision and context for the Interstellar Question.

1.1 Philosophy of "space"

For a place that we barely know, we talk about "space" with a fair degree of confidence.

This is not surprising—we are, after all, surrounded by space. We see it every night, gazing down on us through billions upon billions of winking stars. As soon as we could imagine, we've asked ourselves how we might live among these stars. In dreaming of its vast potential, we have answered this question in different ways.

In ancient times, space was a place for immortals, ancestors, and beings with magical powers. With the advent of the Enlightenment as Medieval belief-based systems of thinking were replaced by rationality, Galileo Galilei and Isaac Newton gave us the concept of planetary orbits as mechanical systems, whereby we imagined ourselves orbiting the Sun. Later, with the advent of the Industrial Revolution, flying machines escaped Earth's gravitational pull and enabled us to tread a pathway from the imagination towards the horizons of possibility. Today, powerful vehicles ferry us beyond our planetary domain—living in space has become a reality.

With experiments conducted within the sealed environment of our first orbital house, the International Space Station (ISS), we have started to discover just a little about what it means to dwell in a non-terrestrial habitat.

But this is not the limit of our experience of space, as we have extended our senses through the visualization systems of robots into the Solar System. We now receive images that we can layer on to these models of space. They are not "reality" as such, but ideas, images, and proposals overlaid on concepts, which are not (and cannot be) mediated directly through our senses. As wonderful as it may be to "see" the bitterly harsh terrains

Rachel Armstrong, PhD. (✉)
Professor of Experimental Architecture, Newcastle University, Newcastle-upon-Tyne, UK

R. Armstrong (ed.), *Star Ark*, Springer Praxis Books, DOI 10.1007/978-3-319-31042-8_1

of Mars through the eyes of rovers and New Horizon's survey of Pluto, it's an experience that is very different from actually trying to live there.

So how do we know what we know about space? On what basis do we construct our ideas about the world, the cosmos, and the way in which its perceived reality unfolds? Crucially, how can we maintain a critical understanding of the assumptions that we accept as being truths, so that we can continue to evaluate, develop, and even inhabit them?

Such questions underpin the concepts that construct our philosophical understanding of our own world as well as other spaces. Can we, for example, expect the same principles of material interaction to operate in non-terrestrial locations as they do here on Earth? As we know, the way we think shapes our horizons of expectation and underpins how we imagine unfolding events. Ultimately, a philosophy of space enables us to create innovative living experiences that relate terrestrial and alien landscapes.

This reflection on contemporary conceptions of "space" is the subject of this book. It is examined, explored, and exemplified through a project called Persephone, which is part of the Icarus Interstellar portfolio of projects that propose to construct a starship research platform in orbit within 100 years.

This book is therefore a creative engagement with a broad range of ideas that seek to influence the way we think about space—as an evolution of scientific ideas, for example, and as technologies that may shape our modes of living or experiencing. The concern is less with degrees of virtuosity in describing non-terrestrial environments, or the construction of mega-structures, and more with curating those values and ideas that may inform how we live together.

And, yet, to do this critically requires us to confront, dissolve, and potentially resynthesize some of our most deeply held preconceptions. In embarking on extended, unbounded, and strategic disorientations of our senses—and the kinds of knowledge that we take for granted—we should seek to open up new potentialities within the unknown and unexplored reaches of space. This would ask us to connect with our deepest desires and ambitions, to engage with our intuitions, so that we can revisit our aspirations and dreams. Who are we? And what is the purpose of our existence?

Ultimately, these visions may help us to conjure up new ways of working and constructing alternative modes of existence, which open up the possibility of inhabiting terrains that are currently inaccessible to us.

That a philosophical approach to the future of space exploration and colonization should stray into the realm of fiction is hardly surprising—our first starship has not yet been built. This book therefore proposes to create a space for a diverse range of narratives and ideas to shape our conversations about human space exploration. It is also anticipated that readers will differ in their reactions to the multiple ideas and perspectives shared in this book, in which conversation—not consensus—is sought. Of course, when we eventually construct a habitat, we must find modes of working that enable us to reach agreement on what we are doing—but that is not the same as expecting everyone's perspective to be homogenous—nor to conform to any particular form of knowledge, or creed.

