PRINCIPIUM

The Newsletter of the Institute for Interstellar Studies™

Issue 6 | Starship Congress Special Issue

Scientia ad sidera

Knowledge to the Stars

www.I4IS.org

Greetings from I4IS

Welcome to this special issue of *Principium* to coincide with the first Starship Congress, organised by Icarus Interstellar. For those of you yet to come across *Principium*, we are the official magazine newsletter of the Institute for Interstellar Studies (I4IS), about which you can discover more in Kelvin F Long's article on the following page. That, as well as the other articles in this issue, provide an overview of the varied and exciting work that we are conducting at I4IS, from technical projects on laser sailing to our educational academy, as well as numerous outreach activities including the I4IS smart-phone app and the superb music of The Light Dreams, a.k.a Alex Storer. You will find articles on all of these in this issue, plus promotional material for our upcoming book, *Beyond the Boundary*, which sports chapters on a diverse number of interstellar topics written by I4IS members. As you can imagine, it is all systems go at I4IS HQ and we're not stopping anytime soon!

During the Starship Congress we'll have a heavy presence, with several of our members and consultants including Kelvin F Long, Andreas Hein, James Benford and Ken Roy giving talks. Our team at the Congress will be delighted to speak to you, so if you have any questions, suggestions or ideas for I4IS, or just want to say hello, feel free to grab any of our crew.

I would also like to make a few thank you notes, first to Icarus Interstellar for their hard work organising such a wonderful meeting for the interstellar community and allowing us to be here in Dallas. Secondly, to the British Interplanetary Society whose unswerving support has helped I4IS continue to grow and prosper (and I should also take a moment to congratulate Reaction Engines Ltd on their award of £65 million from the UK Government to invest in their revolutionary SABRE engine for the SKYLON spaceplane, which will hopefully one day make space accessible to all). Finally, I'd like to thank all our members and all those in the community who have supported I4IS over the past twelve months and helped put us on the interstellar map. We would not be here without you.

So here's to an excellent Congress and to our future as a prosperous, peaceful, space-faring civilisation. To the stars!

Keith Cooper

Editor, *Principium*

I4IS twelve months on: what have we accomplished?

It has been an exciting and eventful year for I4IS as we work towards incorporation. Executive Director Kelvin F Long looks at how I4IS has been putting itself on the interstellar map.

Kelvin F Long, Director I4IS

It seems timely to reflect on where we are with founding the Institute for Interstellar Studies (I4IS) since work started in August of last year, although the Institute formerly went live on 13 September 2012. You can see our mission and vision statements on the back cover of this issue and with positive optimism our team is focused on the interstellar goal. Let us think about what has been achieved and where we are going.

The formation of the world's first Institute for Interstellar Studies is an ambitious undertaking. This is made especially difficult starting from a position of zero capital. Instead, the team are required to move forward based on their ideas, access to online technological tools and the resources of willing and enthusiastic volunteers.

The Institute currently has around 80 people involved in some capacity, as either pending Directors, Senior Advisory Council Members, Consultants, Senior Researchers, Researchers and Technicians. We have a main web site (www.I4IS.org) built by Adrian Mann and a sister web site (www.interstellarindex.com) built by myself and maintained by Stephen Ashworth, which in the future we will seek to integrate. The Interstellar Index in particular is the first ever global electronic archive of interstellar related material and it currently contains the listings for hundreds of published papers. The team occasionally also blogs on this site via 'The Starship Log' and we have plans to upgrade this output going forward.

Our front-face activity is our popular community newsletter, *Principium*. This is edited by Keith Cooper and produced by Adrian Mann. It is the world's first ever dedicated interstellar publication and we are very proud to bring news of our community's activities, whilst also educating and inspiring the public. This is our sixth issue and we hope you agree it looks amazing.

With this issue, we have also launched our very own iPhone app (search for 'I4IS' on the Apple Store). This is thanks to the sterling efforts of Jeremy Clark. We plan to continue to upgrade this app and it has the purpose of educating people about space exploration, including teaching you how to do space related calculations. See page 9 for more.

We are very lucky to have several honorary space artists involved with I4IS. This includes the world-renowned David Hardy and Jon Lomberg, whose work we have recently exhibited in *Principium*. We continue to work with them on various opportunities. Meanwhile, one of our younger space artists and our official Honorary Interstellar Musician is composer Alex Storer who has produced in association with I4IS an interstellar-themed music album called *Future Worlds* (see page 13 for more) and he has many more planned.

Core team

We have formed our own Board of (pending) Directors and we have an excellent team who all work together at regular meetings. This includes myself, George Abbey Jnr, Rob Swinney, Keith Cooper, Jeremy Clark, Pamela Menges, Adrian Mann, Andreas Hein and Robert Kennedy III. Our Board of Directors are working towards a set of six priorities and 30 sub-goals to be achieved in the first 15 months of start-up. We also have a Senior Advisory Council, chaired by interstellar pioneer Dr Gregory Matloff. All of this team and many from the wider Institute were involved in writing our mission, vision and values statements and we operate in a transparent and ethical way. There was also a core team discussion which led to the design of our logo and motto, "knowledge to the stars".

The team has held many virtual and physical meetings to discuss our progress and strategies for the future. We also recently hosted our very own one-day symposium in London at the headquarters of the British Interplanetary Society. The event, titled 'The Philosophy of the Starship', is reported in this issue (page 17) and featured a nice collection of presentations. We plan to repeat this event in future years and the symposium has led to several technical academic papers and along with others they are in transit for submission and production. At I4IS we recognise the importance of peer reviewed publications.

We have our own bank accounts and our own legal team. Our board has also been involved with creating our founding documents, including writing our own Memorandum of Association and developing many of our own policy statements and activities led by myself, Rob Swinney and Stephen Ashworth with crucial input from the respected astronomer Professor Ian Crawford. These are all essential activities ahead of full incorporation, in order to set up a robust structure that can survive the tests of time, the temptations of distractions and the potential for competing philosophical goals.

The three arms

The organisation itself has been set up with three arms. There is the Educational Academy to foster education

and capabilities. There is the Technical Developments arm that manages the technical programmes and then there is the Enterprise arm that manages any spin-off opportunities, products or other outputs. The organisation and its personnel are structured around these three arms. We aim to facilitate education and research across the Science, Technology, Engineering and Mathematics (STEM) fields, but also in other areas too. In particular, we embrace the role of the arts.

The team have also been busy giving presentations around the world, including to the NASA Glenn Research Centre in Ohio, the NASA Marshall Spaceflight Centre in Huntsville and the International Space University in Strasbourg. To date the team has given a total of seventeen presentations and these were by myself, Stephen Ashworth, Chris Welch, Divya Shankar, Rob Swinney, Keith Cooper, Ian Crawford, Martin Ciupa and Gregory Matloff; A big thank you to all those people so far. We have attended several conferences and we were participants and sponsors to the outstanding 2013 Tennessee Valley Interstellar Workshop, an activity led by Les Johnson. Currently we are supporting the Icarus Interstellar Starship Congress in Dallas, Texas to help make that the best event it can be. We are confident that the Icarus Interstellar team will do an outstanding job in representing the wider interests of our interstellar community, whilst also facilitating activities that contribute to their own mission of achieving interstellar flight by the year 2100. The Icarus Interstellar Vice President Andreas Tziolas is one of our own Consultants and we are proud to have him on board.

I4IS involves people from across the globe. We are proud to have representatives from England, Scotland, the United States, India, Australia, France, Hungary, Germany, Italy, Uganda and Ecuador. We aspire to broaden our outreach to people from every continent on Earth. Given more resources we would like to connect all these people and we made a start in 2012 by helping to sponsor a student from India to attend the United States for the first time.

The Institute has also been featured or quoted in several press publications, including *Astronomy Now*, *Spaceflight*, *All About Space* and *The Times* newspaper. At I4IS we believe it is important to work

> ***Keep faith to the heart and wisdom to the mind, because some day our distant star-wandering cousins will look back on our bold attempts***

with the media in helping to communicate the positive vision of the stars, whilst educating the public to the challenges ahead. As well as writing dozens of our own blog articles we have also had articles appear on other sites such as *Motherboard* and *Centauri Dreams*; a big shout out to Paul Gilster who continues to be a staunch supporter of the entire interstellar community.

Interstellar students

Our Educational Academy is also up and running under the leadership of Rob Swinney. We have recently helped to organise and supervise four MSc students on interstellar-themed technical projects at the International Space University under the outstanding guidance of Professor Chris Welsh, who is also our Senior Advisory Council Deputy Chairman (see *Principium* issue three). These were on deceleration options for interstellar missions, the design of a FOCAL point solar sail mission, the design of an interstellar solar sail mission and finally the design of an agricultural space habitat. One of these students is currently being presented with a 500 euro award from I4IS for the best project. Our relationship with the ISU continues with future plans underway.

We have also launched many technical projects under the leadership of Andreas Hein, all of which are on-going research. This includes Project SENTINEL (a theoretical study of starship emissions – see *Principium* issue five), Project CATSTAR (using CubeSat architecture to demonstrate interstellar technologies – see *Principium* issue one), Project OAKTREE (a data capture exercise on the nearest 20 light year stars – learn more in Ian Crawford's article in issue two) and many others. Our biggest activity currently is the production of our own interstellar book entitled *Beyond the Boundary: Seeking Interstellar Destinations*, which is available for pre-orders (see page 16 of this issue). We also continue to support the excellent *Starship Century* book, an activity led by our own consultant James Benford (see page 25 for further information).

Looking to the future

Our latest exciting announcement is Project Dragonfly, a laser-sail powered starship project (see page 22). As for the mid-term, we have lots of exciting things planned. Next year we will be organising some more of our own dedicated interstellar events but we will also be contributing to others, including the World Science Fiction Convention in London during August 2014 where we will have a strong presence. We also continue to look at several opportunities to enable us to someday have our own facility from which to manage our global activities and where we can warmly invite people to come and share in our excitement about the stars. Currently our address is the home of the British Interplanetary Society and this is our opportunity to say thank you to them for their continued support, particularly the President Alistair Scott and the Executive Secretary Suszann Parry. There is something appropriate about the idea of the world's oldest space organisation (80 years this year) helping one of the world's youngest.

