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NOVEMBER/DECEMBER 2014
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GUEST-EDITED BY NEIL LEACH

SPACE ARCHITECTURE

THE NEW FRONTIER FOR DESIGN RESEARCH

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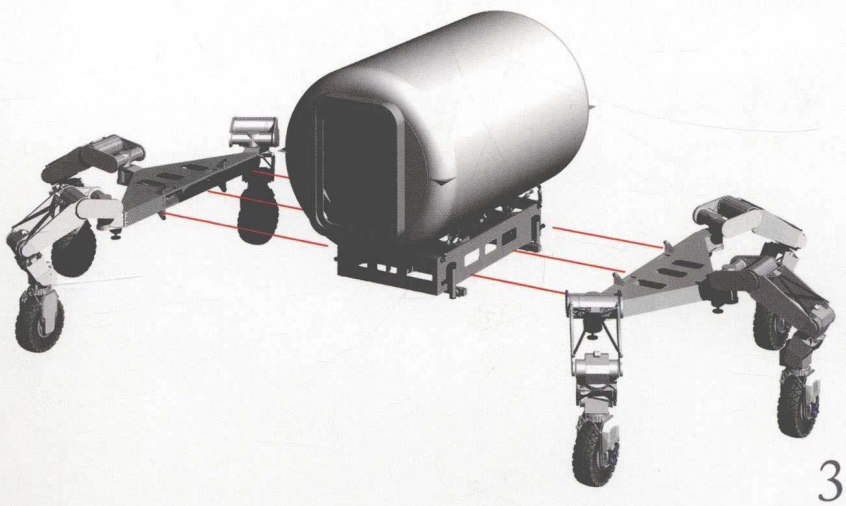

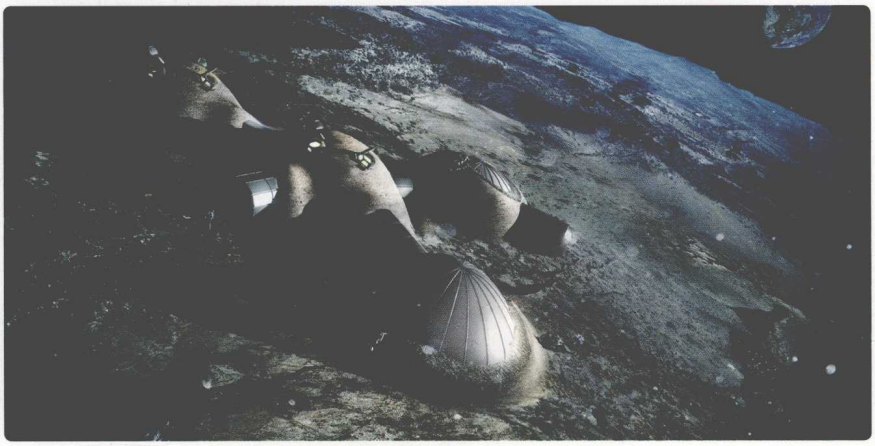

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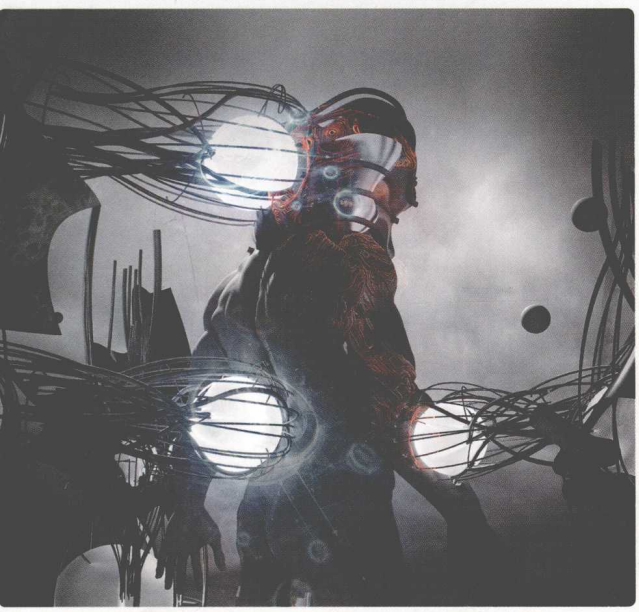

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The future of the past is in the future
The future of the present is in the past
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— John McHale, 1965, in Δ 2000+, February 1967, p 64