Indeed, the current publication should be read as an experiment into different modes of thinking concerning topics that are so vast, complex, heterogeneous, or shaped by so many contingencies that they require us to work with our differences to the extent that we can ultimately co-imagine experiences in those terrains best described as "unknowns."

Such a synthesis of ideas is well encapsulated by an ancient parable from the Far East, which describes the consternation that a group of learned men experience when encountering a specific natural phenomenon for the first time. All observers have an incomplete

view of the subject owing to a preferred perspective. Since they are all holding a different part of the elephant, they describe the nature of the beast depending upon where they touch, likening it to a rope, a snake, a tree, a spear, a wall, or a fan. Ultimately, their observations are all correct in some ways and completely wrong in others:

"It was six men of Indostan
To learning much inclined,
Who went to see the Elephant
(Though all of them were blind),
That each by observation
Might satisfy his mind.

The *First* approached the Elephant,
And happening to fall
Against his broad and sturdy side,
At once began to bawl:
'God bless me! but the Elephant
Is very like a WALL!'

The *Second*, feeling of the tusk,
Cried, 'Ho, what have we here,
So very round and smooth and sharp?
To me'tis mighty clear
This wonder of an Elephant
Is very like a SPEAR!'

The *Third* approached the animal,
And happening to take
The squirming trunk within his hands,
Thus boldly up and spake:
'I see,' quoth he, 'the Elephant
Is very like a SNAKE!'

The *Fourth* reached out an eager hand,
And felt about the knee
'What most this wondrous beast is like
Is mighty plain,' quoth he:
''Tis clear enough the Elephant
Is very like a TREE!'

The *Fifth*, who chanced to touch the ear,
Said: 'E'en the blindest man
Can tell what this resembles most;
Deny the fact who can,
This marvel of an Elephant
Is very like a FAN!'

The *Sixth* no sooner had begun
About the beast to grope,

Than seizing on the swinging tail
That fell within his scope,
'I see,' quoth he, 'the Elephant
Is very like a ROPE!'

And so these men of Indostan
Disputed loud and long,
Each in his own opinion
Exceeding stiff and strong,
Though each was partly in the right,
And all were in the wrong!" (John Godfrey Saxe (1816–87), *The Blind Men and the Elephant*)"

This book similarly seeks to remind us that—as citizens of a late modern era—there are certain latent assumptions we make that are the equivalent of the "elephants in the room." The essays that follow accordingly try to re-engage with, and re-describe, some of the bewildering elements of this thing we call space, while acknowledging that this is only one start. The thing we call space remains—thankfully—both largely unchartered and inaccessible to our current imaginations.

1.2 Prototyping the Interstellar Question

The Interstellar Question—whether humankind will ever colonize the stars—is not about business as usual in a place that is just a very long way away.

It is also not a typical question that can be broken down into a finite set of soluble steps. It is more of a conundrum, or manifold that harbors many overlapping and related concepts, which change with context and over time. These are often dissected using the sharp instruments of modern analysis and lead to a mismatch between the nature of the question and the instruments of its validation. Consequently, the Interstellar Question invites much skepticism.

An example of high modern criticism—which positions science and technology as central to human endeavor—is Nick Beckstead's blog from the Future of Humanity Institute in Oxford. He reviewed the starship question in relation to existential risk—the study of human extinction-level risks that may emerge from technological advances, in which this organization is invested. He is interested in rejecting the claim that there is a reasonable chance of colonizing space in the future. If humanity can actually escape the threat of extinction, then it is less pressing to take the Future of Humanity concerns so seriously. During his survey, he makes some insightful comments about interstellar exploration (Beckstead 2014).

Beckstead notes that most authors writing about the Interstellar Question already believe it is possible, which results in bias, as a foregone conclusion leads to a lack of critical debate among experts. He claims that starship advocates tend not to go into great detail with their proposals and also fail to engage with relevant counterarguments.