When you look at what we have accomplished in under a year, we hope you agree that we are steadily making progress on the formation of the world's first dedicated Institute For Interstellar Studies. We hope you also appreciate that this is no small undertaking that stretches our personnel resources to the limit. The activities listed above are indicative of what we would do if we were a fully operational and financed Institute.

It is with a huge sense of honour and humility that I am leading this team to found this unique venture. I have confidence that in the weeks, months and years ahead we will do good things that contribute towards our ultimate goal of becoming a star-faring civilisation. Keep faith to the heart and wisdom to the mind, because some day our distant star-wandering cousins will look back on our bold attempts and it is our hope that we will be judged worthy by our efforts. We would like to thank all of those who have been contributing to the foundation of this unique organisation so far. If you have not been mentioned by name, know that you are in our thoughts and you have our heartfelt thanks. It is only through all of our joint efforts that the mission can be achieved and the vision be fulfilled. Live long and prosper I4IS.

Kelvin F Long is the Executive Director of I4IS.

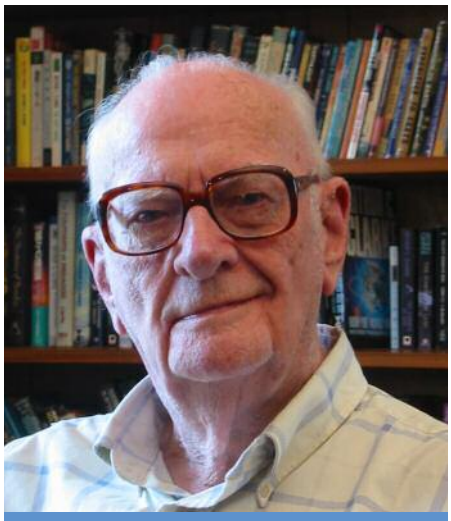
Why an Institute Now?

Kelvin F Ilong, Executive Director and founder of the Institute for Interstellar Studies, explains why an interstellar institute is needed now and what it can bring to the community.

We at I4IS are committed to the vision of interstellar flight. In our quest for the stars, we seek to determine our own pathway by pointing a technological strategy towards the horizon we wish to reach and then using this as a basis for a programme of work. This is, after all, the approach that got the United States to the Moon and it is a philosophy borrowed from science fiction writer Sir Arthur C Clarke, who frequently spoke about "creating a self-fulfilling prophecy."

There are many reasons for being optimistic about the interstellar vision. We live in highly exciting times where we are witnessing the rise of space tourism and space commercialisation. This may be seen as a form of nexus point from which opportunities present themselves, socially and technologically. Under such conditions the emergence of new industries is made more realisable. National space budgets have also been reduced substantially since the days of Project Apollo, suggesting a need to renew the vision and purpose for space exploration. We also live in a time where hundreds of planets around other star systems are being discovered, prompting the public to wonder, "can we someday travel there?" We can also point to more philosophical and profound reasons for doing interstellar studies, such as to escape the apparent 'limits to growth', to advance humanity on the Kardashev scale and to provide a back-up for our species as our Sun is limited in age or to mitigate external threats like asteroid collisions.

The multitude of exoplanet discoveries are proving a tantalising taster of what is out there for interstellar voyagers to discover. Image: C Pulliam and D Aguilar (CfA).



Sir Arthur C Clarke, who spoke of creating self-fulfilling prophecies in regards to humanity's presence in space. Image: Rohan de Silva.

The subject of Interstellar Studies can arguably be considered to have begun with the publication of Dr Les Shepherd's paper on interstellar flight in the *Journal of the British Interplanetary Society* in 1952. This paper addressed the fundamental velocity and energy requirements for an interstellar mission, possibly for the first time in history. Although this did not directly lead to a programme of interstellar research, it laid the seed for the idea that interstellar flight was something that could be a part of our plausible future. It has been over sixty years since that publication and a lot has been achieved since. However, it remains a fact that the subject of interstellar studies is largely theoretical-based research with lfew efforts to push experimental programmes. It is manned entirely by a volunteer work force, which is in itself a small community. It has no organised programme of work or clear leadership to determine the direction and pace of interstellar research. It has a severe lack of grant, scholarship or other funding sources from which to provide incentives for progress and to reward success. Given these points, it is quite easy to see why the Paul Allen's and Mike Lazaridis' of this world would not currently choose to put their money into this subject when the tangible benefits, financial or otherwise, are not clear.

Necessary requirements

In order to change this circumstance and bring investment into the community it is clear what needs to happen first. The following is a set of requirements for any organisations that seek to establish leadership positions in interstellar studies.

A certain degree of effort to self-fund raise must be demonstrated to show that these organisations have the capacity and maturity to manage large funds in an appropriate and proper way. This also demonstrates some degree of financial independence. Any aspiring interstellar organisation must also have the specification and undertaking of a solid research and development programme, theoretical (including numerical) and experimental, which is geared towards making real progress in the maturity of certain space technologies, particularly propulsion, and across the options / solutions space. These organisations must also have the in-house capabilities to design vehicles and mission architectures. In particular, very few actual 'designs' for starships exist in the literature and very few people have the knowledge and capability to design them. The British

The heady days of Saturn V rockets and the Apollo missions are long gone, suggesting a new need to renew our vision for space exploration and aim for even grander goals. Image: NASA.

> ***Interstellar organisations must have the specification and undertaking of a solid research and development programme, theoretical and experimental, geared towards making real progress***

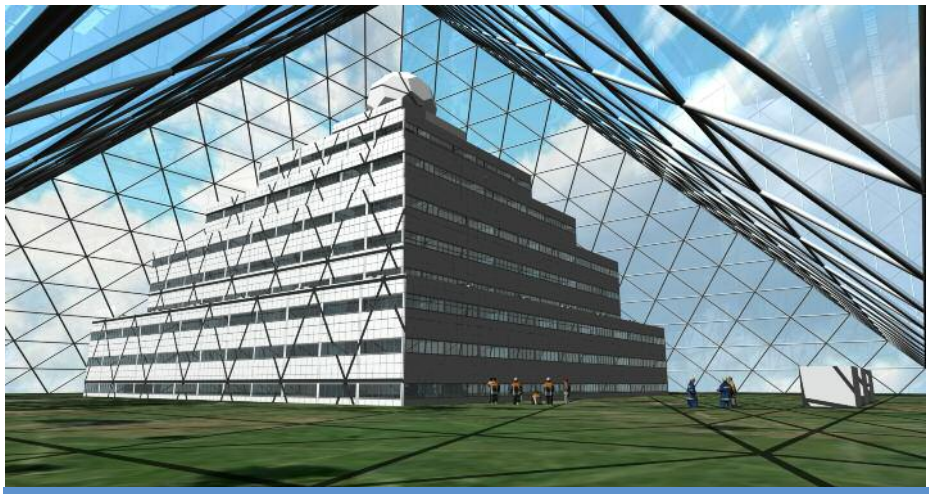
Interplanetary Society's Project Daedalus study from the 1970s remains the only starship design in history.

Another requirement is that a core team of willing and enthusiastic individuals and appropriate experts are built around the organisations to ensure that they are heading in the right direction and using resources efficiently in their research, avoiding overlap, redundancy and bias as well as maintaining objectivity. It must also be possible to compensate those people where possible so as provide incentives for further progress and to support the work force. These organisations also need to have a technology management structure in place so as to ensure appropriate management of any new technology and its output to society. This is particularly the case with disruptive technology.

Practical needs

An interstellar organisation is also required to demonstrate a strategic plan and business model, which is produced to show context, purpose and return for any investments. They also need to demonstrate proper channels of access to government, academia and industry so that if new technologies do emerge then they have the capacity to turn them into real world products or fold them into existing industries. They should also be involved with national space agencies and industry to participate in and/or ensure that missions beyond the Solar System are being pursued. They need to have education and public outreach programmes so that the consequences of the organisation's work can be clearly demonstrated as a positive force for good as a social enterprise. Another important requirement is for these organisations to own some facilities and assets, so as to protect any investment and ensure the organisation has a sound financial and moral foundation with appropriate protection.

They should be open to involvement with anyone, in the quest to develop an interstellar society, so that opportunities are afforded to many, regardless of their gender, ethnicity, education, background or philosophical outlook. Creating an interstellar society has wide ramifications for all the people of Earth. That said, advancement should be based upon a meritocracy and we should not place people into positions for the sake of meeting quotas. We are one species, let people be judged on their own merits and let their success be their own. However, if there are social, cultural, political or economic factors which lead to disharmony in our mission, then yes they must be addressed.



An artist's impression of what an Interstellar Institute building may one day look like. Image: Adrian Mann.

In short, an institute can help organise research and experiments, provide direction and leadership and seek out the funding necessary to kick-start our quest to the stars. We hope I4IS can live up to this important role we have set out for it.

Dr Leslie Robert Shepherd (right), shown here presenting the BIS Gold Medal to Werner von Braun, is credited with creating the field of interstellar travel studies in 1952. Sixty years later the first Interstellar Institute was founded.

The I4IS Academy

I4IS Academy Director Rob Swinney details the Institute's outreach and education goals.

The International Space University in Strasbourg

When setting our plans for the Institute we knew there were three important pillars to build it on. As mostly technical space enthusiasts a clear goal was to work in the technical programmes, able to pick and choose our favourite areas. Another no-brainer was that in the end, even for a not-for-profit venture, we needed to generate income to cover the costs of running our programmes and, with our proposed business model, we have a great balance between generating funds for use in the Institute and being flexible enough to spin-off businesses should that be appropriate.