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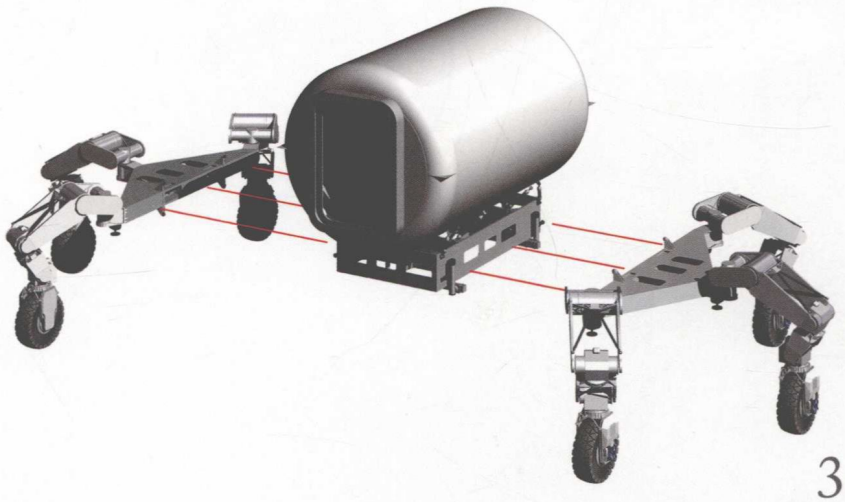

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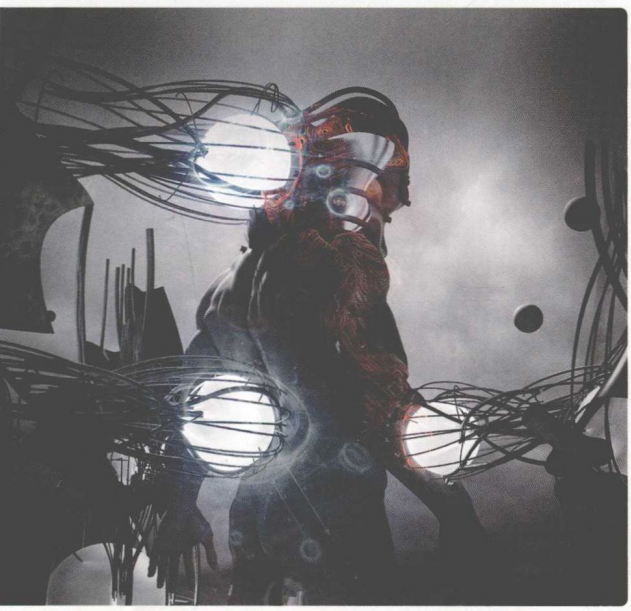

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Front cover: Self-portrait of Tracy Caldwell Dyson in the Cupola module of the International Space Station observing the Earth below during Expedition 24, 2010. Courtesy of NASA/Tracy Caldwell Dyson

Inside front cover: Julia Koerner, Space Collective (detail), (tutors: Greg Lynn and Brennan Buck), MArch, University of Applied Arts, Vienna, 2007. © Julia Koerner

06 / 2014

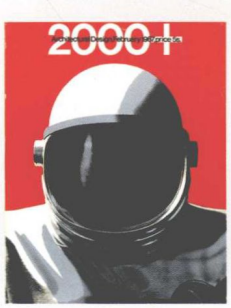
EDITORIAL

Helen Castle

Space represents a unique chance to look up and beyond ourselves. It is an opportunity that has not been missed by AD over the years – forever casting its eye on the horizon for what might be happening next culturally, socially and technologically. *Space Architecture* is the third issue of AD on the subject. The first, seminal issue *2000+* was published in February 1967 under the editorship of Monica Pidgeon and Robin Middleton (technical editor). The material was compiled and much of it written by scholar–artist and Father of Pop Art John McHale, who was then Executive Director and Research Associate of the World Resources Inventory at Southern Illinois University. With its red, eye-catching cover depicting the head of an astronaut, it captured the zeitgeist with two articles by Buckminster Fuller, its late-1960s enthusiasm for technological hardware and everything space related. It also anticipated the lunar landings by two years. Pasted together from a whole range of astronautical engineering sources, it fully established AD's and its readerships' penchant for the nerdily technical. The second issue, guest-edited by Rachel Armstrong in April 2000, conspired to reinvigorate the enthusiasm of the design community in the astronautical and bring their attention to the new possibilities introduced by space tourism. Like the first issue, it also foreshadowed events by coming out a year before the first space tourist Dennis Tito blasted into space on the 28 April 2001.

