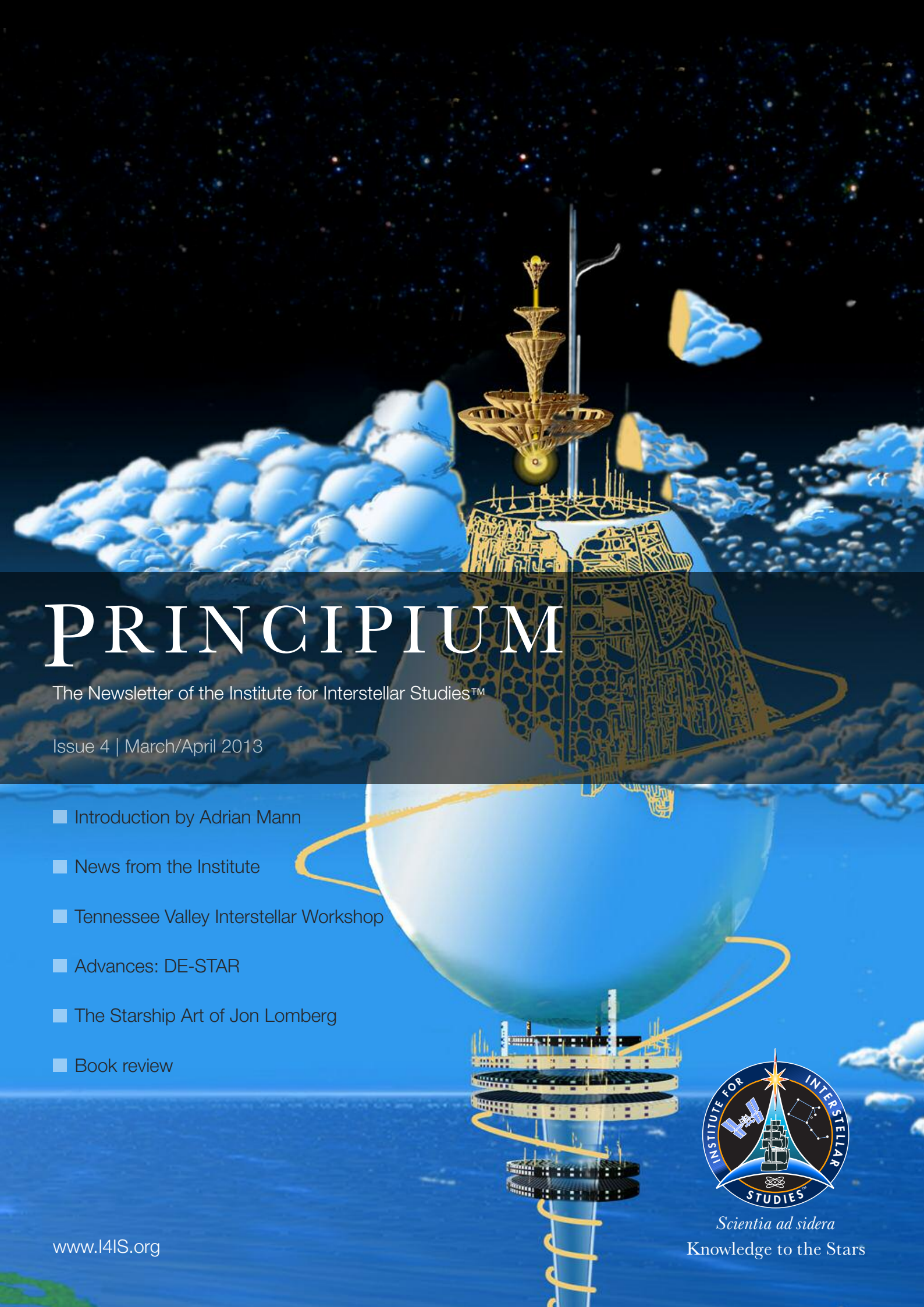




PRINCIPIUM

The Newsletter of the Institute for Interstellar Studies™

Issue 4 | March/April 2013

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Scientia ad sidera
Knowledge to the Stars

Introduction by Adrian Mann



“I affirm that next to the soul, the most beautiful object in the galaxy is the spaceship!” So said Alejandro Jodorowsky in his foreword to Chris Foss’ book *21st Century Foss*. And who could argue with that sentiment?

Witness the work of Jon Lomberg in this issue. He creates radical, ground-breaking concepts of great beauty that inspire and force us to reconsider notions of what is possible, or how things can be. Which is right and proper, of course.

It seems many of us can recount the same sort of childhood experiences – an early interest in astronomy or science fiction, a teacher that inspired or encouraged, and a tireless curiosity and a desire to know more. Almost all the people I know in the ‘Interstellar Community’ have taken the science or engineering route. I was presented with a dilemma when it came to my further education – choose either maths and physics, or art. Naturally, I decided to pursue all three – much to the consternation of teachers, other pupils and parents who couldn’t imagine what on Earth I was thinking. To be honest, I had no idea either – but also couldn’t see why science and art couldn’t get along.

And yet, it now makes sense. Though the design of spacecraft is constrained by the iron hand of physics and mathematics, there’s no reason why the form that follows the function can’t be beautiful. Take some examples from aviation – the Supermarine Spitfire, the deHavilland Comet, Concorde – all governed by the principles of flight and yet some of the most beautiful objects created. So why not spacecraft?

Personally, I don’t think the truly beautiful spacecraft has yet been built. One could hardly describe the Space Shuttle, or a communications satellite, as ‘beautiful’. Perhaps better to describe them as solutions to problems – engineering, thermal, materials and even political problems, but hardly objects of great aesthetic value. There are designs as yet unbuilt which aspire to beauty. Reaction Engines’ SKYLON spaceplane, for instance, though designed at the very limits of the possible, has that sense of purpose and elegance that harks back to

the golden age of aircraft design. I wonder what Geoffrey deHavilland, Reginald Mitchell or Barnes Wallis would have designed? I suspect it might not have been too dissimilar. As the old adage goes “If it looks right, it *is* right.”

So here we stand, at the birth of the concepts and ideas that will surely one day carry humanity to the stars. Ships that burn antimatter for fuel, harness the processes at the hearts of stars, or travel on exa-watt lightbeams, hurling colossal masses at fantastic velocities, on journeys of decades or centuries, out into a vast, dangerous and dark unknown. Take a moment, stand back and consider what an outrageous, audacious undertaking that is.

What on Earth – or beyond it – would that look like? I read a lot of papers on the physics of interstellar travel and, though I struggle with the mathematics, those graphs and charts are telling us things about how the Universe works and what will be needed to travel through it. The answers are truly awe-inspiring.

So the starship must be beautiful! How could we voyage to the stars in rusting hulks, or a thing that looks like a collision between an oil refinery and an aircraft carrier, with old boilers and heating ducts riveted to it? No – the starship will be a thing of beauty and elegance, because it must be. The uniquely demanding set of principles will inevitably conspire to make it so.

Finally, I have a personal vision of some far distant future – imagine, on the observation deck of one of the first interstellar cruise ships, somewhere in the darkness between the stars, some of the passengers are listening to a talk on the history of interstellar travel, and how they got to be where they are now. Perhaps right at the start of the presentation, the work we’re doing today will be mentioned – we can only hope our far distant descendants will look kindly on our endeavours.

Adrian Mann
Director, I4IS

News from the Institute

I4IS' First Starship Symposium

I4IS will be holding its first ever one-day symposium, entitled *The Philosophy of the Starship*, on 29 May 2013 at the British Interplanetary Society in London. Speakers already confirmed include I4IS' Kelvin F Long, Keith Cooper and Stephen Ashworth, as well as Bob Parkinson who worked on Project Daedalus and Frederik Ceyssens of Icarus Interstellar and KU Leuven in Belgium.

Even though the first interstellar mission may be a century or more away, planning for an interstellar future starts now. What sorts of vessels shall we send into deep space, and what will they be tasked with? How will they be constructed, financed and governed? What are the risks or benefits inherent in going to the stars? What evolutionary future possibly awaits those star-faring humans going on a one-way colonisation trip? Indeed, who amongst us should go, and why? Given that a starship will be more than just technology but also an artifact of the culture that builds it, what do we truly mean when we talk about starships?

Organised in conjunction with the Journal of the British Interplanetary Society (<http://www.jbis.org.uk/>), in which papers presented at the symposium will

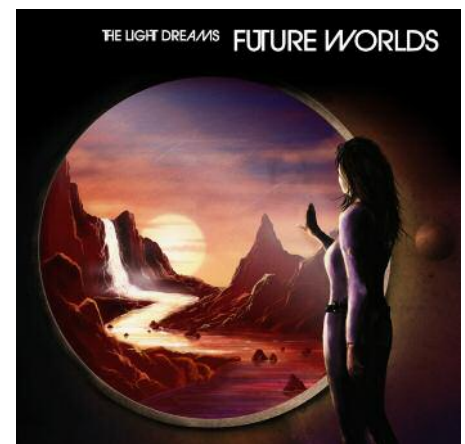
be peer reviewed and considered for publication, this I4IS conference invites the submission of further innovative and thought-provoking papers to explore the philosophy of the starship. All submissions should be sent to interstellarinstitute@gmail.com, while you can find more details at http://www.i4is.org/info_events.html. For those simply wishing to attend, tickets are £55 for non-members of the British Interplanetary Society, £45 for members and £25 for students. To book tickets pay a visit to <http://www.bis-space.com/products-page/symposia/the-philosophy-of-the-starship/>.