Beckstead identifies six phases of development whose technological integrity can challenge the starship question, where potential advances in artificial intelligence (AI), robotics, manufacturing, and propulsion technology could overcome the obstacles implicit in each of these stages. Further analysis could anticipate the relevant, necessary advances in

AI, robotics, manufacturing, and propulsion technology as an investable road map that would take the project toward realization:

1. colonize (interplanetary) space;
2. resources to build a civilization into a starship;
3. propulsion technology;
4. enough provisions to keep a civilization intact during the voyage;
5. slow the starship down at target location (exoplanet);
6. build a civilization at the target location.

Interestingly, Beckstead observes there are no major voices insisting on the fallacy of the enterprise. Notably, the question has had high-profile coverage by commentators such as Stephen Hawking. If persuasive counterarguments existed, then the publicity surrounding the debate would have already brought them to the fore. Prominent critics like Charles Stross, whom Beckstead suggests makes the strongest counterarguments, also pulls his punches from completely killing the idea. He concedes that the interstellar ambition will eventually be accomplished with the relevant advanced AI and robotics.

Beckstead's observations are typical of a dominant discourse. He places a definable boundary around the challenge and takes an Occam's razor to the Interstellar Question, breaking it down into solvable steps. The interpretation becomes something like: Do we have the industrial capabilities to successfully settle an exoplanet today? The current answer to this highly reduced question is "no." We are simply not set up to do this.

Given that this is the Future of Humanity Institute making the analysis, it is also possible to add a secondary question—that if it is not possible today, then when is success likely? The response to this contingency is "we don't know," although there is a spectrum of opinions on when and how this may be possible.

Beckstead adopts a deterministic viewpoint that assumes the answers to the question are calculable, or finite. Of course, this seems like a good idea, as nobody wants to invest significantly in a project that is doomed from the outset. Yet, the Interstellar Question depends upon so many contingencies that are unknowable in the anticipated timescales involved that it cannot possibly address or control for all variables. For example, it does not allow for radical breakthroughs in scientific research and development, or the discovery of characteristics of space that could significantly alter the chances success of an outcome, such as discovering an Earth-like planet in the Centaurus constellation, in which Alpha is the brightest (binary) star.

According to Beckstead, the feasibility of the enterprise rests on our capacity to make appropriate technical advances and their implied existential risks of extinction, where humans and machines are the only players in the outcome. Yet, the characteristics of space itself may also contribute to being able to travel to another star system, such as the discovery of wormholes, which are theoretical tunnels through the fabric of space-time that could potentially allow rapid travel between widely separated points—from one galaxy to another, for example, as depicted in Christopher Nolan's 2014 movie release *Interstellar*.

A current understanding of technological advances is assumed. This is the approach that Gerard O'Neill took in designing off-world colonies. Again, there is nothing wrong with this perspective, as it lends credibility to the venture by making direct reference to the latest findings. However, it does not acknowledge what Kevin Kelly describes as

concurrent landscapes of technical evolution. These create the context in which a breakthrough technology suddenly seems to appear (Kelly 2010). Specifically, the motorcar revolution would not have been possible without simultaneous advances in petrochemical engineering or the construction of highways. Of course, we have the opportunity to address these developments in the second part of the question and consider how, for example, we might first become an interplanetary civilization but, until the "radical" technology emerges, we cannot be sure, in the present, what the relevance of specific "landscape" innovations may be.

Whether we will one day live among the stars is a very old question indeed. It is not just simply about technical accomplishment. It is highly contingent on who we are, what we aspire to, and also on unfolding events such as economic investment, natural disaster, or political agendas. Nor can it be addressed by a single discipline. In addition to the practical feasibility of technical challenges, the Interstellar Question provokes many existential challenges from the nature of humanity to our understanding of the cosmos. Over the millennia, a variety of solutions to the Interstellar Question have been proposed. Currently, we prioritize technical approaches. Yet, the variety of ideas that we share about our future among the stars suggests the protean nature of this question and invites us to be more diverse, collaborative, and expansive in our expectations.

While the Future of Humanity analysis interprets the Interstellar Question through the lens of high modernism, this is not the only possible way in which the challenge can be read.

The Interstellar Question embraces many kinds of concepts, whose causalities are not fixed, which exist at different times and scales.