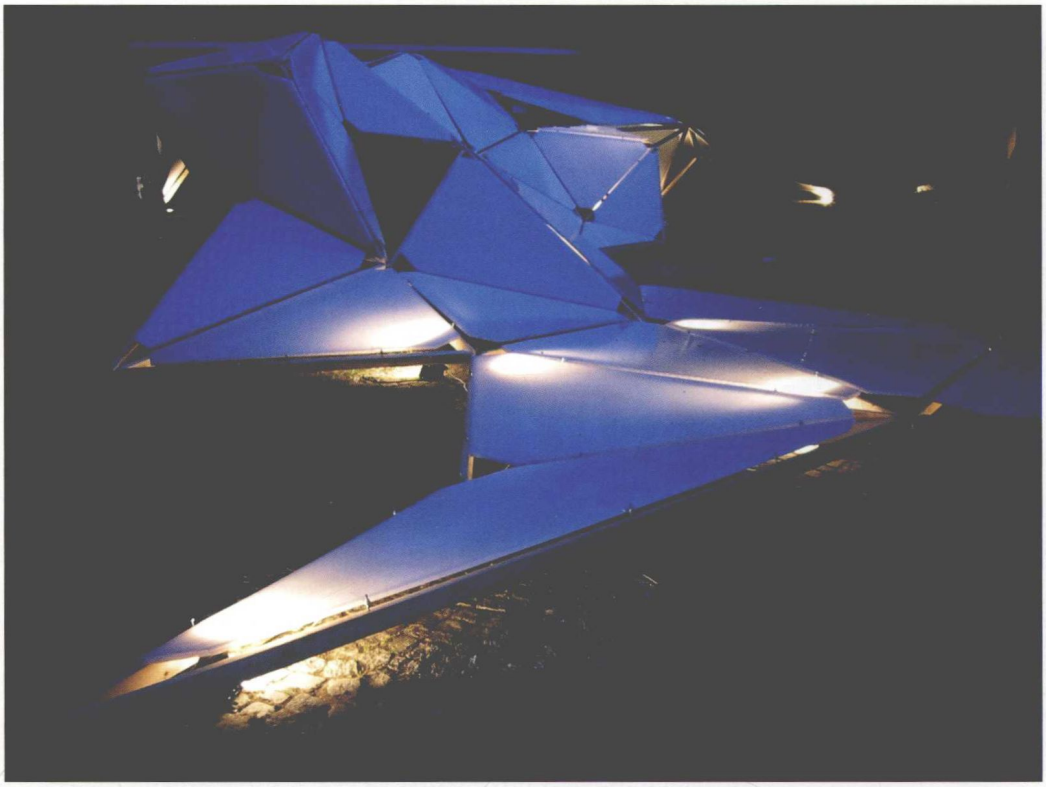
This third issue of AD on Space brings with it an entirely different emphasis on design research. It is guest-edited by Neil Leach, who has a distinguished career as an architectural educator and author, but is also a NASA Innovative Advanced Concepts Fellow working at the University of Southern California (USC) on a research project to develop a robotic fabrication technology to print structures on the Moon and Mars (see '3-D Printing in Space' on pp 108 –13 of this issue). Leach demonstrates how Space provides not only a test bed for new technologies, such as robotics, that are set to become game-changing for terrestrial architecture, but also provides a catalyst for pushing the boundaries in terms of ideas, imagination and lifestyles: whether it prompts inventive speculative design from the likes of Greg Lynn (pp 82–7) or seeks us to explore the climatic and practical challenges that might be thrown up by the human colonisation of the Moon or Mars. Moreover, for architects, designing for Space is now becoming less a matter of speculation and more one of live projects. This is epitomised by the engagement of a premier international firm like Foster + Partners on the design of Spaceport America in New Mexico and the firm's further participation in space research as a key collaborator in the European Space Agency (ESA) consortium that is investigating the potential of 3D printing on the Moon.

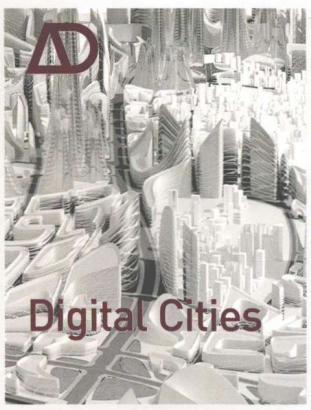
There is a neat circularity to this volume, as Rachel Armstrong provides the Counterpoint to this issue. With characteristic tenacity, she challenges readers to explore a wider notion of how planets might be developed as biological ecologies for habitation rather than as discrete territories for exploitation. AD

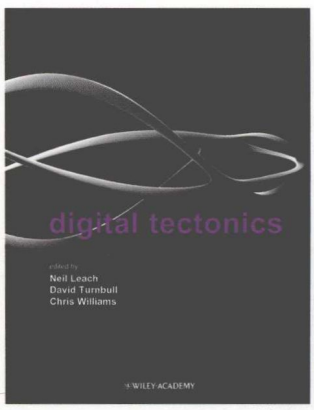


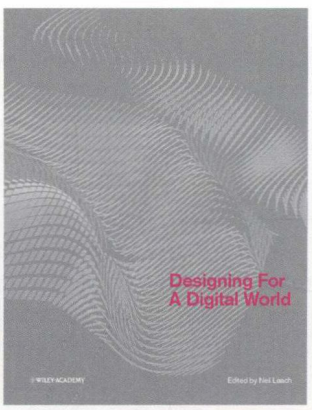
left: AD *2000+*, February 1967.

right: Rachel Armstrong, AD *Space Architecture*, April 2000.