The final pillar and probably one of the key foundations of the Institute for Interstellar Studies is the educational Academy. The Academy is being designed to help foster and promote education and develop personnel with the knowledge and capabilities to work in the Institute programmes or at the very least encourage people towards a career in space. In the first year, still being essentially a virtual organisation and 100 percent volunteer, we developed working relationships with established providers of space science and space engineering courses. The first and most established relationship has been with the International Space University (ISU) in Strasbourg, France. During the last academic year we developed and helped supervise the individual projects of four MSc students undertaking the Space Studies Masters Programme at the ISU. The ISU Director of Masters Programs, Professor Chris Welch, was the key in developing this collaborative programme and is also on the I4IS Senior Advisory Council. The four Academy-based personal advisors to the students were Dr Gregory Matloff (New York City College of Technology), Professor Ian Crawford (Birkbeck College, UCL), I4IS Executive Director Kelvin Long and Academy Director Robert Swinney.

The students assigned to the projects were James Harpur (from Ireland), Piotr Murzionak (Belarus), Wei Wang (China) and Erik Franks (USA). The interstellar-themed projects were the design of a low mass interstellar solar sail mission, the design of a FOCAL point solar sail mission, deceleration options for interstellar missions and finally the agricultural design trade-offs for a space habitat. It is hoped that the reports can be written up appropriately for publication in the near future. The best project will win the I4IS award of 500 euros and the winner is just about to be announced as we go to press. Separately we have also helped fund students to attend international conferences to expand their horizons and gain personal experience.

> ***The Academy is designed to foster and promote education and develop personnel with the knowledge and capabilities to work in interstellar programmes***

Developing future starship engineers

Over the year we have had people working 'internally' with I4IS members and students acting as an Academy team. The tasks undertaken are wide and varied; remember the Academy is still virtual and building its capacity and capability from the ground up. One of the aims is to develop an internal course of study dedicated to interstellar studies. We are developing plans for Internet course material but we still need a location to hold short residential courses and some work has been done to identify an appropriate location. While we've been looking at a possible home for the I4IS this would also be the base of the Academy. We intend to hold study retreats and involve one of our benefactor's and his plans for a new start up training school whose goals are to help people improve themselves through learning practical skills, adventurous training, personal development and other educational activities. In this venture we plan to add some wonder and delight that will help develop better attitudes towards themselves and others.

In the future we are looking at developing further channels with academia, including potentially a group project with the ISU. Starting this year we will be working with more universities but this time at undergraduate level. Indeed, we plan to work through all the traditional learning years from eight years of age at school (Key Stage 2 in England and Wales) through to postgraduate. We believe we have one of the most engaging subjects that can satisfy cross-curricular themes through the more obvious core Science, Technology, Engineering and Maths subjects, to art, creativity and beyond. There is something for all youngsters to enjoy.

This is just the start of aiming to meet our I4IS mission and values. These are the early days and we are to continuing to build the Academy, virtual and otherwise, raising capital, increasing the number of

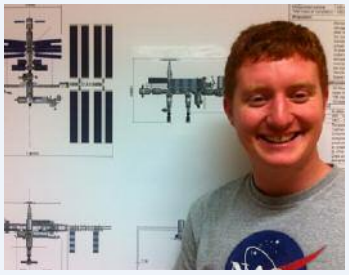
Professor Austin Tate teaches artificial intelligence and robotic systems at the University of Edinburgh and has included interstellar applications in a Massive Open Online Course that he runs on artificial intelligence.

universities with which we can collaborate and indeed building up to doing more project work and courses on our own. Finally, we plan to regularise the structure of the Academy with its own mission and vision as a part of I4IS. If you feel this is something you might like to be a part of to help in the mission, then feel free to get in touch.

Rob Swinney is the I4IS Academy Director. He has a degree in Astronomy and Astrophysics and a Masters in both Radio Astronomy and Avionics and Flight Control Systems and has been an Aerosystems Engineering Officer in the RAF.

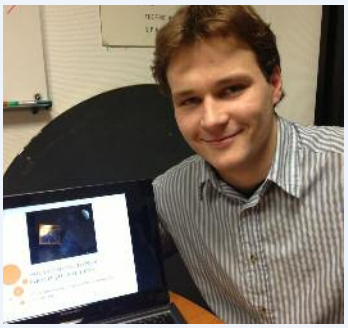
The ISU Interstellar Students

James Harpur



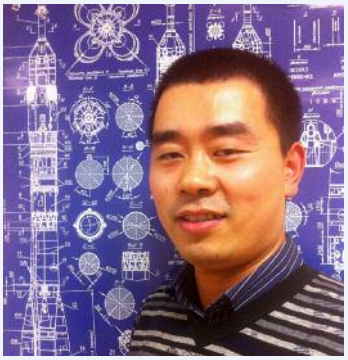
James Harpur hails from Ireland and has a BA (Hons) in Mathematics from Trinity College, Dublin and attended ISU's 2012 Space Studies Programme in Florida before starting his ISU MSc. For his interstellar module James undertook the design of an interstellar probe with a science payload of only 100 kilograms. The study is of interest as earlier concepts and designs for interstellar missions have often resulted in massive space vehicles. The focus given for the mission itself was to study the planets in the target star system with efforts made to gather science data and transmit that data back to Earth.

Piotr Murzionak



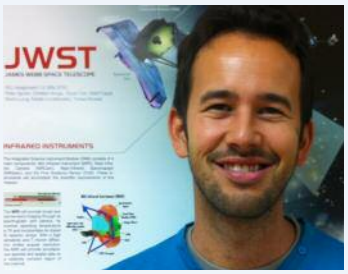
From Belarus, Piotr Murzionak originally studied for a Bachelor of Aerospace Engineering at Carleton University in Ottawa, Canada, receiving a high distinction before joining ISU. For his interstellar module he performed a study of an interstellar precursor probe with a target range of 550–1,000 astronomical units which will be important in illustrating the ability to reach the Sun's gravitational lensing point. The aim of the mission was to study stars and exoplanets, with a focus on data gathering techniques and requirements for observation.

Wei Wang



Wei Wang was born in Xi'an in China. He has a BSc and MSc in Spacecraft Design from Beihang University and has worked for the Shanghai Institute of Satellite Design since 2009. Wei investigated the deceleration options for a robotic interstellar spacecraft entering the system of another star. Credible engineering designs of interstellar orbital craft to date have proved challenging and a major issue has been the difficulty in decelerating the vehicle. The aim of this project was to not only consider as many deceleration options as possible as well as considering the advantages and disadvantages of each technical solution, but also to consider other relevant factors such as technological readiness levels and estimated first use date.

Eric Franks



Eric Franks gained a BA in Economics with a Minor in Business from the University of Texas at Austin. Before coming to ISU he founded his own company and over eight years helped it grow to 50 employees. For his interstellar module Eric considered agricultural techniques for deep space microgravity or low gravity environments that might satisfy the requirements of a viable habitat in space populated by around 1,000 people. He also considered livestock populations plus plants, fungi and other life forms necessary to produce food and other useful products as well as addressing the necessary technology, processes and techniques.

Gravity and the 'APPle'

I4IS is coming to a smart-phone near you! Jeremy Clark, author of the new I4IS app, gives a historic perspective on one of the equations presented in the I4IS mobile app.

Looking around today, it seems that almost as many people have an app-serving smart-phone in their hands as have their feet stuck to the floor by gravity. However, even if your feet are not glued down by gravity, there are a variety of ways you can still get your I4IS fix online – Principium, Facebook and Twitter – and now they are also ready and waiting for you on your smart-phone.

The I4IS mobile app also contains a set of calculations that highlight milestones in the development of astrophysics. It begins with a reference to Eratosthenes calculating the circumference of the Earth in 300 BC and ends with calculations for how solar sails will work in the near future – figures are given for the NASA solar sail demonstration project, Sunjammer (http://www.nasa.gov/mission_pages/tdm/solarsail/solarsail_overview.html), which is planned for launch in 2014. Some of the app's calculations, which are listed in the accompanying sidebar, give a flavour of some key aspects of astrophysics.

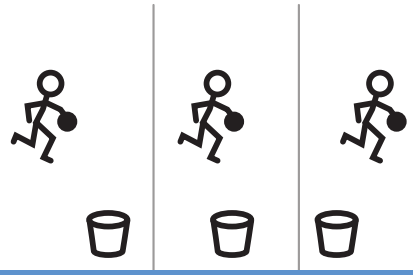
I will not describe the equations in this article as this information is all available in the app. However, I will attempt to put one of them into an historic and psychological context. The list of equations was chosen to demonstrate the geometric rate of development within the world of astrophysics. As for the technology to realise them, the app's help text states that "In 1903 the Wright brothers flew the first aeroplane covering a distance barely the length of a modern passenger plane. Today it is common to fly around the world." If we project this rate of change into the future then clearly we live on the verge of very exciting times.

The equations start with Sir Isaac Newton's (1642–1726) calculation of the force of gravity and apply this to the orbit of planets. Real astronomical data is included in the app, which can be used to test the results of the calculations. There are differences. Some will be thanks to over-simplification in the astrophysical models e.g. they ignore the effects of magnetism. In other cases our understanding of astrophysical phenomena has been updated, for example from Newton's law of gravity to Einstein's General Theory of Relativity. The calculations are available on the app to allow the user's imagination to explore the vast reality that lies beyond Earth.

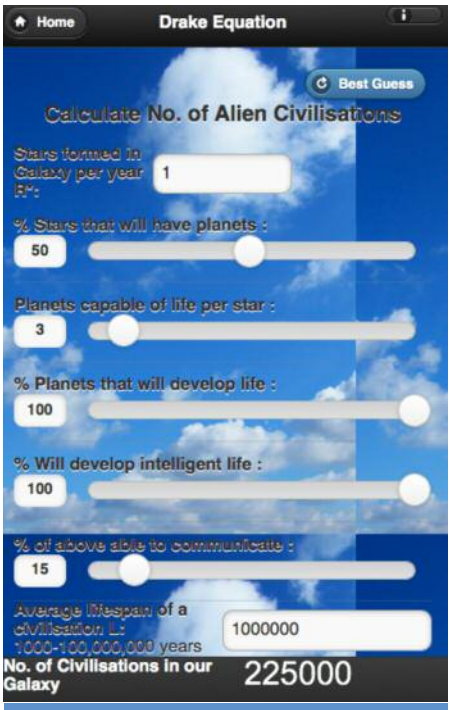
Stick men experiments

Let us consider the way our understanding of the physical world has evolved, using gravity as our example and focusing on how human imagination created those equations, the mistakes we made along the way and where the power of human understanding may take us. For space reasons this article is largely limited to the development of thought within the western world, but it should be acknowledged that the West owes a debt to Arabic culture that both preserved Greek learning and gave us many mathematical tools, most obviously our numeric characters. Humankind shares one physical reality, even if a deep understanding of it varies from place to place, time to time and person to person.