The speaker list currently stands as follows, with more speakers to come:

- The Invention of the Starship, by Kelvin F Long
- Von Neumann Probes: Close to Reality? by Keith Cooper
- The Philosophical Heritage of the Starship, by Stephen Ashworth
- The Starship as a Philosophical Vehicle, by Bob Parkinson
- Future Geopolitical Scenarios, Their Dominant Philosophy and the Impact Thereof on Deep Space, by Frederik Ceyssens.

Music to fly to the stars by

I4IS' honorary Interstellar Musician, the exceptionally multi-talented Alex Storer, a.k.a. The Light Dreams, has released *Future Worlds*, his brand new album of electronic space music in the style of Jean Michel Jarre, Tangerine Dream and Vangelis. Inspired partly by I4IS, and featuring an introduction in the accompanying PDF booklet written by the space artist David Hardy, the album features twelve tracks with themes ranging from leaving Earth, star-flight and the colonisation of new worlds, to climate change, endangered life in the oceans and the ultimate destruction of Earth as our Sun ages and grows into a red giant. Alex took influences from science fiction such as Arthur C Clarke's *The City and the Stars*, Poul Anderson's *Tau Zero* and Karen Thompson Walker's *The Age of Miracles*, or space art from the likes of David Hardy and Chris Moore, and melded them into his own future tapestry. Indeed, as an accomplished artist himself, the album's cover is one of his own paintings, entitled *The World Outside*.



Future Worlds is available as a digital download priced £7.99 and, if you purchase it from Alex's bandcamp page (<http://thelightdreams.bandcamp.com/album/future-worlds>) then it comes with two bonus tracks, 'First Steps' and 'Origins'. Alternatively, you can purchase the standard 12-track album from a variety of Amazon stores around the world, as well as iTunes and Spotify. Alex has kindly promised to donate a percentage of each sale to I4IS. So if you want a fantastic musical experience, what are you waiting for?

While you're at it, don't forget to check out Alex's back catalogue of albums plus his artwork on his website, www.thelightdream.net.



I4IS Consultant Gerry Webb speaking at a previous British Interplanetary Society 'Worldship' symposium.

News from the Institute

Learning about artificial intelligence the interstellar way

Professor Austin Tate, Director of the Artificial Intelligence Applications Institute at the University of Edinburgh and a Senior Researcher with I4IS, has infused a Massive Open Online Course (MOOC) on artificial intelligence with a dose of interstellar applications.

MOOCs have, in the last few years, become a popular way to make freely available educational materials to tens of thousands of students across the world. Although many register to just dip in to view the free materials, others partake in learning the course, watching video lectures, completing assignments and taking exams to earn 'Statements of Accomplishment'. While this is not a formal university certificate, it gives the student a sense of achievement that they can take forward into pursuing their interest in the subject further.

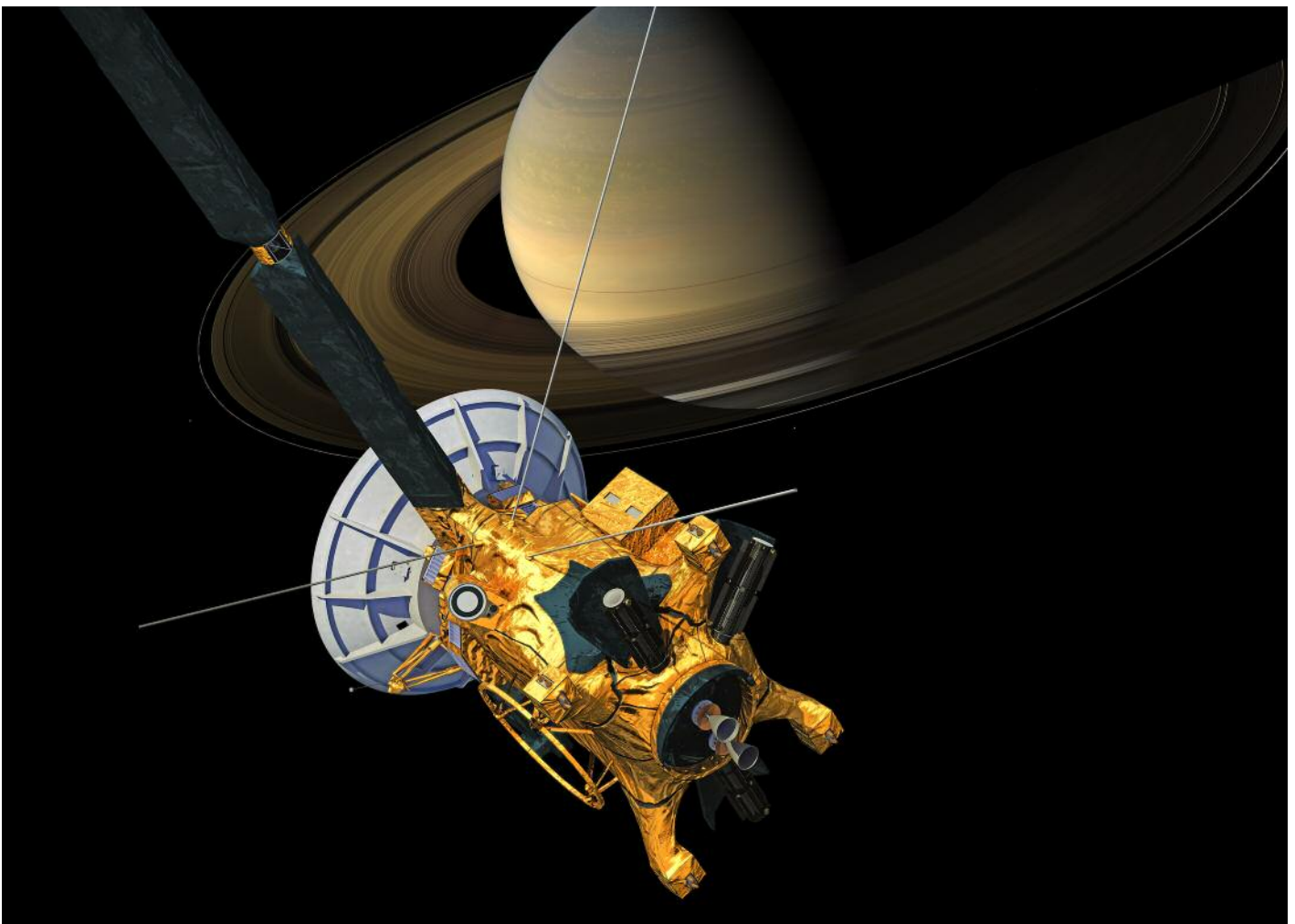
At Edinburgh, Tate has been running a MOOC in artificial intelligence planning alongside his colleague Gerhard Wickler. The intention of the course is to provide a foundation in the topic, which concerns itself with the execution of strategies and action plans by artificial intelligence – for example a robotic space probe acting out procedures on a deep space mission. Students have the opportunity to learn the basic algorithms used in robots to deliberate over which courses of action to take, with one week on the syllabus focusing on applications to space probes. For instance, if a rover on Mars encounters a large rock, can it decide whether to drive around it or over it without waiting for commands on Earth, which can slow the rover's progress? As well as teaching the student how to get to grips with the basics, Tate has included modules on planning for interstellar probes as part of a tie-in with I4IS.

The course ran for five weeks in January 2013 with a total of ten hours of material and the next course is scheduled to begin on 13 January 2014.

To learn more, visit <https://www.coursera.org/course/aipplan>.

Another Edinburgh MOOC potentially relevant to those interested in interstellar studies is a course given by Professor Charles Cockell on Astrobiology and the Search for Extraterrestrial Life. The course explores what is known about life's ability to live in extreme environments on Earth and how it might have originated. It looks at some of the missions to search for life in our own Solar System and on planets orbiting distant stars.

To learn more, visit www.coursera.org/course/astrobio.



The Cassini space probe at Saturn. Deep space probes could one day be able to make decisions themselves by using their artificial intelligence to critically examine and choose from a range of potential courses of action. Image: NASA/JPL-Caltech.

Going Interstellar at the Tennessee Valley Workshop

Scientists, engineers, journalists and interstellar enthusiasts converged on Huntsville in Alabama, United States, in February for the Tennessee Valley Interstellar Workshop, co-sponsored by I4IS. Here workshop organiser Les Johnson and Stephanie Osborn describe the discussions and presentations that took place at the four-day event.



Attentive attendees listen carefully and take notes during the various talks. Image: Kelvin F Long.