Neil Leach, Δ *Digital Cities*, 2009
This issue of Δ looks at the impact of computation not only on the design of cities, but also on techniques of analysing and understanding them.

Neil Leach, David Turnbull and Chris Williams, *Digital Tectonics*, 2004
The book addresses the use of computation in designing structures and structural systems in architecture. In so doing it outlines both a structural turn in architecture, as structural efficiency becomes an increasingly important factor in design, and the impact of computation on structural design.

Neil Leach, *Designing for a Digital World*, 2002
This volume brings together some of the leading architects, philosophers and cultural theorists from across the globe to look at the impact of digital technologies on the world of design.

Neil Leach, Kristina Shea, Spela Videcnik and Jeroen van Mechelen, eifFORM installation, Academie van Bouwkunst, Amsterdam, 2003
Constructed in the Academie's courtyard, the design of this installation was generated using eifFORM, a software program that produces structurally efficient forms in a stochastic non-monotonic method, using simulated annealing.

Neil Leach is an architect and theorist. He is currently Professor of Digital Design at the European Graduate School, Visiting Professor at Harvard Graduate School of Design (GSD) and Tongji University, and Adjunct Professor at the University of Southern California (USC), Los Angeles. He is also a NASA Innovative Advanced Concepts Fellow, working in collaboration with colleagues from USC on a research project to develop a robotic fabrication technology to print structures on the Moon and Mars. The project stems from deeper research into computational design and robotic fabrication technologies, especially Contour Crafting, a technology for layered concrete construction invented by Behrokh Khoshnevis, with whom he has collaborated for several years.