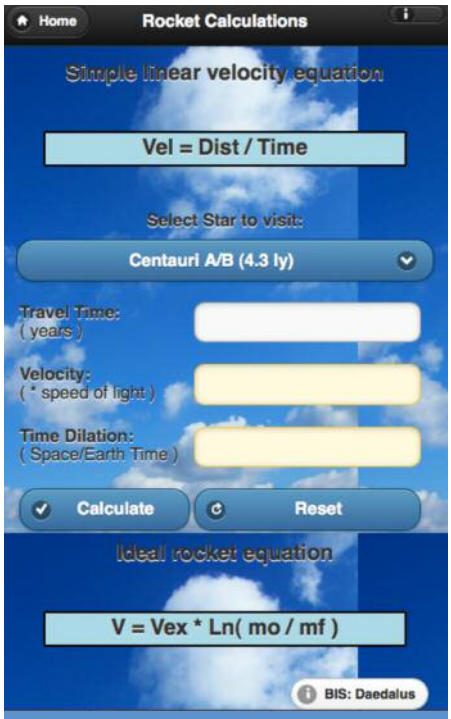
Before Eratosthenes calculated the Earth's circumference, Aristotle (384–322 BC) produced a theory of gravitation that dominated western thought for a millennium. Before this Plato presented a theory suggesting a possible source of this human knowledge, which raises questions such as, are we born with a



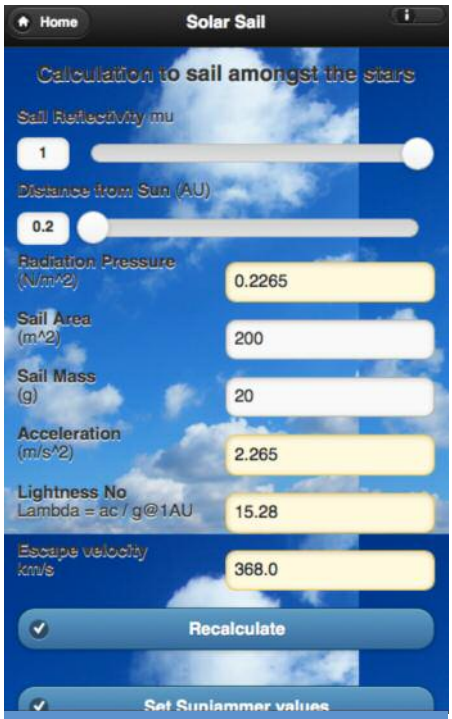
Which of these running stick men will successfully throw the ball into the box? Twenty-seven percent of physics students answered incorrectly.



Ever wondered if we are alone in the Universe or not? Plug numbers into the Drake Equation and discover what the likelihood of life elsewhere is.



A simple calculation can tell you how long it will take to reach the nearest stars.



There are a number of factors that go into a successful solar sail.

predisposition towards an understanding of phenomena such as gravity? Richard Feynman (1918–1988) said, "It is safe to say that nobody understands quantum mechanics." Does this mean that an intuitive understanding of the laws of physics can only relate to the classical Newtonian world that we experience? The journey to and from these equations may be as exciting and informative as any possible destination.

Surely one of anybody's first experiences is that objects fall down. Until the first child is born in outer space, we will never know what it is like to experience inertial mass in the absence of gravitational mass during our first encounters with reality. Evolution has clearly prepared our bodies to live in a reality containing the phenomena of gravity and it is hard to believe that it has not also shaped our minds to process this concept.

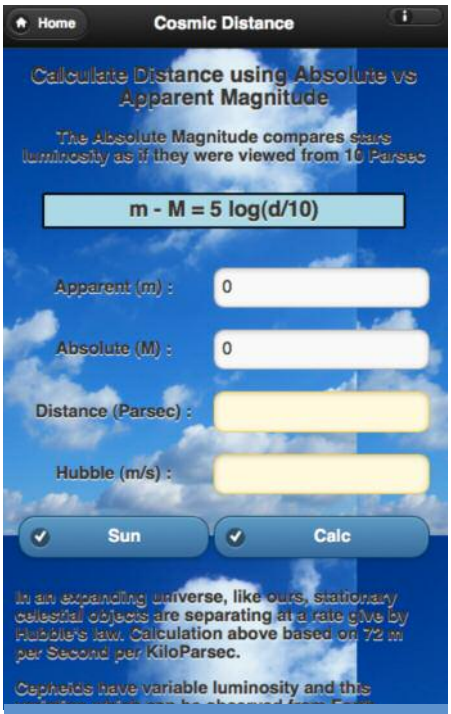
However, in 1980 the psychologists McClosky, Carmazza and Green conducted an experiment showing that a surprisingly high proportion of physics students, 27 percent, failed to correctly chose which of the running stick men in the picture on the previous page would successfully drop a ball into a box. Eighty-seven percent of non-physics students also failed this test and yet of course the majority of people can effortlessly drop a ball into a large box while running past it. Surely in a fairer world the physicists would use this knowledge to command the adoration and income of today's top sports stars! The body may intuitively come to understand Newton's laws but despite the familiarity of these equations, they do not seem to have been absorbed to the point of becoming self evident.

Prior to Newton, Aristotle had taught that objects have a natural place in the Universe and that they want to get to this place. The stars 'want' to be in their celestial sphere and objects on Earth 'want' to be at the centre of the Earth. In the 1970s and 1980s, tests on six year old children demonstrated that even this simpler theory of gravity is not our default setting. Children were presented with a circular drawing of Earth, with two stick men drawn on the Earth each holding a ball, one at the North Pole and one at the South. The children were asked what would happen if the ball was dropped. They correctly stated that the one at the North Pole would see her ball fall to the ground, while the one at the South Pole would see his ball fall down away from the Earth and out into space. Children do not correctly predict the behaviour of objects on an unfamiliar part of our world and it was three centuries after Newton that Einstein opened our eyes to the behaviour of objects with unfamiliar and extreme velocities and masses that no human has yet experienced. Humankind has certainly experienced a rapid acceleration in our understanding of the cosmos in the two millennia between Aristotle and Newton.

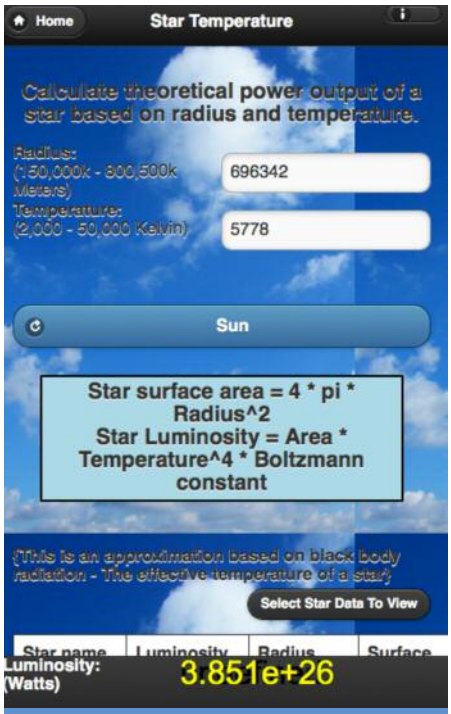
Differences in reasoning

Civilisation has gone from animistic explanations of common experience to explanations using mathematics and now arguably to explanations of reality that can only be understood by mathematics. As we develop from childhood to adulthood, according to the psychologist Jean Piaget (1886–1980), we lack the mental tools to grasp sophisticated mathematical concepts until we reach a cognitive developmental phase referred to as 'Formal Operational Stage.' This normally happens at about age 11. However, according to the Soviet psychologist Lev Vygotsky (1896–1934), everyday reasoning and scientific reasoning work in the opposite direction. As people we like to take specific experiences and then generalise but as scientists we take general rules and calculate specific instances. Vygotsky's writings only became available to the West long after his death and the end of the Cold War but have in some ways superseded Piaget's theories. An example of the short comings of human reasoning is given in my chapter, 'An introduction to Artificial Intelligence as Applied to Space Exploration' in the upcoming I4IS publication, *Beyond the Boundary*. This demonstrates our ability to solve problems framed in a social context but to struggle when using abstract logic, just the sort of abstract logic that we require to apply the equations of physics.

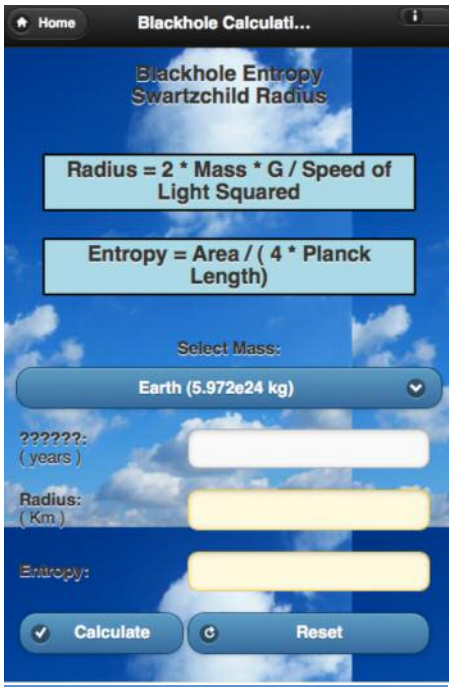
The I4IS app uses Newton's laws of motion to calculate the paths of orbiting bodies. The inbuilt help text also describes



Astrophysics is a major part of the I4IS app – here we calculate the distance to stars based on their absolute and apparent magnitudes.



Another astronomical equation works out the surface temperature of a star.