What began in Oak Ridge, Tennessee in 2011 as a gathering of like-minded Tennessee Valley scientists, engineers and space enthusiasts to discuss reasons, methods and challenges associated with interstellar travel became an international workshop on the subject in February 2013 with the advent of the Second Tennessee Valley Interstellar Workshop. Sixty-five people attended the four-day workshop, held this year in Huntsville, Alabama. It began on Sunday 3 February with a pre-workshop reception and culminated on Wednesday 6 February with a tour of the United Launch Alliance rocket factory in nearby Decatur, Alabama.

The theme of the workshop was 'Let's Get Started!', with a focus on near-term steps that can be taken now to jump-start future ultra-deep space exploration, development and interstellar travel. With this theme in mind, there were breakout sessions during the day and into the evening hours to strategise on this topic. The slate of presenters included an astronaut, engineers from NASA, private space companies and space advocacy groups, a neuroscientist examining what

we need to know about the human brain before we can undertake serious long-term space travel, a lawyer discussing the implications of developing the technology, an anthropologist speculating on the impacts that might result from contact with an extraterrestrial civilisation, and a high school student who may have inadvertently discovered a gamma-ray burst that formed a black hole – just to name a few.

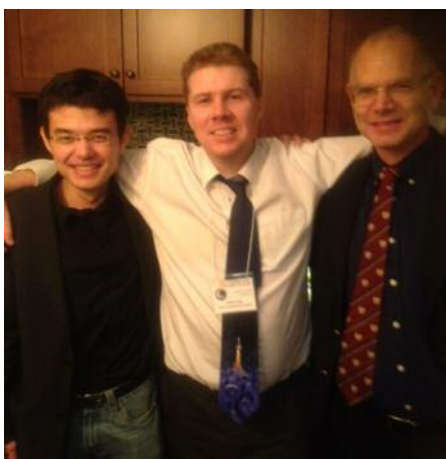
Highlights

It would be impossible to summarise each of the excellent papers presented in the workshop, so here instead is a sampling:

- Gerald Driggers, author of *The Earth-Mars Chronicles*, made the case that our first interstellar voyagers might not be natives of planet Earth, but instead the potentially genetically-engineered inhabitants of other planets within the Solar System – most likely Mars.
- Noted space blogger Paul Gilster built on this theme as he laid out his vision
- for humanity's expansion throughout the Solar System as a precursor step toward interstellar travel.
- Oak Ridge engineer Ken Roy proposed the next logical step in this theme of stepwise outward expansion by suggesting that we may use planets circling brown dwarf stars as future homes and way-stations to the stars.
- Retired NASA engineer Al Jackson postulated ways we might be able to detect alien civilisations travelling between the stars.
- Robert Kennedy envisioned a future where large 'Dyson Dots' block a fraction of the Sun's light incident upon the Earth to mitigate climate change and then use onboard photovoltaics to generate power – power that would then be beamed back to Earth to help run our future global civilisation.
- Kelvin F Long of the Institute for Interstellar Studies and Richard Obousy of Icarus Interstellar provided overviews of the many activities occurring in the field of interstellar



Speakers and attendees at the second Tennessee Valley International Workshop. Image: Les Johnson.



I4IS members in attendance at the Tennessee Valley Interstellar Workshop, from left to right: Andreas Hein, Kelvin F Long and Rob Swinney. Image: Kelvin F Long.

studies today, prompting one attendee to comment that we may be living in a new 'Golden Age' of interstellar exploration planning.

- Claudio Maccone, Technical Director for the International Academy of Astronautics, provided an overview of how future interstellar explorers might make use of stars' gravitational lensing properties to establish a galactic internet, allowing interstellar communication utilising systems of astonishingly low power.
- Former National Space Society Director, Gordon Woodcock, kept attendees on terra firma by reminding us that any future interstellar travel will be limited by the known laws of physics and engineering in his talk, called 'Interstellar Travel Without 'Magic.''



Astronaut Jan Davis was the keynote speaker, with workshop organiser Les Johnson looking on. Image: Kelvin F Long.

- Travis S Taylor, scientist and star of The National Geographic Channel's *Rocket City Rednecks*, sent participants off on an enthusiastic note by outlining what needs to be done to lay the groundwork for us to become an interstellar species, pointing out that it is well within our grasp to begin today – now – with current technologies.

Building towards a terawatt

In keeping with the gathering's workshop status (as opposed to a conference), attendees rolled up their sleeves in various working sessions to actually develop near- and mid-term plans for making the dream of interstellar exploration a reality. The outcome was the audacious goal of humanity generating a terawatt of power from space by 2050. The rationale behind this goal is based on the premise that if we are going to build a civilisation capable of sending spaceships to the stars, then we must be masters of our own Solar System, harnessing the energy from our parent star to not only power the Earth, but also our growing interplanetary presence. The one key component to all of the viable approaches to interstellar travel is the availability of tremendous energy and being able to generate a terawatt from space before mid-century seems to be a reachable goal.

Sponsors of the workshop included Baen Books, who are the publisher of the books *Going Interstellar* and *A New American Space Plan*; developers of the sun shield for the James Webb Space Telescope, Nexolve Corporation; the Ultimax Group; ORION Astronomy Club; the Huntsville, Alabama Chapter of the National Space Society; and the Institute for Interstellar Studies. Selected papers from the workshop will be published in a special edition of the *Journal of the British Interplanetary Society*.

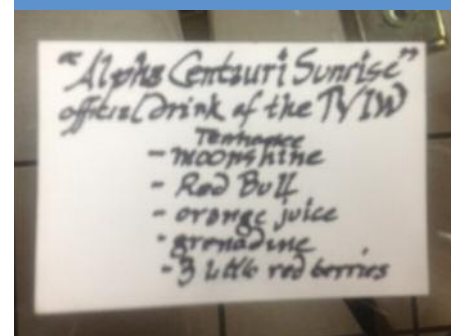
The third Tennessee Valley Interstellar Workshop won't be held for another 18–24 months but, in between on roughly eight-month intervals, there will be working

sessions to advance the goals outlined in the 2013 workshop so that serious progress can be reported at the next workshop.

You can learn more about the Tennessee Valley Interstellar Workshop at the event's website, http://lesjohnsonauthor.com/tn_valley_interstellar_workshop/tviw_2013.



Speaker Robert Kennedy makes Alpha Centauri Sunrise, the official drink of the Tennessee Valley Interstellar Workshop, made from one jigger of Tennessee moonshine, two jiggers of Red Bull, four to six ounces of orange juice, half a teaspoon of grenadine and three little red berries representing the three stars of the alpha Centauri system. It's best served in a martini glass or a champagne flute. Enjoy! Images: Kelvin F Long.



To keep up to date with the latest I4IS news, check out the Starship Log on the Institute's **Interstellar Index**

 <http://www.interstellarindex.com/blog/>

or follow the Institute on **Facebook**

 <http://www.facebook.com/InterstellarInstitute>

and **LinkedIn**

 http://www.linkedin.com/groups?home&gid=4640147&trk=anet_ug_hm

Icarus' Texan Gathering



Icarus Interstellar have announced the Icarus Interstellar Conference, to be held at the Hilton Anatole in Dallas, Texas, over 15–18 August 2013.

The four-day congress aims to bring together the interstellar community to foster discussion and generate tangible action towards the goal of moving humanity toward becoming an interstellar civilisation by the year 2100.

The event is organised around interstellar accomplishments over specific timescales, with each day featuring speakers focused on one of those time frames. The first day of the congress centres itself around the 'Interstellar Now', in particular what can feasibly be realised over the next 20 years, including interstellar precursor missions, exploration of the Solar System, fission-based energy generation, propulsion technology and the necessary social and economic factors that need to be in place to see humanity move towards becoming an interstellar civilisation.

The second day focuses on 'Interstellar This Lifetime', which covers 20–50 years from now, looking at the potential of fusion rockets, antimatter rockets, colonisation of the Solar System, asteroid mining and the commercialisation of space.

The third day is about our 'Interstellar Future', beyond 50 years and up to 500 years from now, looking at such topics as the exploration and colonisation of nearby star systems and beyond into the Galaxy, the ethics of colonisation, SETI and first

contact scenarios and exotic propulsion such as warp drives, wormholes and vacuum energy as well as slower worldships and sleeper ships. Finally, day four wraps up the congress with networking and planning opportunities.

"It's worth noting that we're running this conference at cost to make the event as accessible to everyone who wishes to participate," says Andreas Tziolas, who is Icarus Interstellar's Vice President and a Consultant for I4IS. "Presentations and papers are welcome from anyone. All approaches, be they a technical innovation, a programme plan, or a social endeavour are welcome here. We need to assess exactly where we are right now and coordinate efforts towards making humanity a star-fairing civilisation.

"This is a time of great change. We are taking deep space and interstellar space exploration into our own hands. We will not wait any longer to see the building blocks put into place because we do not need to wait any longer! This is the Maker Movement taken into space exploration. This is where gamers and game designers will build associations with scientists, engineers, artists and thinkers for building games that educate and inspire. Icarus Interstellar will not stop until it is done. And we know we have friends everywhere who will support this mission: to build a starship."