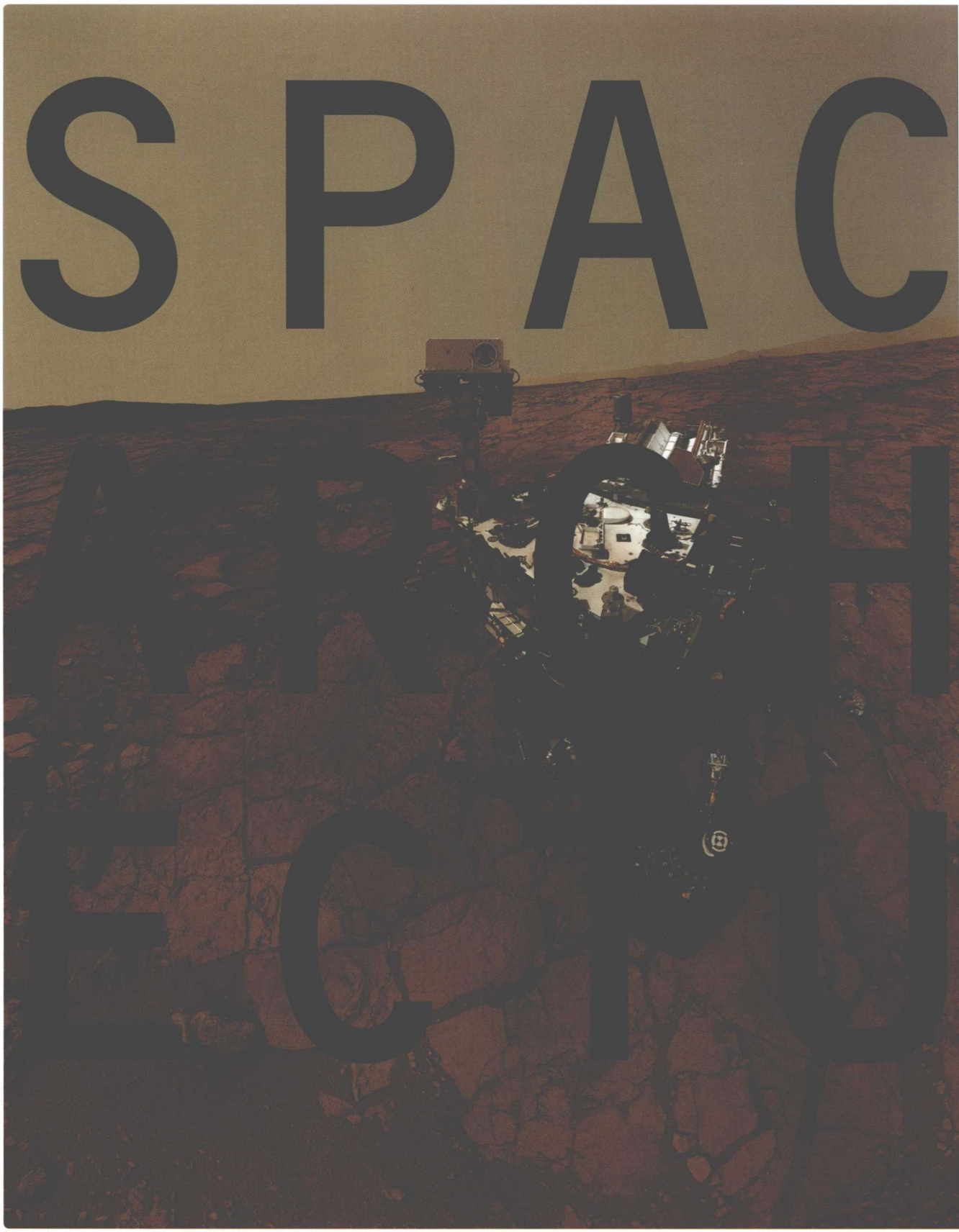
His research work on computational design and robotic fabrication technologies has taken the form of a series of publications, exhibitions and conferences. His publications in this field include: *Designing for a Digital World* (Wiley, 2002); *Digital Tectonics* (Wiley, 2004); *Emerging Talents, Emerging Technologies* (China Architecture and Building Press (CABP), 2006); *(Im)material Processes: New Digital Techniques for Architecture* (CABP, 2008); *Digital Cities* (Wiley, 2009); *Machinic Processes* (CABP, 2010); *Fabricating the Future* (Tongji University Press, 2012); *Scripting the Future* (Tongji University Press, 2012); *Digital Workshop China* (Tongji University Press, 2013); *Design Intelligence: Advanced Computational Research* (CABP, 2013); and *Swarm Intelligence: Architectures of Multi-Agent Systems* (Tongji University Press, 2014). He has also curated a series of exhibitions and associated conferences in this field including: 'Fast Forward>>' (Architecture Biennial Beijing (ABB), 2004); 'Emerging Talents, Emerging Technologies' (ABB, 2006); '(Im)material Processes: New Digital Techniques for Architecture' (ABB, 2008); 'Machinic Processes' (ABB, 2010); 'Swarm Intelligence: Architectures of Multi-Agent Systems' (Shanghai, 2010); 'DigitalFUTURE' (Shanghai, 2011); 'Interactive Shanghai' (Shanghai, 2013); and 'Design Intelligence: Advanced Computational Research' (Beijing, 2013).

His other field of research is the intersection between architectural theory and critical theory/philosophy. His publications in this field include: *Rethinking Architecture: A Reader in Cultural Theory* (Routledge, 1997); *The Anaesthetics of Architecture* (MIT Press, 1999); *Millennium Culture* (Ellipsis, 1999); *Architecture and Revolution: Contemporary Perspectives on Central and Eastern Europe* (Routledge, 1999); *The Hieroglyphics of Space: Reading and Experiencing the Modern Metropolis* (Routledge, 2002); *Forget Heidegger* (Paideia, 2006); *Camouflage* (MIT Press, 2006); and *The Politics of Space* (Routledge, forthcoming).

He holds an MA and Diploma of Architecture from the University of Cambridge, and a PhD degree from the University of Nottingham, and is a registered architect in the UK.

INTRODUCTION

Neil Leach



Curiosity rover self-portrait, Mars, 3 February 2013
The self-portrait was taken on a patch of flat outcrop called John Klein, where the NASA rover was due to perform rock-drilling activities. The image is actually composed of dozens of exposures stitched together.

Space Shuttle Atlantis seen from the Mir space station, 29 June 1995
Fish-eye view of the Atlantis as seen from the Russian Mir space station during the STS-71 mission.