Use the I4IS app to calculate the Schwarzschild radius of a black hole.

the three earlier laws of Johannes Kepler (1571–1630) that specifically describe planetary motion rather than gravity in general. The app allows the user to select one of the four bodies listed below to be the 'stationary' orbited body:

- The Sun at 2 x 10^{30} kg
- Earth at 5.972 x 10^{24} kg
- A low mass star, OGLE-TR-122b, at 2 x 10^{29} kg
- The most massive star that we know, R136a1 at 53 x 10^{31} kg

The orbital distance can be set in astronomical units (AU; the average distance between Earth and the Sun – the app also has a function to allow conversion between units of distance). As there is a graphical display of the results as well as orbital velocity and period of orbit in years, the orbital eccentricity can also be visibly adjusted. A list of planetary data is also presented in a selectable table. This includes Mercury, which orbits the Sun in 88 days at a distance of 0.39AU. This is good enough as a rough approximation using Newton's laws as embedded within the app. However, there is a discrepancy between the orbit calculated using Newton's laws and the actual orbit. This requires the post-classical modern physics as proposed by Einstein.

It had been known since the late nineteenth century that Mercury's orbit did not agree with what was expected using Newton's laws. For Newton, space and time were a reliable fixed backdrop against which our experience of the cosmic drama played itself out. For Gottfried Leibniz (1646–1716), space and time are more like account ledgers just for keeping score of objects. The objects are primary. For Einstein, space and time depend entirely on the observer. Not only that but gravity emerges from the bending of space-time or a rearranging of the cosmic ledger books. Mercury rolls around the brim of a dent in space-time created by the mass of the Sun. Humankind is unlikely to directly experience the extreme conditions required to highlight the post-classical world described by Einstein – certainly future generations capable of the time travel made possible by distorted space–time have as yet been very unwilling to come back and expand our consciousness or subject us to a level of cultural shock to outdo any ever perpetrated by the most zealous conquistador!

Gravitational waves

We might not intuitively grasp a reality where space and time are relative but anybody who has ever tried to hold something still in a wind will be familiar with the flapping nature of waves. As mass can bend space-time, then like a ship moving through water we would expect to find ripples or waves in space-time, produced by the movement of that mass. However, this would require truly enormous events such as colliding black holes to produce observable gravity waves. Between 2002 and 2010 the Laser Interferometer Gravitational-Wave Observatory (LIGO) started the search. An alternative approach for the detection of gravity waves was suggested in 2012 by George Hobbs of the Australia Telescope National Facility. He proposed monitoring for fluctuations in the radio beams transmitted by pulsars. However, it is a very tall order to detect here on Earth what are expected to be very low amplitude waves with very long wavelengths. For this reason the intention in the near future is to build an instrument in space, the Laser Interferometer Space Antenna, or LISA. Spinning or colliding neutron stars may produce a gravitational displacement with a wavelength of 300 kilometres. However, to date Earth based detectors are yet to find evidence of the gravity waves predicted by general relativity but based upon the rate of scientific development highlighted in the app, amazing discoveries are just around the corner. There is only one place to go for that sort of research. To stretch our mind we need the head room of interstellar space.

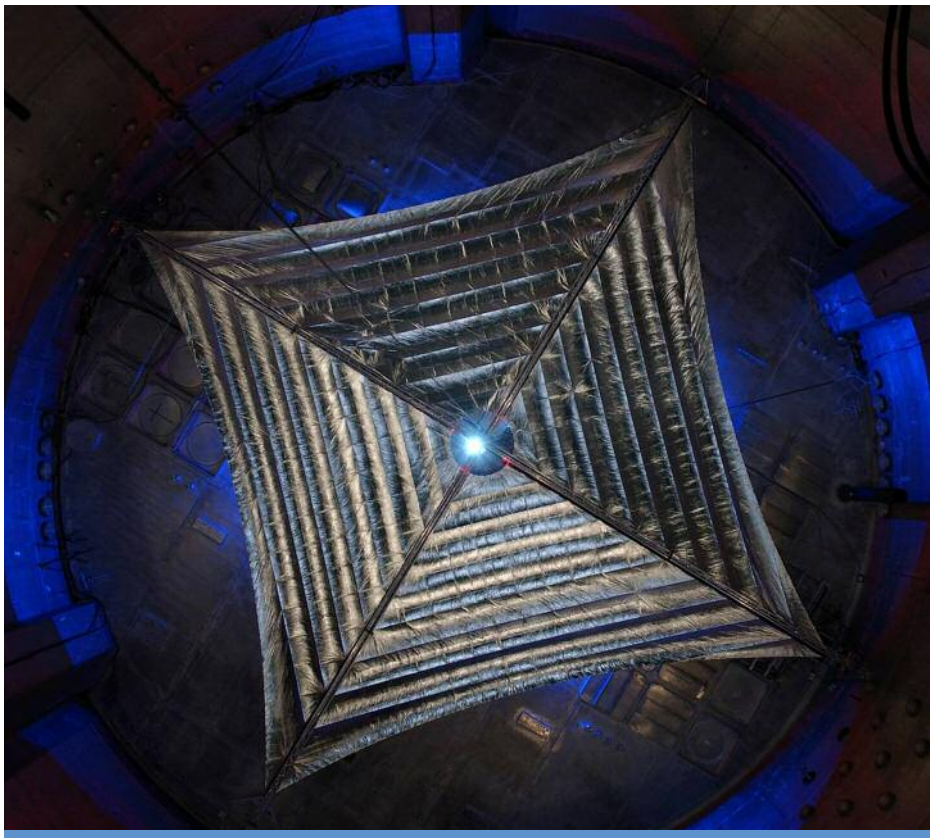
We have come a long way and arrived at a world that may seem counterintuitive but the story is not over. The large scale theories of General Relativity do not agree with the small scale theories of quantum mechanics. One of the solutions to bridge the smooth space-time of general relativity and the foaming space-time of quantum mechanics is string theory. However, testing this theory is the problem. String theory implies that for gravity an associated particle called a graviton should exist, in the same way that a particle of light called a photon exists for electromagnetism. It is predicted that the graviton would have

no rest mass and a quantum spin of two. All well and good until we try to find or make one. A suggested test is that a detector with the mass of Jupiter orbiting a neutron star might be able to pick up one graviton every ten years. Sadly no government is likely to finance that sort of upgrade to CERN! However, the possibility for naturally occurring experiments beyond our Solar System is endless and with them the possibilities for the growth and development of humankind. This is the job of I4IS. As the app's help text states, "In 1924 Edwin Hubble (1889–1953) gave us the first glimpse of how big the Universe really is. Thirty-seven years later Yuri Gagarin became the first man in space. Forty years later, in 2001, the first space tourist slipped the surly bonds of Earth. The pace of exploration has accelerated at a rate that must inevitably lead to a near future where humankind shares its borders with the stars."

The I4IS mobile app is available on the Apple App Store – just search for I4IS.

Jeremy Clark, Director, I4IS

Jeremy Clark MSc MBCS MBPsS is an I4IS director and has worked for some of the world's leading financial institutions as well as having a successful career in IT.



The Sunjammer solar sail, being built for NASA to launch in 2014 by French space company L'Garde. Solar sails feature heavily in the I4IS app.

In App Calculations

Rocket Velocity
= Exhaust velocity x log(Initial mass/Final mass)

Solar Sail Pressure
= (1 + Sail reflectivity) x Solar radiation/Speed of light

Drake Equation for the number of alien civilisations
(R = rate of star formation; Fp = fraction of stars with planets; Fp = fraction of stars with Earth-like planets; Fl = fraction of planets with life; Fi = fraction of planets with intelligent life; Fc = fraction of cviilisations that are communicating; L = longevity of civilisations)
= R x Fp x Ne x Fl x Fi x Fc x L

Distance:
Apparent star magnitude – Absolute star magnitude
= 5 log(Distance to star/10)

Star luminosity
= Star's surface area x (star's temperature)^4 x Boltzmann Constant

Orbital Velocity
= square root (Gravitational Constant x mass/radius)

Black hole (Schwarzschild) radius
= 2 x mass x Gravitational Constant/(Speed of light)^2

Black Hole Entropy
= Black hole surface area/(4 x Planck length)

Escape into Tomorrow

As I4IS' Honorary Interstellar Musician, The Light Dreams, a.k.a. Alex Storer, specialises in electronic space sounds that take the listener to other worlds and other times. Coupled with his evocative brand of fantastic futuristic art, he spearheads a new wave of creators that are capturing our interstellar dreams on canvas and in sound. Here Alex speaks about his work and inspirations.

I've been composing electronic music under the name 'The Light Dreams' since 2006. I don't remember where the name came from – it was actually the title I gave to my very first musical experiments, back in 1997, and it stayed with me. I've always been fascinated with the images of dreams and space and, for me, certain styles of music provide escape into these worlds.

It has been an ambition of mine to make instrumental music – not rock or pop songs, but thought-provoking atmospheric pieces. This stems from discovering the work of artists such as Jean Michel Jarre and Mike Oldfield at an early age, as well as hearing music like the *Doctor Who* theme tune. This kind of music transported me to another place; a sonic landscape to explore and it was this that I wanted to create. All the musical influence I've soaked up over time has been absorbed and recycled and is now in a steady return flow.

I prefer the term artist to musician. Perhaps because I am primarily an artist, so to me, making music is like painting, but with sounds rather than colours, yet still building up a piece layer by layer. I have no formal musical training at all – I'm self-taught, through a combination of passion and creative instinct – so I work in a rather unconventional way, thinking more like a painter than a musician. But this works for me, and it is the end result that counts, rather than how something was made.

I also experience synesthesia (the association of colours with sounds) and this probably plays a big part in the creation of my music (and artwork). It is impossible for me to hear a piece of music or a sound without seeing it in a particular colour. It is an automatic process and an accepted aspect of my creativity. The main emphasis in my music is atmosphere, mood and the exploration of various textures and forms, and as I see it, colours.

I work in a very independent way – no labels, contracts or managers, just me, my iMac and a midi-keyboard. I like it this way – I can release my work as and when I want.