With speakers including scientists, physicists, engineers, researchers, science fiction celebrities and authors, and representatives from international space programmes and present-day commercial

space operators, as well as popular and well-known interstellar personalities and space journalists, the Icarus Interstellar Starship Congress is set to be one of the interstellar events of the year.

A follow-up summit meeting between the Project Icarus Design Team will take place at the British Interplanetary Society in London later in the year.

For more details visit www.icarusinterstellar.org.

Open hailing frequencies!

If you're interested in contributing to future issues of *Principium*, you can contact the editorial team via e-mail at principium@i4is.org. Or perhaps you're an I4IS team-member and would like your research featured in the newsletter – we'd also be delighted to hear from you.

Meanwhile, we would be fascinated to receive readers' correspondence on all matters interstellar, your thoughts on *Principium* and I4IS and your suggestions for future topics of discussion in these pages. We look forward to hearing from you!

The Editor reserves the right to edit or shorten letters.

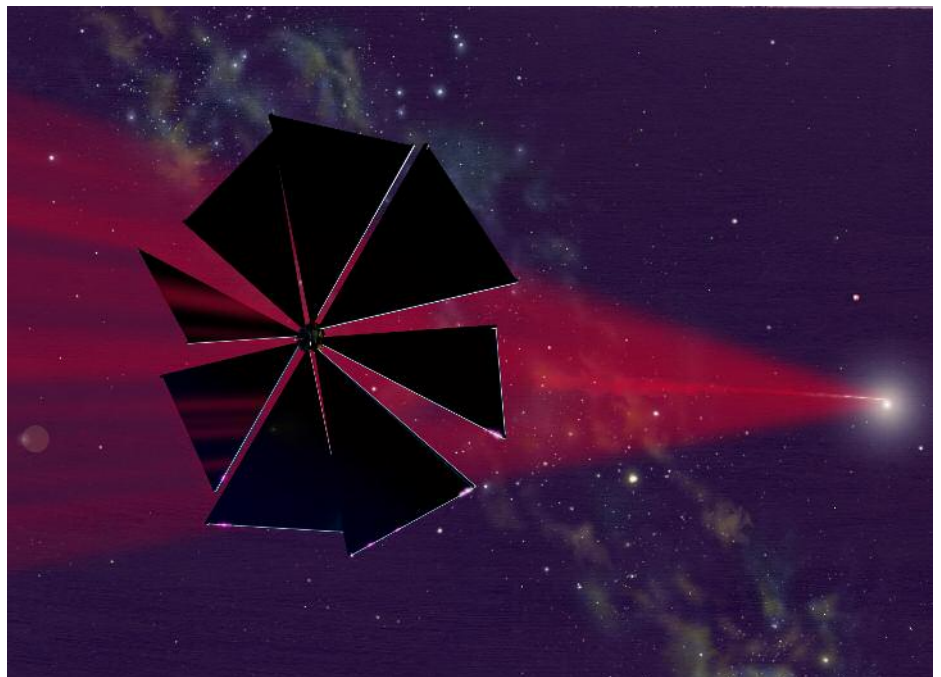
The DE-STAR: Riding laser beams to the stars

Could a new defensive system designed to vaporise hazardous asteroids be adapted to power interstellar spacecraft as well as solve the Earth's energy problems? That's the claim from a pair of Californian scientists who have developed DE-STAR, or Directed Energy Solar Targeting of Asteroids and exPloRation.

Think of a giant solar collector, ten kilometres across, in orbit or perhaps positioned in the L1 Lagrange point. Soaking up the solar photons, the collector's solar panels could generate 440 gigawatts of energy, converting it into a multitude of powerful laser beams or microwaves emitted from a phased array. This is DE-STAR and, say its inventors Professor Philip M Lubin of the University of California, Santa Barbara and Professor Gary B Hughes from California Polytechnic State University, its primary aim is to deflect or destroy incoming hazardous asteroids that could collide with Earth. However, the spin-offs from DE-STAR could go far beyond planetary protection.

Lubin and Hughes' announcement of the DE-STAR concept in February couldn't have been more timely; it was the same day that a meteor, 17 metres in diameter, exploded in an airburst 23 kilometres above the Russian city of Chelyabinsk. The 440 kiloton blast unleashed a shockwave that blew in windows, caused roofs to collapse and set car alarms wailing, injuring 1,491 people with flying glass in the process. It was to be a fateful 24 hours – that evening, a 45-metre asteroid named 2012 DA14 also flew within 28,000 kilometres of Earth, which is inside the ring of geostationary satellites.

With the potential danger of an asteroid impact back on people's minds, there has been much discussion on how to tackle the problem. Many strategies have been proposed to deal with them, such as attack with nuclear missiles, 'gravity tractors' that see the small gravitational pull of a spaceship parked next to the asteroid slowly pull it off course, or even painting the asteroid white or black to take advantage of sunlight either pushing it like a solar sail, or being absorbed and then re-emitted as heat in a different



An artist's impression of a lightsail, driven by laser beams shone from a phased array like DE-STAR. Image: Michael Carroll/The Planetary Society.

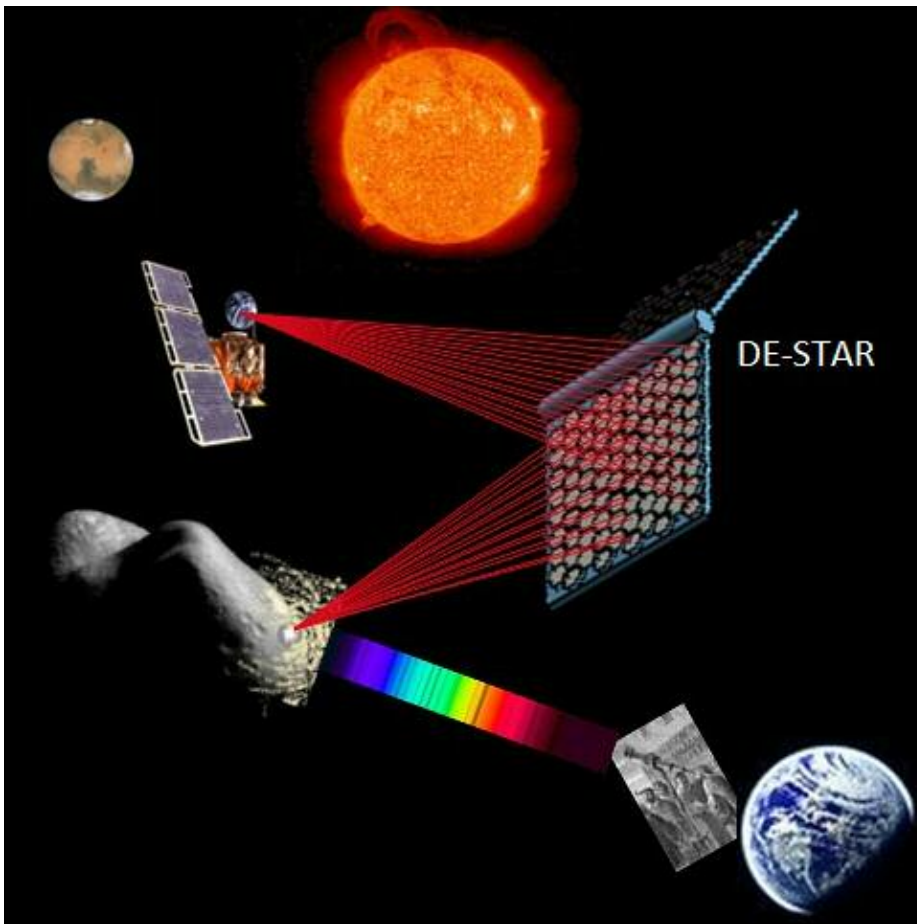
direction after the asteroid has rotated on its axis. This provides a thermal impulse providing enough power to heat the asteroid, causing a plume of evaporated material that helps push the asteroid from its hazardous orbit. The trouble is, all these strategies are either risky, uncertain of success or require decades of advanced warning.

For Lubin and Hughes, DE-STAR is a viable alternative that, once constructed, could act quickly and powerfully. With its phased array of laser beams targeted at a dangerous asteroid, it won't obliterate the asteroid instantly but, depending on the size of the DE-STAR system, could either nudge the asteroid thanks to the Yarkovsky effect or vaporise it entirely over the course of a year.

The different scales to which DE-STAR could be built will determine its power. For example, DE-STAR 2 would be a 100-

metre diameter system, providing enough power to take advantage of the Yarkovsky effect and heat the asteroid, causing it to drift off its hazardous orbit. Working to a scale formula where DE-STAR 'X' has a size of 10^X , DE-STAR 4 would therefore be bigger, 10^4 metres, or ten kilometres across. This could impart 5.8576×10^{15} joules per day onto a target asteroid, equivalent to unleashing the explosive force of 1.4 megatons onto the asteroid's surface on a daily basis. Over the duration of a year, this amount of energy could vaporise a 500-metre asteroid, whittling it down to virtually nothing, even from a distance of one astronomical unit (where one astronomical unit is the average distance between Earth and the Sun, 149.6 million kilometres).