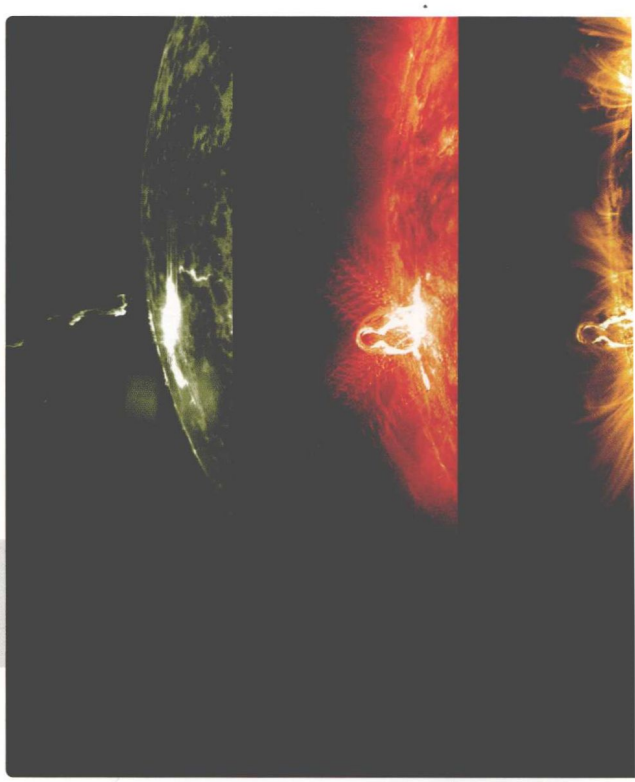
E I T R E

THE NEW FRONTIER FOR DESIGN RESEARCH

Architecture in Space is entering a new era. It is over 40 years now since the late Neil Armstrong became the first human being to set foot on the Moon. For many people space exploration has not advanced much since that historic moment, but in reality there have been numerous developments. Space exploration has taken on a collaborative international dimension through the International Space Station (launched in 1998) and other ventures. Likewise, the practice of one-off flights has given way to the introduction of reusable hardware such as NASA's Space Shuttle (operational 1981–2011). More recently, in 2011 the US sent the Curiosity rover, its most sophisticated robotic vehicle, to investigate the climate and geology of Mars. And other countries have joined the space industry, with China sending its first astronaut, Yang Liwei, into Space in 2003 and then landing its own lunar rover, Yutu (or Jade Rabbit), on the Moon in December 2013. Significant research has also been undertaken into harnessing energy from Space, and the space tourism industry is gearing itself up to send the first space tourists into low earth orbit.

Over the last decade there has been a fundamental shift in the space industry from short-term pioneering expeditions to long-term planning for colonisation and new ventures such as space tourism. Architects are now involved in designing the interiors of long-term habitable structures in Space, such as the International Space Station, researching advanced robotic fabrication technologies for building structures on the Moon and Mars, envisioning new 'space yachts' for the super-rich, and building new facilities such as the Virgin Galactic Spaceport America in New Mexico designed by Foster + Partners (2011). Meanwhile, the mystique of Space remains as alluring as ever, with architects including Greg Lynn (see his article on pp 82–8 of this issue) involved in design fictions set in Space, and educators such as Michael Fox of the California Polytechnic State University (Cal Poly – see pp 100–101), Larry Bell of the Sasakawa International Center for Space Architecture (SICSA) at the University of Houston (pp 118–21) and Lynn running design studios drawing upon ever more inventive computational design techniques.

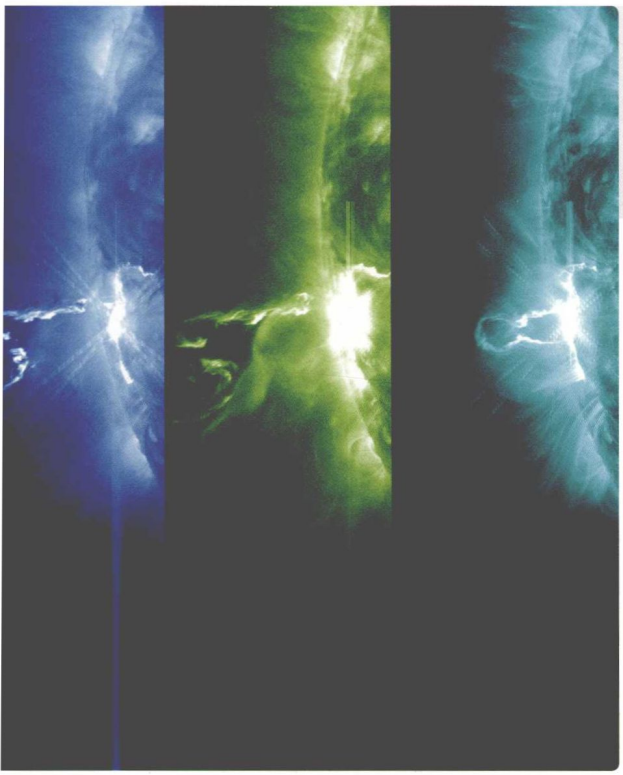
OVER THE LAST DECADE THERE HAS BEEN A FUNDAMENTAL SHIFT IN THE SPACE INDUSTRY FROM SHORT-TERM PIONEERING EXPEDITIONS TO LONG-TERM PLANNING



This issue of Δ features the most significant of projects currently underway and highlights key areas of research in Space, such as energy, materials, manufacture and robotics. It also looks at how this research might be realised in outer space and the potential for applying it to conventional architectural design and construction. It is structured along the lines of the four key domains of Space Architecture: space colonisation, habitable artificial satellites, space tourism and terrestrial space-related industries.