My musical direction was defined in 2007 with an album called *Into the Light*, which was an album about dreams and travel. But when artist David A. Hardy allowed me to use one of his paintings as the cover, it automatically gave the entire thing an other-worldly feel. That painting felt like the perfect illustration of one of the songs on the album. I'd like to think that the music makes you want to venture into that scene on the cover and explore the landscape, find out what is around the corners, just out of shot! This combination really set things in motion.

After making *Mechanical Drive* in 2009, I took a break from music to concentrate on my artwork. However, by 2012 I was feeling the urge to pick up where I had left off, so I bought some new equipment and software, and the result was an album called *Inferno*. This was the first album I released commercially as a digital album, using the Bandcamp platform. I had reached a stage where I was finally confident in my output and wanted to reach a like-minded audience.

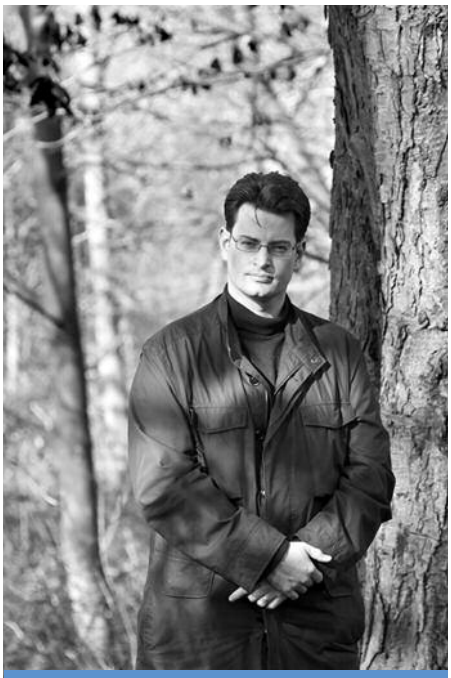
> ***Each track explores a different time and setting, from the threat of Earth's changing environment to SF-inspired utopian societies and the exploration of space***

Although science fiction inspires all of my music on some level, I was yet to produce a real SF concept album so in late 2012 I decided this would be my next project – and the coincidental invitation to be first honorary musician for the Institute for Interstellar Studies proved to be a timely catalyst!

Stellar symphony

The title *Future Worlds* (note the plural!) came to me relatively early on, although I was aware it resembled *Future World*, the disappointing follow-up to the iconic science fiction film, *Westworld* (one of my all-time favourites). But the title stuck, as this would indeed be the exploration of multiple futuristic worlds and scenarios through music. My idea was for each track to explore a different time and setting, from the real threat of

Alex Storer's tools of the trade – his home studio.



Alex Storer, a.k.a. The Light Dreams.

Earth's changing environment to SF-inspired utopian societies and the exploration of space.

I had just completed a symphonic project: a new soundtrack to David A Hardy's English edit of the 1957 Soviet film, *Road to the Stars*. David had requested an orchestral soundtrack rather than electronic, so I soon discovered the power of working with symphonic sounds. I knew then that I wanted my next project to be a powerful combination of electronic and orchestral.

The Korg M1 was one of the most popular synthesisers in the late 1980s and early 90s, widely used by artists such as Gary Numan, Depeche Mode and Tangerine Dream. When I discovered that Korg had made this classic synth into an authentic software plug-in, it was something I could not ignore – to finally be able to play with the sounds I'd listened to on albums by my favourite artists was an absolute delight, and this helped define the album's overall sound, as I fused classic and modern synths with symphonic sounds.

A lot of literary influence went into *Future Worlds*. One of the starting points was the title 'Souvenir of Earth', which was an evocative line straight out of Karen Thompson–Walker's début novel, *The Age of Miracles*. That was one of those moments where I just knew I had to write a song around those words and that it would be slow, reflective and melancholic; looking back on a home planet ravaged by humankind's strain on its natural resources. This poses the recurrent "what if?" question that is present throughout the album.

Interstellar travel punctuates the themes of the songs on several occasions, the first being 'To the Stars', which launches us on an epic voyage of deep space exploration and discovery. It is the first song to offer a mid-point transition; the first part slow and flowing, almost hypnotic in its repetition as I imagined the visions of stars and galaxies in passing – and following a break in the music comes the increase in acceleration as our ship and crew take the mission to the next level as the music gathers momentum.

'Utopia' is one of the more SF-centric tracks and also goes through several evolutions as it progresses. I was looking to novels such as Arthur C Clarke's *The City and the Stars* or *The Sleeper Awakes* by H G Wells for inspiration, where underneath a seemingly harmonious society lie dark secrets and cover-ups, and I wanted this layer of unease and suspicion to be represented.

We're back in space for the next track, 'Colony' – or to be precise, on a new homeworld. It is one of the album's faster tracks, again with a transitional point where the music goes from heavy electronics to orchestral combined with thunderous tribal drumming. The imagery I had in mind with this track was both high-tech and dynamic, heralding progress and the building of a new empire.

Although it was not my intention for the concept to link one track to the next, the first few tracks on *Future Worlds* certainly play out a scenario – leaving Earth, travelling through space and establishing a colony on a new world

> ***Ever since starting out with my own music, I've been itching to make a space travel album***

where one can look out over an alien terrain now called home.

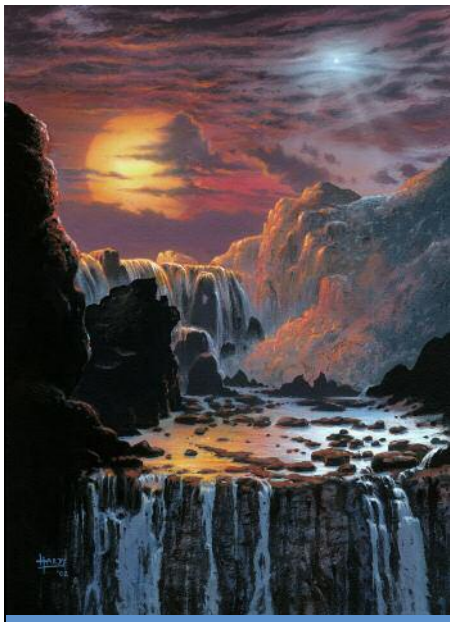
Cover song

'The World Outside' was a title I had in mind for a while and I knew exactly how I wanted it to sound. At the same time I had imagined a panoramic alien landscape, seen through a window, perhaps from a colony building or portal on a recently landed spacecraft. The more I thought about it, the stronger the desire came to paint this scene – which I did, the resulting painting going on to become the album cover.

I'm fascinated with the space art of the 1970s, the vintage paperback covers and classic album sleeves of the same time and I wanted the album cover to pay homage to that and look as if it could have come straight from that period. The visions of the future as depicted in the art, movies and music of the 1970s remain unparalleled in their ambition and creativity and I wanted to embody all of that while still creating something modern.

The second song to have an artistic reference is 'Second Sun'. The original inspiration came from a David A Hardy painting, 'Antares II', which featured two suns in a vibrant sky, gloriously reflected in cascades of water below. I wanted to make a soundtrack to this stunning painting.

From concept to cover art – Alex's original sketch of The World Outside, the finished painting and the picture on the album cover.



The stunning David A Hardy painting Antares II that adorned the wall in Alex Storer's family home and provided some of his inspiration. http://www.astroart.org/

The following two tracks explore climate change and the environment. 'Icefall' depicts the melting of the polar ice caps. The ecological direction continues with 'Beneath the Surface', the most epic track on the album and also the longest, dedicated to the endangered life under the sea.

We venture back into science fiction territory with the dark industrial tones of 'Cities in the Sky', before returning to an interstellar mood with the upbeat 'Flightpath'. Here I introduced some electric guitar sounds to add to the dynamics and create a real driving track to denote the thrill and adventure of such a voyage, not unlike those depicted in novels such as Poul Anderson's *Tau Zero* or *Eon* by Greg Bear.

'Earthlight' – as referenced in several of Arthur C Clarke's early works as well as his book of the same name – was a title that was just crying out to be a piece of music. Taking the concept of the partial illumination of the dark section of surface of the Moon, by light reflected from the Earth, I knew this would be a slow piece with no drums and I wanted the sounds to somehow glow and radiate, to shimmer and feel warm if not blinding at times. I also wanted a sense of wonderment to the music and for it to sound as vast as space itself. Sometimes you can slave over a piece of music for days, and it still doesn't feel right – other times it is as if it falls out of the sky and lands in front of you, coming together perfectly in just a few hours, which was the case with 'Earthlight'.

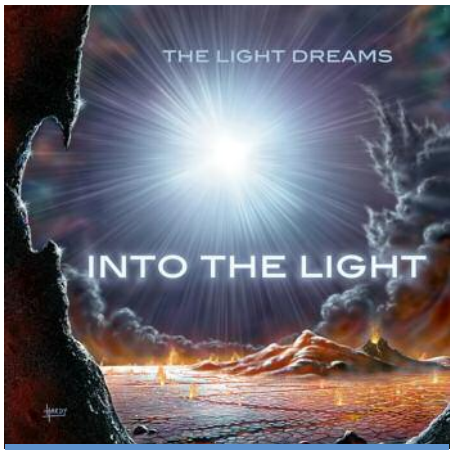
The closing track, 'Sea of Flames', was composed relatively early on before the album's concept had firmly established itself. Again we are in science fiction territory with the image of the Earth's oceans burning, but to me it felt right to close the album. It is a dark and dramatic piece that delivers a warning message. I envisaged it working like the music over the closing titles to a movie.