Perhaps an analogy can be made to quantum physics, where a fundamental split between the world we see around us and its quantum underpinnings can be observed during the course of experiments. For example, the two-slit experiment demonstrates the paradox that light and matter can display the characteristics of both classically defined waves and particles (Al-Khalili and McFadden 2014, pp. 105–118):

> "Quantum mechanics does in fact provide us with a perfectly logical explanation of this phenomenon; but it is only an explanation of what we observe—the result of an experiment—not what is going on when we're not looking. But since all we have to go on is what we can see and measure, maybe it makes no sense to ask for more. How can we assess the legitimacy or truth of an account of a phenomenon that we can never, even in principle, check? As soon as we try, we alter the outcome." (Al-Khalili and McFadden 2014, p. 115)

Stuart Kauffman refers to this kind of question as being one in which "phase space is changing in ways that we can't pre-state" (Kauffman 2012). In other words, the Interstellar Question is so large, complex, and contingent that it is actually evolving. We may call this "black-sky thinking."

So, since we are actually living in a high modern era, how can we open up our range of perspectives?

Space is a screen into which our ideas are projected. Since the Space Age, we have held a largely industrial view of our civilization, which shapes our expectations. Existing space pioneers cite activities such as mining and communications enterprises as being justifications for brave new forays. Yet, we are living in very exciting and confusing times, in

which we are moving away from an industrial age of development and toward an ecological view of reality. The growing realization that our species is not simply an isolated body, but deeply entangled in and dependent on its ecosystems, is changing the way in which we live on Earth and, by implication, the way we address the Interstellar Question.

An ecological perspective no longer finds it acceptable to simplify the challenge into a dance of mutual survival between human and machine. Rather, the issues at stake must first be understood through a reading of the cosmos as an ecosystem and working through multiple, overlapping perspectives and includes science, technology, the arts, and humanities.

This requires us to be able to coherently embrace a range of overlapping and sometimes contradictory sets of ideas. It is not about exchanging one dominant model of reality for another. Rather, it is about finding opportunity in the spaces that lie between these differing worldviews.

The literature that begins to describe this perspective exists in science-fiction novels such as Kim Stanley Robinson's 2009 *Green Mars* (2009) (terraforming) and *Aurora* (2016) (worldship). Within these thought experiments, we are still shaping the kinds of questions that are relevant to these third-millennium challenges. They are no longer concerned with the atomic control of matter, but with synthesizing life and increasing the complexity of environments. These perspectives help us survive even the most extreme environments.

Indeed, we have not fully addressed these challenges on our own planet: notably, we cannot build ecosystems from scratch, despite millennia of gardening them, so the research and discoveries that we are currently making will certainly reflect back on our expectations of non-terrestrial civilizations and what they may need to settle new territories. The tools, methods, and materials that will enable us to do so do not yet exist, but they are not hypothetical. They are still emerging, and we do not yet understand all the possible choices they have to offer. These findings will not just affect our ideas about why and how we might travel into interstellar space, but also how we can persist and potentially thrive in ecologically barren terrains, including our own planet.

When considered from an ecological perspective, the Interstellar Question is no longer a challenge posed for human and machine, but invokes new ideas about the broader community and set of conditions for life.

Yet, there is another twist to the Interstellar Question.

To date, the challenge of making grand proposals for starship blueprints has largely been addressed by enthusiasts and theorists, such as Freeman Dyson, and professionals, such as Alan Bond and Tony Martin. These generally explore the physics of the cosmos, knowledge of engineering practices, and projections for future possible forms of existence. Yet, even from the most rational perspectives, these designs make significant assumptions that may take them from concept to reality, such as the propulsion systems available, the existence of certain technologies, or that an industrially based interplanetary society has already been established.

Since possible future events shape the outcomes of the Interstellar Question in unpredictable ways, science fiction has served as a critical literary prototyping instrument for a range of possibilities. Proposals range from the classical *Starship Enterprise* to the organic vessel *Lexx*, and even advanced intelligences, as depicted in Ian M. Banks's "The Culture." However, it is now possible to go beyond thought experiments and actually explore a range of physical systems by interrogating ideas through small-scale prototypes that help us to address the Interstellar Question in new ways.