Space Settlement

Space settlement remains one of the most contested topics. Should humankind continue to explore the potential of sending a handful of human beings to planets such as Mars and other celestial bodies, or should the emphasis be placed instead on relatively large-scale settlement programmes on the Moon? Contributors to this volume remain divided. Space architect Madhu Thangavelu (pp 20–29) favours the potential settlement of the Moon, as does fellow space architect Brent Sherwood (pp 16–19), who sets out the various future options in terms of space developments. Designer Andreas Vogler's MoonCapital proposal (pp 30–35) offers an architectural vision of such a project. Meanwhile, former astronaut and the second man to set foot on the Moon, Buzz Aldrin (pp 40–45), argues that the next important milestone is surely to send a human being to Mars, despite the unlikelihood of being able to bring that person back. Aerospace engineer and author Robert Zubrin (pp 46–53), himself a long-time passionate advocate of missions to Mars, agrees with Aldrin that we should be investing our energies in settling Mars, although his vision is slightly different.



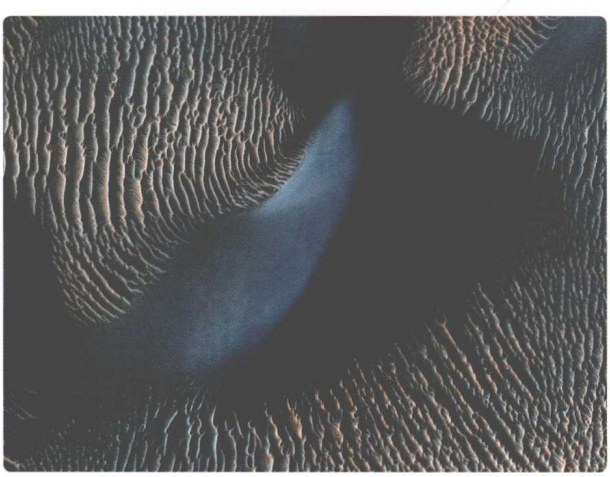
NASA Solar Dynamics Observatory, Solar flares, 24 February 2014
The harvesting of solar energy remains a further potential opportunity in Space. These images show the first moments of an X-class flare in different wavelengths of light.

Space architects have also been involved in researching other concerns related to space settlement, exploring ways of constructing habitats and other infrastructural facilities on the Moon and Mars, which has developed considerably in the past few years, and devising novel rovers for traversing their surfaces, such as the ATHLETE moon rover developed by A Scott Howe (see pp 36–9). For example, a series of consortia are now exploring the potential of robotic fabrication technologies for printing structures on the Moon and Mars that echo the growing interest in 3D printing in general. These technologies can also be deployed in habitable artificial satellites for printing replacement parts and even for printing food. My own article on pp 108–11 of this issue offers an overview of developments in 3D printing in Space.