Bonuses

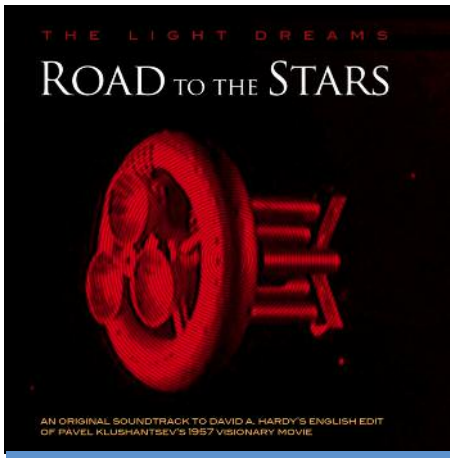
While I knew I wanted to make an album of twelve tracks, lasting around 45 minutes, two additional songs came about in a very short space of time. 'First Steps' was another orchestral track, which continues the idea of setting foot on other planets and exploring the unknown. This was followed by 'Origins', which in this case is the origins of a new civilisation on a new world. Both songs feature as bonus tracks, but only available with *Future Worlds* on Bandcamp.

An album project is always an interesting thing and also very personal. While you're working on it, you live and breathe it; listen to it day and night, wake up at random hours with sudden ideas for improvement, play it to death and get sick of it. One day you lose all faith in it, the next day you think it's your best work. You revise it, refine it – and then release it!

The hard part is knowing when to stop; you can go on tweaking for days or months, and sometimes the danger is overworking something. You can also work on something until you think you've done all you can, and somebody will still come along and point out the obvious! You can only do the very best you can at the time. It is also inevitable that as you near the end of the process, you go back to some of the earlier pieces and suddenly realise where things can be improved, which was the case with 'Colony' – just prior to my declaration that *Future Worlds* was complete, I completely changed the lead synth and replayed the bass line entirely, in a different sound!



The Light Dreams' first album, Into the Light.



Alex Storer's collaborative effort with David A Hardy: the score for Hardy's English edit of The Road to the Stars.

With both my artwork and music I find that I usually reach a natural cut-off point, where it simply feels right to pause or stop. Luckily, as the album progressed and the need to associate it with I4IS became increasingly important, I planned the release date to coincide with I4IS awareness month in February 2013.

A project like this really takes on a life of its own, making unexpected turns. I would like to think of *Future Worlds* as a rich and interesting album, with an appeal to fans of science fiction, space travel enthusiasts and electronic music lovers. I'm certainly proud of *Future Worlds* from an artistic and creative point of view. *Future Worlds* is out there now – its journey into stereos and iPods across the globe has only just begun.

I often find that within any album project comes the origins of the next project. My work reached a new level with *Future Worlds* and keeping the creative momentum, combined with everything I learned in the process, I am now working on two new albums of contrasting styles, one of which is of an interstellar theme.

Ever since starting out with my own music, I've been itching to make a space travel album. With 2013 having so far presented us with even more photos of Mars' landscape, breathtaking spacewalks and photographs of Earth as seen from Saturn, as well as Chris Hadfield performing David Bowie's classic 'Space Oddity' onboard the International Space Station, it certainly feels like the right time to be immersing myself in such a project. Music remains one of humankind's greatest and most universal art forms, but it is also something that is perfectly at home, out among the stars.

Alex Storer is a digital artist, illustrator and electronic musician based in Sheffield in the UK.

Beyond the Boundary

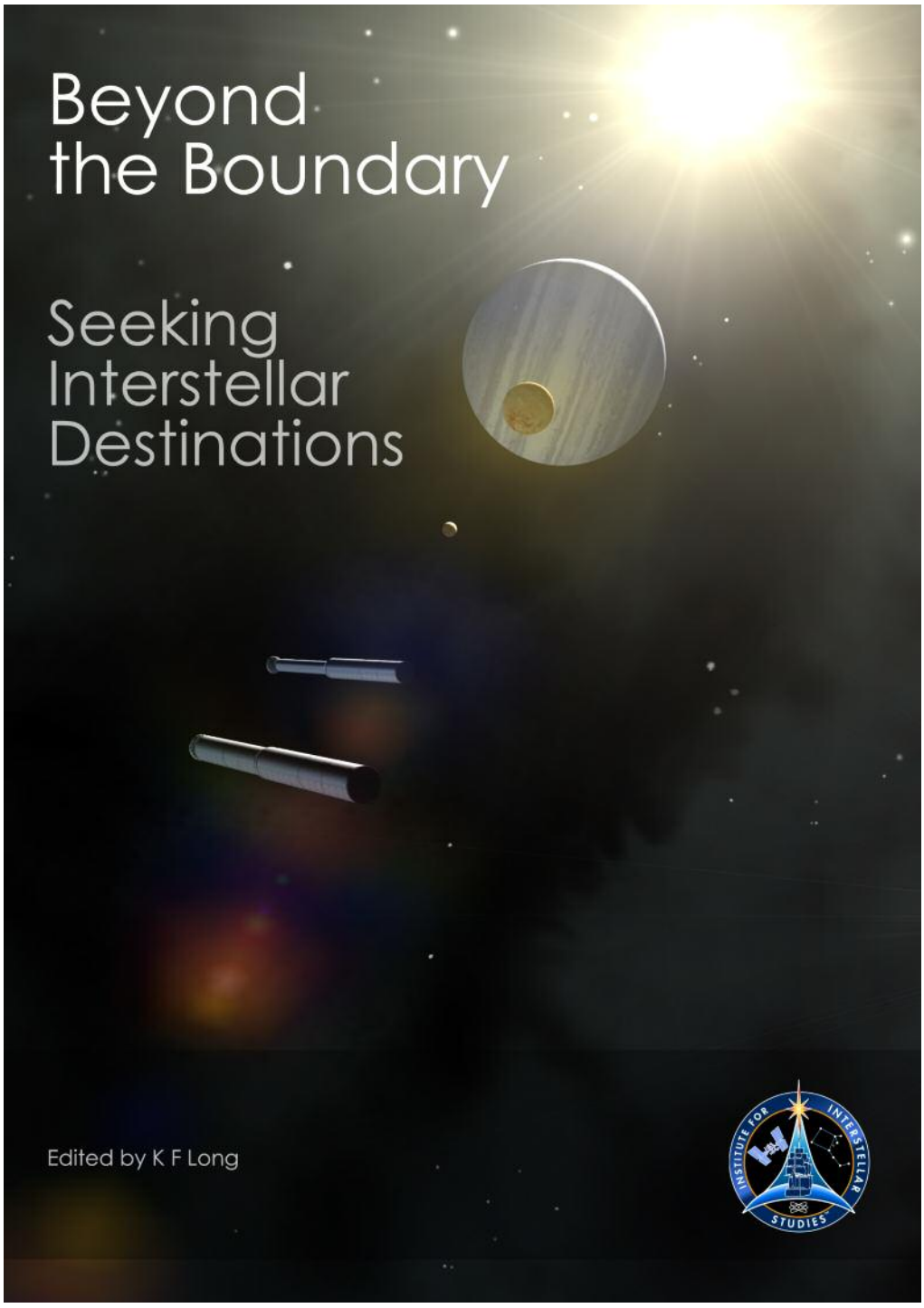
Seek new interstellar destinations with I4IS' brand new hardback book, coming soon!

A compendium of essays written by a diverse cross-section of I4IS team-members and edited by interstellar supremo Kelvin F Long, *Beyond the Boundary* explores the challenges of interstellar flight and presents new worlds to voyage to.

Chapter contents include the philosophy of starships, propulsion technology, nearby planetary systems, SETI, artificial intelligence, space art, music and much, much more!

Contributors include Stephen Ashworth, Jonathan Brooks, Martin Ciupa, Jeremy Clark, Keith Cooper, Ian Crawford, Bill Cress, Adam Crowl, David Fields, Tiffany Frierson, Remo Garattini, Angelo Genovese, David A Hardy, Andreas Hein, Kelvin F Long, Tobias Lugoloobi, Adrian Mann, Gregory Matloff, Mike McCulloch, Ken Roy, Divya Shankar, Alex Storer and Giovanni Vulpetti.

A luxurious hard cover book with stunning cover art by Adrian Mann and a foreword written by the legendary space artist Jon Lomberg, *Beyond the Boundary* is a unique collection of thoughts and treatises on the interstellar vision and can be yours for just £35!
You can pre-order copies now by e-mailing interstellarinstitute@gmail.com.



The Philosophy of the Starship

The stars were brought down to London in May as delegates from across Europe convened for the first I4IS conference on the Philosophy of the Starship. Rob Swinney and Kelvin F Long report.

Part of helping to build and contribute to a community like the interstellar fraternity is to convene get-togethers, meetings and workshops for the community to take part in. As such on Wednesday 29 May 2013 the Institute for Interstellar Studies (I4IS) hosted its first conference, which took place at the headquarters of the London-based British Interplanetary Society (http://www.bis-space.com/). Chaired by I4IS Academy Director Rob Swinney, the one day meeting was attended by around thirty people and featured six presentations followed by a workshop session on Project Dragonfly (see the following article to find out more). The name of the symposium was chosen to promote as broad a thinking as possible, but also in honour of three papers published in the 1970s by Dr Bob Parkinson and so the symposium was dedicated to him. These historical papers were 'The Starship as Third Generation Technology' (JBIS, 27, 4, pp.295–300, April 1974), 'The Starship As An Exercise In Economics' (JBIS, 27, 9, pp.692–696, September 1974) and 'The Starship as a Philosophical Vehicle' (JBIS, 28, 11, November 1975).

The day kicked off with Rob Swinney giving an introduction to I4IS and briefly discussing its mission and vision statements as well as some of the activities the team were currently undertaking relating to permanent founding. This included the online newsletter *Principium*. Swinney discussed the Educational Academy, research projects and the enterprise arm of the Institute.

Renaissance people

The first talk of the day was from Kelvin F Long, who spoke about 'The Invention of the Starship' and the approach adopted by the Renaissance man Leonardo da Vinci, arguing that because today we are designing starships that use technologies perhaps decades or centuries ahead of our time, we too are students of the Italian Master's legacy. Long discussed the approach of human civilisation to the solution of the starship problem by bending, stretching and perturbing the Tziolkovsky rocket equation. Long also talked about the process of creative invention and discussed how *Star Trek's* famous warp drive was created. Reading from the book *The Making of Star Trek* by Gene Roddenberry and Stephen E Whitfield, Roddenberry was quoted thus:

"'We're a hundred and fifty or maybe two hundred years from now. Out in deep space, on the equivalent of a cruise-size spaceship. We don't know what the motive power is, but I don't want to see any trails of fire. No streaks of smoke, no jet intakes, rocket exhaust, or anything like that. We're not going to Mars, or any of that sort of limited thing. It will be like a deep-space exploration vessel, operating throughout our Galaxy. We'll be going to stars and planets that nobody has named yet.' He then got up and, as he started for the door, turned and said, 'I don't care how you do it, but make it look like it's got power'."