That's great for saving the planet, but what does this have to do with interstellar travel? DE-STAR 4 is where things get



How DE-STAR could operate, absorbing sunlight and converting it into laser beams to both analyse an asteroid's composition and evaporate an asteroid on a collision course with Earth. Image: Philip M Lubin.

interesting, because now it is large enough to collect enough energy to do more than one thing. Diverting the focus of its beams, it could target more than one asteroid, and not always for defensive purposes but also for scientific knowledge, burning off a layer of an asteroid's surface and allowing telescopes on Earth or in orbit to make a spectral analysis of the vapour and determine the asteroid's composition – information that both scientists and asteroid prospectors would pay good money to get their hands on. DE-STAR could also switch to what Lubin calls the SPS, or Space Power System mode, in which it beams microwave energy rather than laser beams down to Earth, where collectors and transformers convert it into usable electrical energy.

"A DE-STAR 4 generates about 100 gigawatts of electrical power, or roughly the same as 100 nuclear power planets," says Lubin. "The average electrical use for 2011 in the United States was about 440 gigawatts, so this is about a quarter of the total US electrical generation. The United Kingdom uses a bit less than ten percent

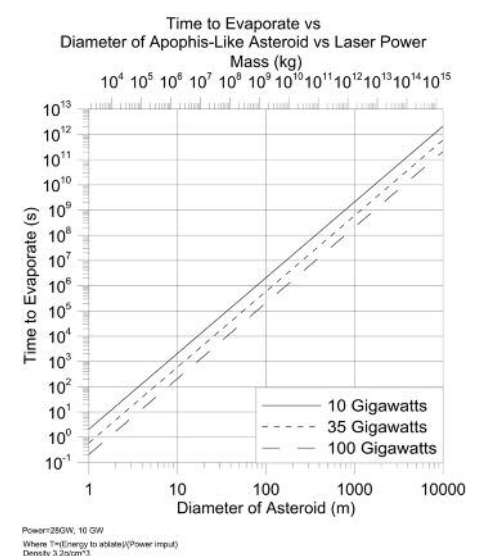
of the United States in terms of electrical energy, hence a DE-STAR 4 could provide more than twice the electrical energy needs of the UK."

Those are highly impressive figures but the power doesn't just have to be put to use obliterating asteroids or sating the enormous appetite for energy that we have here on Earth. DE-STAR 4 could also fire its beams towards interplanetary probes, giving them the energy required to propel them through the Solar System not in years, but in months or even days. Lubin claims that DE-STAR 4 could provide power to drive a 100 kilogram interplanetary probe to Mars in just three days, and a ten ton spacecraft to the red planet in just a month. If DE-STAR 4 can do that, what could a bigger system, say DE-STAR 6, do?

A thousand kilometres across, DE-STAR 6 could provide enough energy to accelerate a 10,000 kilogram spacecraft on an interstellar journey, accelerating at 50 G to close to the speed of light. Lubin describes this as a 'photon rail gun';

basically the photons slung towards the craft's reflector (think of a form of sail, catching the laser light like the wind) impart their momentum onto the craft as they strike it. 50G would be far too high an acceleration for a human crew to survive inside, which means the craft must either be robotic – which the first interstellar probes could very well be, perhaps as precursors to potential human missions – or by lowering the power the acceleration will be lessened, but even then the acceleration would likely be uncomfortable high if you actually wanted to get anywhere at a decent speed.

"Such a system would push the craft to very close to the speed of light – the final speed depends upon the reflector design on the spacecraft – but the travel time to the nearest stars as counted by a clock on Earth would be the equivalent number of light years to the star," Lubin tells *Principium*. So, a probe driven by DE-STAR 6 towards alpha Centauri, 4.3 light years away, would take about that time to reach it, from the point of view of mission control on Earth (in practice it would take a little longer, because of the acceleration phase and also because it will still be travelling less than the speed of light). For the probe, thanks to time dilation, the travel time would be even shorter. Of course, once the probe has got up to speed, slowing down and stopping would still be a problem. Nevertheless, similar concepts have been published previously, perhaps most notably by physicist and science fiction author Robert Forward,



How long it would take to evaporate an asteroid, depending upon the energy of the beam and the mass and diameter of the asteroid. Image: Philip M Lubin.

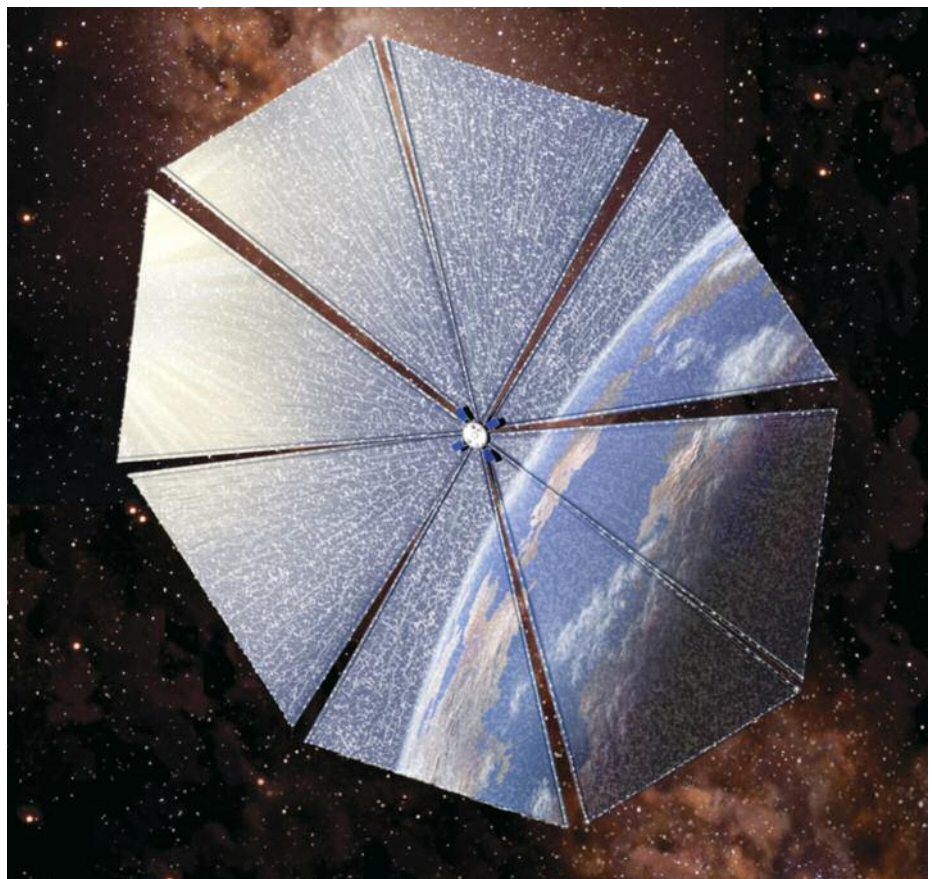
who developed ideas such as a laser-pushed 'lightsail', as well as Starwisp, which was effectively the same thing but using a microwave beam instead. Although the beams would disperse over interstellar distances, a large enough phased array should negate the need for any intervening optics such as a lens.

The DE-STAR concept certainly sounds incredible, but it is within reach of our growing ambitions in space. Recently companies such as Planetary Resources and Deep Space Industries have announced their intention to prospect and mine asteroids, ultimately using the material in conjunction with 3D printers to construct communications and energy platforms in the coming decades. Meanwhile, at the Tennessee Valley Interstellar Workshop this February, the attendees concluded that aiming to produce a terawatt of energy from power stations in space by 2050 was a viable, if ambitious, aim. Meanwhile, various space agencies such as NASA and JAXA are experimenting with solar sails, as are private organisations such as the Planetary Society. It may be that a convergence of these technologies may provide an opportunity for interstellar travel in the future.

"This is a futuristic system but requires no new physics," says Lubin. "A DE-STAR 6 is not a practical system for humanity at its current state of technological advancement but may be in the future. The reason we mentioned a DE-STAR 6 was to show that it is a possible path to interstellar travel."