Habitable Artificial Satellites

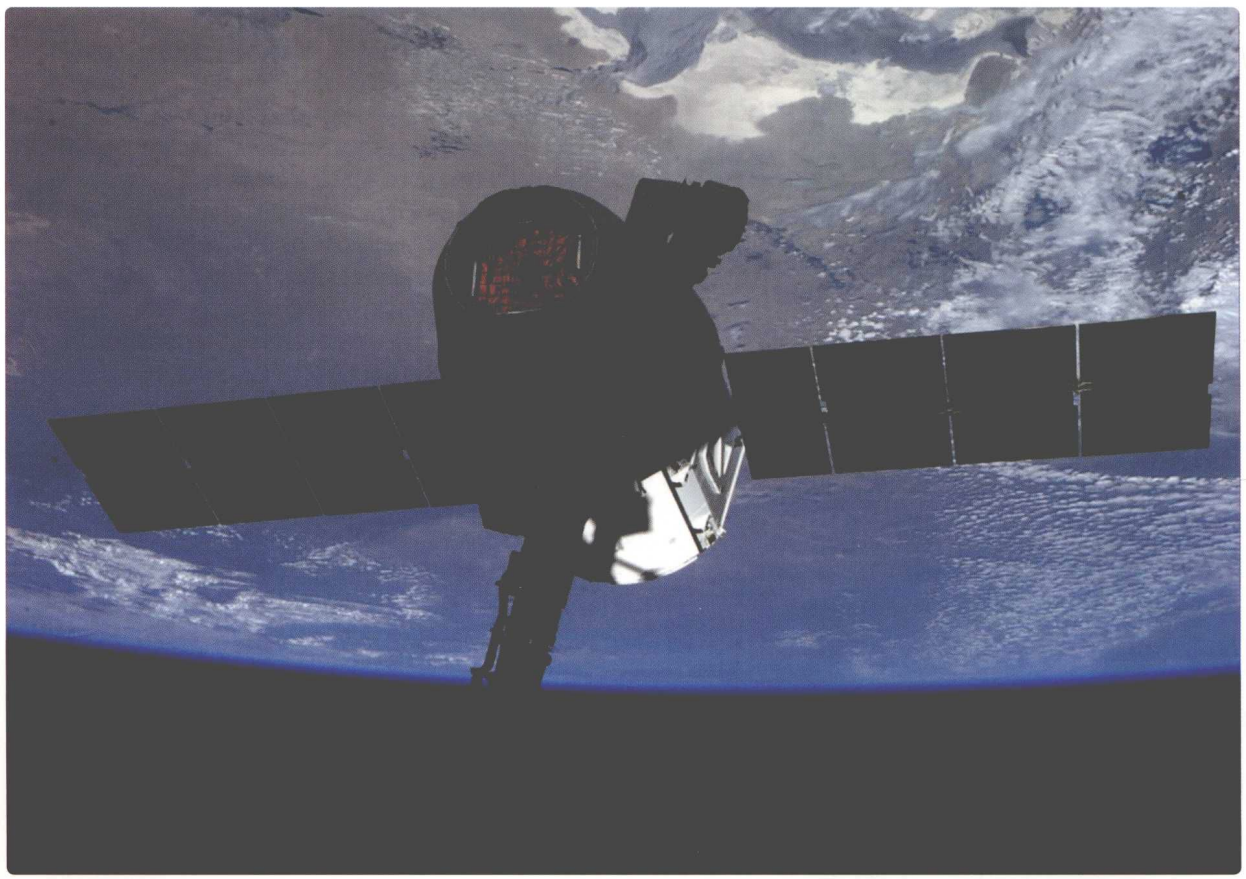
In terms of habitable artificial satellites, despite the many speculative ideas promoted by a variety of designers, the International Space Station (or 'Alpha', as it is known in the space industry) remains the only actual human habitat that has been deployed in Space to date. In her article (co-authored with Rod Jones), Constance Adams, who was involved in the design and fabrication of Alpha, recounts the process (see pp 70–77).

While research has been conducted into other possible space habitats – some of which are featured in this issue – the experience of astronauts actually inhabiting the International Space Station has itself generated a valuable new field of research into the physiological and psychological problems of keeping human beings in Space for extended periods. What has become clear is that human beings face considerable obstacles if they are to survive in Space, given the recurrent problems of radiation, weightlessness and diet. In his article on pp 90–95, Ondřej Doule (chair of the Space Architecture Technical Committee at the American Institute of Aeronautics and Astronautics (AIAA)), considers the issue of gravity, which he considers to be the fundamental challenge in space exploration, not only in terms of the problems of weightlessness in space habitats such as Alpha, but also in launching rockets in the first place. Likewise, space architect Sandra Häuplik-Meusburger (pp 114–17) looks at the potential of different greenhouse systems in Space in which to not only grow vegetables, but also to provide some visual relief to the monotony of life on board. Equally, space architect Marc M Cohen (pp 78–81) describes his vision of a Water Wall whereby waste fluids are redeployed as a radiation shield for spacecraft.



NASA Mars Reconnaissance Orbiter, Proctor Crater, Mars, 9 February 2009
Photo taken by the orbiter's High Resolution Imaging Science Experiment (HiRISE) camera showing one of the many dunes composed of fine sand.

SpaceX Dragon capsule grappled by the International Space Station's Canadarm2 Mobile Servicing System (MSS), 20 April 2014
Private enterprise has emerged as one of the most important drivers within the space industry, with companies such as SpaceX playing an increasingly prominent role. Here, a SpaceX Dragon craft is grappled by Canadarm2 as it delivers supplies.



NOT ONLY DO CERTAIN TECHNOLOGIES USED ON EARTH OWE THEIR ORIGINS TO DEVELOPMENTS IN THE SPACE INDUSTRY, BUT ALSO THE WHOLE OF THE SPACE INDUSTRY IS ULTIMATELY CONDITIONED BY TERRESTRIAL CONCERNS.

Michael Maltzan Architecture, New building for NASA's Jet Propulsion Laboratory (JPL), Pasadena, California, 2010
In this proposal for the new JPL building, the upper courtyard, with its reflecting fenestration, gives the impression of endless space.