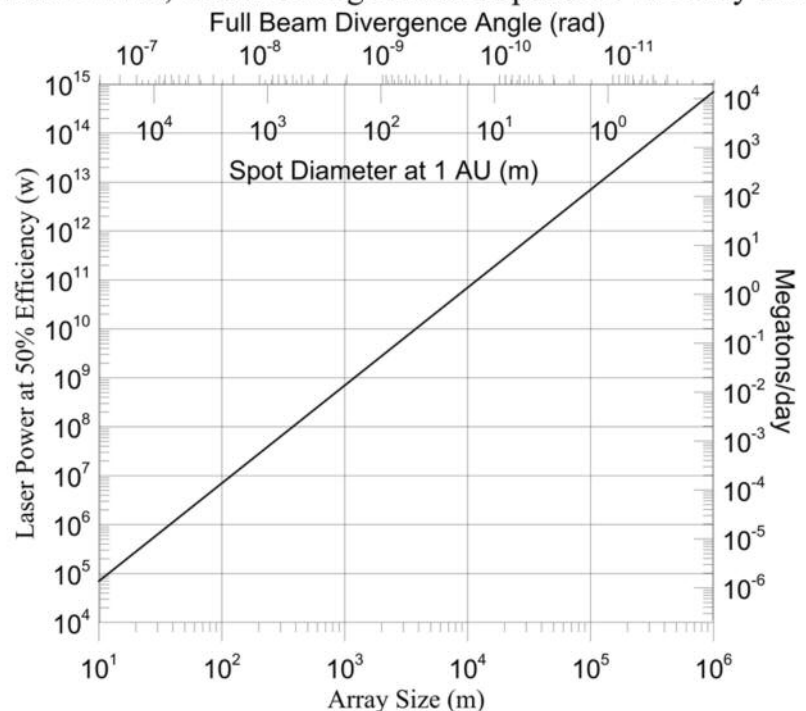
So could DE-STAR be pushing probes around the planets and towards the stars within the next fifty years?

"This system is not some far-out idea," added Lubin's colleague, Gary Hughes, in a press release on the subject. "All the components of this system pretty much exist today – maybe not quite at the scale we need and scaling it up would be a challenge, but the basic elements are all there and ready to go. We just need to put them into a larger system to be effective and, once the system is there, it can do so many things."



An artist's impression of a lightsail, driven by laser beams shone from a phased array like DE-STAR. Image: Michael Carroll/The Planetary Society.

Laser Power, Beam Divergence and Spot Size vs Array Size



This graph illustrates the amount of dispersion (the spot diameter) at one astronomical unit versus the array size, as well as the laser power and amount of energy delivered to the target per day. Image: Philip M Lubin.

A Living Ship to the Stars

A world first! Legendary space artist Jon Lomberg tells the epic story of a worldship travelling to the stars over the course of a million years of future history, through his new series of starship art. Here he tells us about the background behind his imaginative starship design as we exclusively present Jon's amazing artwork.

To be a successful space artist, you've got to be able to think big. Planets, nebulae, even whole galaxies with starships rocketing to and fro amongst them demand a large canvas and a big imagination to boot.

"My mind is a little bit more of a poet than an engineer," admits space artist extraordinaire Jon Lomberg (jonlomberg.com), whose work has been recognised by organisations as significant as NASA and the Smithsonian Museum, and watched by over 500 million people on the television series *Cosmos*, for which he has also received a prestigious Emmy Award. "I've always been drawn to thinking about the big vision, the far future, the ultimate destiny, those kinds of things a little bit more than the nuts and bolts stuff."

That far-seeing vision is no more evident than in Lomberg's latest artistic project, a twelve piece extravaganza depicting a worldship embarking on a voyage that takes us through a million years of future history. A project four decades in the making, mixing traditional paintings and silkscreen printing with modern digital imagery, its origin dates back to early 1970s Canada, where he worked with science fiction author Judith Merrill who had donated a grand collection of science fiction to the Toronto Public Library (the collection is now named the Merrill Collection in her honour and constitutes over 72,000 items). Whilst there, Lomberg charted the intertwined stories of SF author Cordwainer Smith [real name Paul Linebarger – his day job was an analyst



The artist in question at the 'Galaxy Garden' that he designed in Hawaii. Image: © Jon Lomberg.

at the Central Intelligence Agency] and how his works of fiction related to one another, when he was struck in particular by Smith's description of one of the immense feats of engineering described in the novels.

"Cordwainer Smith created this world of the far future with technologies that are almost magic as far as we're concerned," says Lomberg. "I describe it as if Lewis Carroll had written 'Tales of 14,000AD'. And [Smith] has this mammoth launch facility called Earthport, where the idea was that you wanted to separate the ships from the ground, so it was up on this enormous pedestal that was like a city."

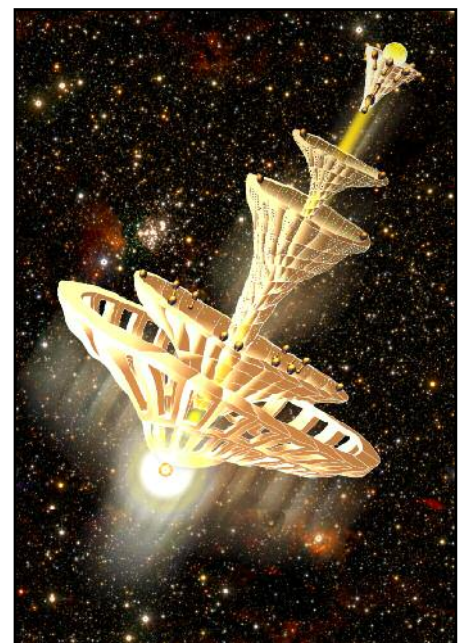
Earthport represents one of those giant 'mega-structures', like Dyson spheres, Matrioshka brains and grand O'Neill stations, which frequently populate science fiction, embodying our hopes for a prosperous and technological future for humanity, endowed in a fragrance of awe and even a little mystery as we wonder how such enormous feats of engineering could possibly be achieved.

"Tommy (Thomas) Gold, who worked with Carl Sagan at Cornell University and was a brilliant physicist, doing all kinds of incredible things, said we've underestimated the role of really big engineering in the future, things that are colossally large," Lomberg tells *Principium*. "These can be somehow combined with the colossally small, through nanotechnology. I imagine that some of the starships I've painted are grown rather than built."

Lomberg made his first sketch of Earthport while in Toronto and now, four decades later, he has revisited it as a stopping off point for one of the most unusual starships that you may encounter. Riffing off the idea that starships could somehow be biological rather than nuts and bolts, Lomberg took inspiration from one of the greats of classic science fiction, Olaf Stapledon.

"I was very influenced by Stapledon's vision and a cover of [his novel] *Star Maker* that I had was a drawing, a biological illustration of a similar structure to what I ended up drawing," says Lomberg. From this came Lomberg's idea of an organic, polyp-like 'petal ship', a vast multi-generational worldship that could carry a sampling of humanity to the stars.

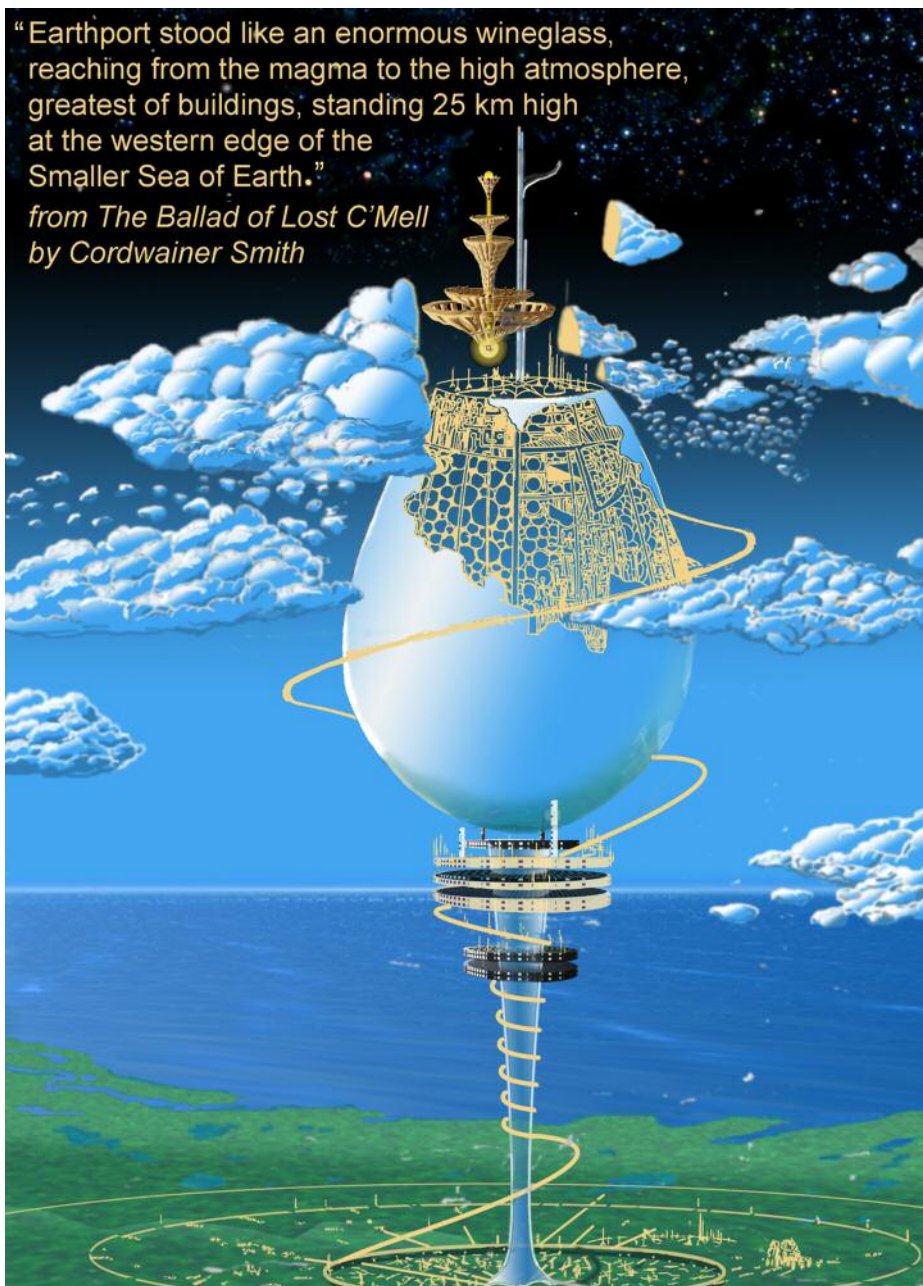
Melding these influences together into a kind of cosmic tapestry of future history, Lomberg's starship art depicts



The petal ship, its engine ablaze, in all its glory. Image: © Jon Lomberg.

“Earthport stood like an enormous wineglass, reaching from the magma to the high atmosphere, greatest of buildings, standing 25 km high at the western edge of the Smaller Sea of Earth.”

from *The Ballad of Lost C'Mell*
by Cordwainer Smith



A starship wanders into the universe of Cordwainer Smith, 14,000 years from now – the time of the ‘Underpeople’, the Instrumentality of Mankind, and Earthport.
Image: © Jon Lomberg.

one of his Stapledon-inspired biological petal-ships departing a massive wine glass-shaped ‘Earthport’ and setting course for the stars, where it finds its ultimate destiny out in the Universe.

Living starships

Organic ships sound bizarre but, intriguingly, it is a relatively old and plausible concept, an idea dating back to 1972 and physicist Freeman Dyson’s ‘Big Trees’, which he speculated could result in the “greening of the Galaxy” by bioengineering. The idea forms the basis of ‘treeships’; a comet tree, grown on one of those icy balls of flotsam and jetsam that lurk in the outer Solar System. “There you have a comet nucleus, a cubic mile of ice, and you genetically engineer these trees that can

exist in a vacuum and grow out of the comet for miles,” imagines Lomberg. “And the crew live in the trees. That becomes their ship.”

Lomberg’s treeship art has appeared in Carl Sagan and Ann Druyan’s book *Comet* and the idea of treeships has also been picked up by science fiction writers, including Dan Simmons in his novel *Hyperion*. Meanwhile, biological starships of one form or another have appeared in Peter F Hamilton’s *Night’s Dawn Trilogy*, while on television *Star Trek: The Next Generation*’s ‘Tin Man’ was a living ship, as were the vessels belonging to the Vorlons and Shadows in *Babylon 5*.

So what would life be like on an organic, growing starship? Lomberg’s petal-ship, topped by a petal like the

torchships in Robert A. Heinlein’s *Time For the Stars*, is divided into six petals along a central stem, with each petal playing a separate role. For instance, the first petal is actually the bud at the forefront of the stem, housing the main computer, drive control and guidance crew. The second petal houses shuttlecraft, workshops, laboratories and equipment for landing and possibly terraforming any worlds the ship comes across. The next three petals are habitation modules, starting with standard living accommodation in the third petal, an agricultural base of farmland, woodland and lakes underneath artificial sunlight in the fourth petal and an untamed wilderness inhabited by wild animals in the large fifth petal. The final petal controls the ship’s life support systems and the main engine drive. Each petal forms part of the ship’s consciousness – on some level, it is aware.

“I tried to come up with the kind of architectural space that humans would need in order to stay sane if they are in there for generations,” says Lomberg. “What experiences would they crave? They’d need a diversity of experience and that, I think, would be the real challenge. I was trying to design a space that could be carved up in a way so that the interior space seemed very large – mile after mile that you could roam, where different parts of the ship had very different character.”

A journey

The idea behind the wilderness petal is to provide some degree of unpredictability for the travellers trapped onboard, a place where stories and myths could be woven. “I thought you need some area of wildness, because it is kind of a paradox: you’re making this starship to explore new worlds but you’re condemning a few generations in it to live in an extremely confined and limited world,” explains Lomberg, who goes on to describe how the hero’s journey in Joseph Campbell’s *The Hero With a Thousand Faces* plays into perpetuating a healthy society. “How do you keep alive their need for the heroic journeys and the obstacles that need to be surmounted? So there are two narratives in the piece that shows a diagram of the wilderness petal (see page 14): one is what happens to a person as he goes from place to place in this wilderness, but then underneath this is the technology that supports it all.”

Next page: a blueprint of Jon Lomberg’s living worldship.
Image: © Jon Lomberg.

GUIDANCE First Petal "the Bud"
 Nexus. Drive control. Non-entropic guidance system. Main Computer (with extensions throughout ship) Brain of ship's nervous system. Simulacron of Life-, Mind-, and ship-support systems. Info Central. R&D on ship as feedback modified cyborg.
RATIONAL CONSCIOUSNESS

EXPLORATION Second Petal

Berths of scouts, orbiters, landing craft mobile labs, ancillary craft of planetfall. Environmental modification equipment for any Terra-type planet. Labs and shops in physical, biological, and non-material sciences. Simulated alien environments. Weaponry.
BODY CONSCIOUSNESS

CITY Third Petal

Complex of modular social areas: dwellings, markets, arenas, museums, hospitals, schools, free-form environments. Extensive hydroponics. Media. Government
HIVE CONSCIOUSNESS

ARCADY Fourth Petal

Ecology of food chains. Extensive soil farms. Domestic animals. Light woods. Hills. Lakes. Villages. Mingling of food productive activity with psychology. Pre-industrial culture. Gentle weather. A kind of slippery tranquility.
LAND CONSCIOUSNESS

STARSHIP

Demands of stellar ballistics and social engineering evolved the design for the Ship/Hive. The Ship-- a vehicle to carry crew-culture of 10,000. The Hive- an imprint of Terran technological/artistic matrix, open-ended for cultural evolution as it would blossom and change in generations of star travel.

WILDERNESS Fifth Petal

Ecology of the Unknown. Many plant and animal species. Modules of desert, cold mountain, deep forest Death. Bright eyes at night, dark shapes in the water. Fairyland beauty in castles and summer. Golden caves where Elves have left word. Xanadu. Strawberry Fields.
CELLULAR CONSCIOUSNESS

MACHINE Sixth Petal

Ship's life support systems. Ship's stores. Factories, automated production. Ship maintenance. Cold Sleep rooms. Fusion pile. Drive housing. Main Drive.
SHIP CONSCIOUSNESS

LABRIAN TANTRONIC DRIVE

Housed between fifth and sixth petals (shown descended) Drive-core shaft linked entire ship together, as the Center, the White Light, the Tao. Reverse entropy. Speed surpasses light. Om.

AXIOM: Ship space and Hive life must seem boundless. Explorers need Far Horizons. Always a new corner to turn. Hence six separate Petals. The diversity of the Petals insures a maximum variety of experience for the crew.



Empire State Building

© JON LOMBERG

Throughout his career Lomborg has been able to flex his talent for depicting epic vistas on the grandest of scales, from spacecraft voyaging to the edge of our Solar System to starship art and a tale of future history, one which we will continue in subsequent issues of *Principium* as we feature more of Jon's art. But while his art tells a story of a hopeful future for humankind, deep down Lomborg is less optimistic about our future than he once was. On the one hand we have the evolutionary trajectory of an Olaf Stapledon or Arthur C Clarke-type future that shows the potential of humanity to grow into a 'higher' kind of being, whether that be technologically or altruistically. "Yet if you look at the world today there's not a lot of reasons to be optimistic. Will we be here as a civilisation in a hundred years, or a thousand years, or ten thousand years?" Lomborg asks rhetorically. "I'd say if we're here in a thousand years then we'll be here for ten thousand."

Next month we will explore Lomborg's work on the famous golden records of sounds, words and images from Earth that now fly on the departing Voyager 1 and 2 probes. Then in issue six we'll tie things up with a retrospective look at how Lomborg got his big break when he met Carl Sagan

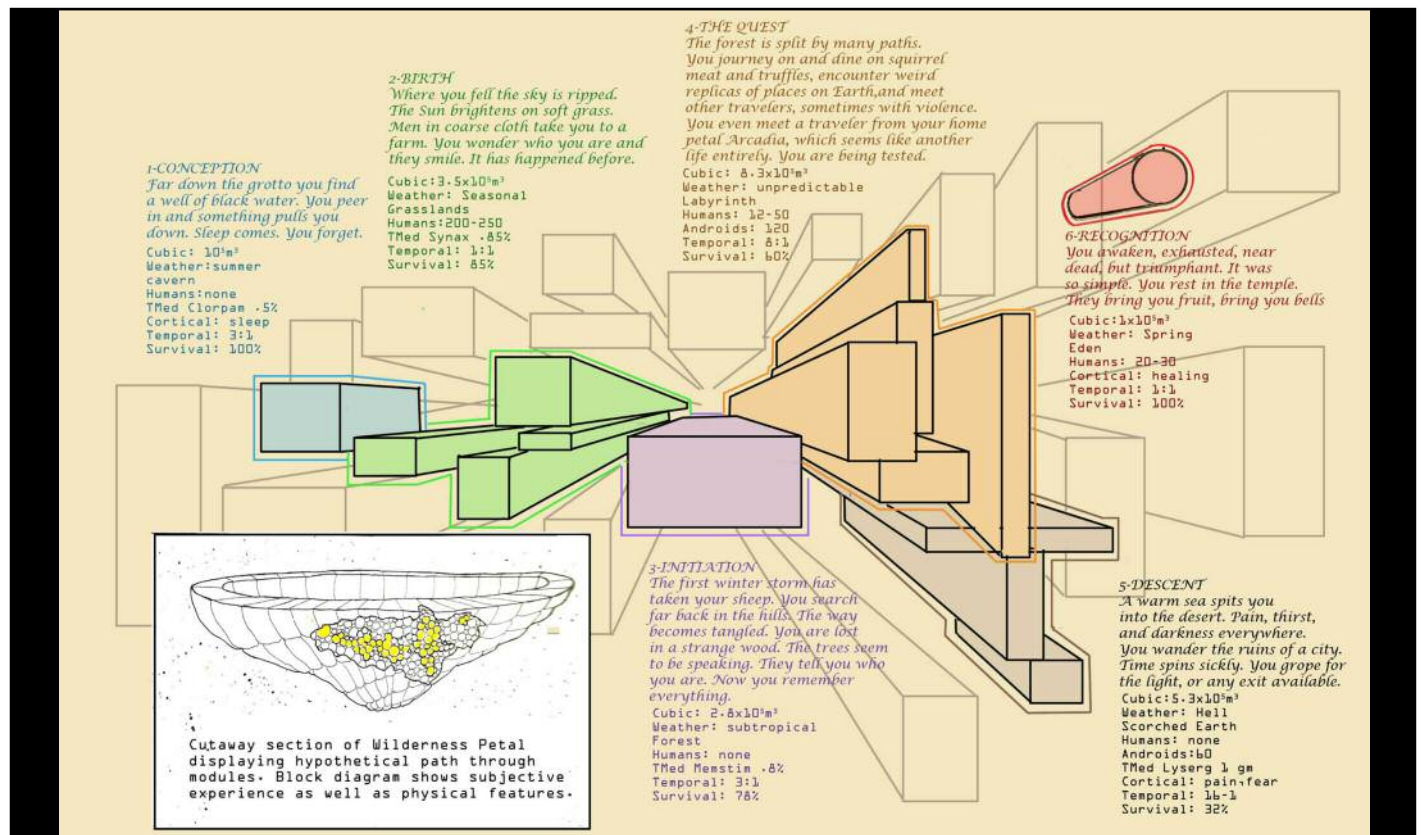
and subsequently served as Art Director on the 13-part PBS documentary *Cosmos*, for which Lomborg won his prestigious Emmy Award. Plus we'll feature more of his epic series of starship art.

Keep reading!

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Order signed prints of this artwork at
http://www.jonlomborg.com/ss_gallery1.html



A petal ship – a vast worldship – being assembled in orbit. Image: © Jon Lomborg.

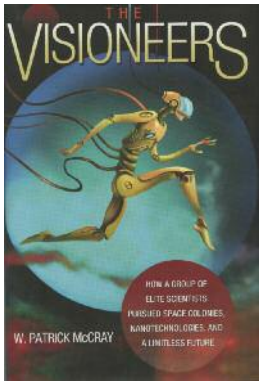


A cross-section of the petal ship's wilderness petal, with twin narratives: one describing what happens to a person as they go from place to place in this wilderness, and then beneath that a description of the technology that underlies it all, monitoring the adventurer's bio-signs. "Essentially it gives somebody in the starship the opportunity to have something like a heroic journey, where there is risk, where there is danger, where it is unknown and where they could get killed," says Jon Lomborg. Image: © Jon Lomborg.

Reviews

The Visioneers

Author: W Patrick McCray



The Visioneers is principally the story of two men. One of them is Gerard O'Neill, the Princeton physicist who during the 1970s promoted the concept of space colonies, succinctly described in his book *The High Frontier*. The other is Eric Drexler, O'Neill's former acolyte who, from being a student at the Massachusetts Institute for Technology, proceeded to become one of the world's leading figures in the arena of nanotechnology, thanks also to his own book, *Engines of Creation*.

Author W Patrick McCray, a professor of history at the University of California, Santa Barbara, skillfully tells their story within the context of the era of the Club of Rome's flawed *Limits to Growth*, which came amidst the growing accessibility of new technology to the public in the 1970s and 1980s. As new ideas began to percolate into the popular culture and find a new and eager audience of dedicated supporters, for a time anything seemed possible. And at the heart of it all were people like O'Neill and Drexler, who scorned the doom-laden assessments of *Limits to Growth* and developed their own visions for a brighter, better, limitless future.

Hence the title of the book. To McCray, a 'visioneer' is a combination of visionary



Gerard O'Neill discussing a 'mass driver' prototype (seen in the foreground) with his students. Image: NASA.

and engineer, someone who not only has big ideas but also the technical know-how to turn their ideas into reality. "Visioneering certainly embraces a probing and exploratory approach to design as technically fluent experts speculate as to what *can* be built," he writes on page 152. "Yet visioneering also involves the popularisation of ideas, the construction of networks of supporters and the cultivation of patrons." McCray successfully argues that it is these qualities, which he sees in both O'Neill and Drexler, that are necessary to nudge society towards an appreciation and ultimately realisation of their visions.

What is most interesting is the parallel this reviewer sees with those physicists and engineers who today are pushing for an interstellar future, producing design concepts for starships or working on ideas for new forms of propulsion. Whereas O'Neill and Drexler were the visioneers of yesterday, those interstellar researchers are the visioneers of

tomorrow. There is much to be learnt from McCray's analysis of O'Neill and Drexler's visions. For sure, we're no closer to building space colonies now than we were in the 1970s and, in hindsight, was it naive to think that millions of people could be living in space by the 1990s? However, the failure to build O'Neill colonies – most famously depicted as giant metal cylinders with towns and landscapes on their inner hull, affixed to the ground through centrifugal force as the cylinders rotate – wasn't a failure of O'Neill's technical concepts or vision, but a failure of political and economic will. Often a visioneer's dreams fall outside of the mainstream and convincing people in power whose focus is on the things here and now that they can comprehend can often be difficult.

Nevertheless, during the 1970s O'Neill was one of the scientific stars of the United States, rivalling Carl Sagan's popularity and appearing on prime time television talk shows, magazine cover stories and newspaper front pages. How O'Neill dealt with the popularity of his ideas perhaps shows a flaw in his status as a visioneer. O'Neill was somewhat wary of the fervour that his ideas fostered and of the people on the edge of society – in this case most notably Timothy Leary – that they would attract. By comparison, today our interstellar visions are operating under the radar, but one day when popularism does come it is something that our visioneers of tomorrow will need to be aware of, accept and deal with accordingly.

The Visioneers is exceptionally well researched and written, at times providing a gripping narrative and insight into the work of these two men and the people around them, and how that work was marketed and assessed. It is surely already a candidate for science book of the year and there is much that we can learn from O'Neill's and Drexler's stories. A must read.

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Find this book on Amazon via our [Interstellar Index website](#).



An artist's impression of an O'Neill space colony. Image: NASA.

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The mission of the Institute for Interstellar Studies is to foster and promote education, knowledge and technical capabilities which lead to designs, technologies or enterprise that will enable the construction and launch of interstellar spacecraft.

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We aspire towards an optimistic future for humans on Earth and in space. Our bold vision is to be an organisation that is central to catalysing the conditions in society over the next century to enable robotic and human exploration of the frontier beyond our Solar System and to other stars, as part of a long-term enduring strategy and towards a sustainable space-based economy.

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To demonstrate inspiring leadership and ethical governance, to initiate visionary and bold programmes co-operating with partners inclusively, to be objective in our assessments yet keeping an open mind to alternative solutions, acting with honesty, integrity and scientific rigour.

The open star cluster NGC 2547. In the foreground are hot, young blue stars within our own Galaxy, stars that may one day be explored by our interstellar descendants. In the background are faint, distant galaxies beyond our own – forever out of reach? Image: ESO.

We'd love to hear from you, our readers, about your thoughts on Principium, the Institute or interstellar flight in general.

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Editor: Keith Cooper
Layout: Adrian Mann

The Institute For Interstellar Studies is a pending institute in foundational start-up phase subject to incorporation in the United Kingdom