> ***"Because we today are designing starships that use technologies perhaps decades or centuries ahead of our time, we too are students of the da Vinci's legacy"***

Long argued that the progress over the last half century has represented the gradual invention of the starship and that by using the tools of physics, engineering, mathematics and the arts, many types of starships have been derived in our mind's eye and some put down onto paper. Long finished by saying that given the rate of technological progress it is possible that none of the starships we conceive today will represent the actual vessels that we someday send to the stars, in reference to the developing theories of gravity, multiple dimensions and the discoveries of dark matter and dark energy still to come.

Liberal humanism

Next up was I4IS Researcher Stephen Ashworth, who discussed 'The Philosophical Heritage of the Starship'.

Stephen Ashworth presents his argument of how starship philosophy is unique.

Speaker Martin Ciupa on the left, chair Rob Swinney in the middle and Principium Editor Keith Cooper discussing self-replicating probes with the attendees.

The first man to consider starship philosophy, Bob Parkinson, revisited his paper on the subject from the 1970s.

> ***The very idea of a starship is a symbol for confronting the ultimate objectives of astronautics.***

He argued that the starship philosophy is unique in that it projects galactic scale expansion for the human species and its descendants for a period of millions of years to come. He addressed the key features of a social philosophy conducive to large-scale civil space engineering up to and including starships.

Ashworth argued that the starship philosophy is a necessary successor to liberal humanism, which must now therefore include the exponential growth of extraterrestrial industries and populations, or else be destroyed together with the civilisation it created. He demonstrated that in every case a philosophical stance in which the interstellar community regards something as true or virtuous is regarded by other groups in society as false or damaging. He referred to the apparent Marxist sociological viewpoint in comparison to the liberal progressive viewpoint as an example of where a clear contrast existed. He said that even within the sphere of interstellar thought there were several points of fundamental disagreement, in reference to the range of possible solutions to the Fermi Question as an example.

After the first coffee break I4IS Director Keith Cooper discussed 'Self-Replicating Probes: Close to Reality?' He described the origin of the concept of a replicating machine and some of the technologies that were being investigated today that could bring such probes into reality. He also described so called Bracewell probes (named after the astronomer Ronald Bracewell) and imagined extraterrestrials sending their own probes to venture out into space to explore the Universe and make contact with other intelligent species. Cooper saw autonomous probes, based on nanotechnology, artificial intelligence and 3D printing as some of the key enablers behind self-replicating machines. He argued that there was a risk that the autonomy of these probes could also sour a first contact scenario with extraterrestrials if those probes trespassed on the aliens' own resources.

The original starship philosopher

This was followed by a lecture from that original starship philosopher Dr Bob Parkinson who fittingly looked at 'The Philosophy of the Starship – Revisited'. Parkinson said that unlike thinking of flying to the Moon or missions to Mars, the very idea of a starship is a symbol for confronting the ultimate objectives of astronautics. He said that the concept of a long-term open-ended project like a starship raises questions about why the human race should engage in such an endeavour. He discussed how social and technological conditions had changed in the four decades since the British Interplanetary Society's Project Daedalus. He said that today one person was now able to do the work that had required entire teams previously, due to technological amplification of ourselves using modern calculating powers, specialised software and the World Wide Web. Thinking about such a project inevitably means considering the effects of change – not only in our technology, but also in our understanding of the world and even of ourselves.

> ***The concept of a long-term open-ended project like a starship raises questions about why the human race should engage in such an endeavour***

Parkinson asked why we bother to search the skies with our radio antennas and why we dream of designing starships. Such things are interesting and exciting, but they are not the ultimate goal. Indeed, we may not be able to define an ultimate goal. He argued that one aspect of conscious life is that it changes things – particularly its environment. And progressively, as we have developed, we have modified things on a larger and larger scale. Why do we imagine this situation will not continue?

From time to time astronomers, having described the origins of the Universe, choose to extrapolate forwards into its future. Missing from this however is that they ignore the effect of creative consciousness, says Parkinson. It is easy to run the laws of physics forward but not the possibilities of choice. He made a point of saying that he was now in the realm of space opera than physics, but we really are unable to imagine this fantastic future. He said, "The question – perhaps the most important question left to us – is whether or not we, or at least our descendants and successors, either genetic or mechanical, are going to be a part of this or not".

Science, adventure, the achievement of engineering at the bare limits of what is possible, expansion into a new environment, communication with alien intelligences – these are all temporary steps along the way, he said. An ultimate reason for going cannot be dependent upon local, short term justifications, even if we have to use those to justify the

> ***Most beneficial when pursuing the interstellar goal is the spirit of global co-operation, the exploratory mind-set and the need for larger scale, long term thinking***

funding. Indeed, we would be naive to attempt an answer – we can only suggest a direction. As a consequence the reasons will often seem to be almost mystical. The paleontologist Teilhard de Chardin speculated that we are seeing a progressive evolution of consciousness towards what he described as the 'noosphere' and perhaps what the idea of the starship represents is an engagement in a Teilhardian evolution of consciousness into the Universe. Parkinson finished by saying, "The human race can choose to be a part of this, to go outwards and participate in something beyond that we cannot imagine, or to sink back into the primeval ooze from which life originated. Change is inescapable."

The symposium presented the perfect opportunity for the audience and speakers to mingle. Seen here is speaker and I4IS team-member Stephen Ashworth answering questions.

Expanding minds

After an excellent lunch of roast salmon cooked by the BIS staff, I4IS Senior Advisory Council member Professor Ian Crawford kicked of the afternoon's discussions with a talk on 'Avoiding Intellectual Stagnation: The Starship as an Expander of Minds'. He spoke about some of the motivations for travelling to the stars, particularly from a scientific perspective, which included studying the interstellar medium and astrophysical studies of target stars. He also described the inevitable coupling between science and the arts and how each would influence the other as we aspire to travel to the stars. He quoted William McLaughlin from a 1993 *JBIS* paper who said, "The fine arts are modes of communication between our centres of thought and emotion and serve to assist in harmonising these centres… Space, in addition to contributing to human knowledge, packs an emotional wallop and, hence, will exert a strong influence on the fine arts." Crawford argued that it is not just that particular space scenes and particular space events will inspire particular works of space art (although they would undoubtedly do so), but that the increasing dominance of the 'Cosmic Perspective' on human thought would change the basic paradigms of artistic expression and interpretation. Art in all its forms would reflect a growing 'cosmic-isation' of the human mind as the colonisation of space expands opportunities for the diversification of culture. He quoted the writer and philosopher Olaf Stapledon from his famous 1948 London lecture: "It is in this connection that the planets open up possibilities… The goal for the Solar System [clearly even more potential on an interstellar stage] would seem to be that it should become an interplanetary community of very diverse worlds each inhabited by its appropriate race of intelligent beings, its characteristic 'humanity'... Through the pooling of this wealth of experience, through this 'commonwealth of worlds', new levels of mental and spiritual development should become possible, levels at present quite inconceivable to man."

Icarus Interstellar's Frederik Ceyssens described the potential geopolitical scenarios that will be necessary to fund such a huge project as an interstellar mission.

Crawford finished by discussing the pessimistic vision presented by Kim Stanley Robinson in his book *2312*, which says, "The stars exist beyond human time, beyond human reach… We live in the little pearl of warmth surrounding our star; outside it lies a vastness beyond comprehension. The Solar System is our one and only home." Crawford said that studies like Project Daedalus presented a more optimistic and hopeful view for the future of humankind in space.

The role of science fiction

Next up was a talk from I4IS researcher Martin Ciupa titled 'The Ethical Implications of Cultural Intervention by Space Faring Civilisations – What Science Fiction has to say'. He showed a set of posters from 1950s movies demonstrating the obsession at the time

Ian Crawford looked at how a coupling of the arts and science could benefit the interstellar vision.

with aliens carrying off our womenfolk. This included *This Island Earth*, *Forbidden Planet* and *It Came From Outer Space* as examples. He argued that science fiction does not just illuminate philosophy, but in fact the genre grew out of philosophy. He also argued that science fiction plays out the concerns of our possible scientistic futures as a source for exploring the deep rooted psychological concerns of humankind with science and the humanities. He proposed that science fiction is a valid source of hypotheses to examine, not as 'evidence' but as candidate – often cautionary – notions. He said that it represents a Jungian mythological-based forecast, putting forward tales that express our unconscious concerns.

Ciupa also considered the *Star Trek* Prime Directive, representing what some now would regard as an ethical approach to managing our relationships with aliens, and contrasted it with the interventionism shown by the Monolith of *2001: A Space Odyssey*, directed by Stanley Kubrick and written with Arthur C Clarke. He said that Klaatu, in the film *The Day the Earth Stood Still*, also presented a similar interventionist philosophy. Ciupa claimed that these stories had parallels with the troubles of today, such as whether the world should intervene in cases such as the civil war in Syria. His conclusion was that the notion of whether or not we should intervene with other alien civilisations has been well established in science fiction. He then spent time examining the Drake equation and asking if alien civilisations are communicating and long lived and what the likelihood of new intelligent life forming is.

The influence of geopolitics

The final talk of the day was from Frederik Ceyssens, representing Icarus Interstellar and the Fourth Millennium Foundation. He spoke about 'Future Geopolitical Scenarios, Their Dominant Philosophy and the Impact thereof on Deep Space'. He described the various geopolitical scenarios (including fictional) that could lead to a spirit of global co-operation, an exploratory mindset and larger scale, long term thinking for space. He discussed some of the large scale giga-projects from history that required government funding. This included the Manhattan Project ($22 billion), Project Apollo ($100 billion), and ITER, the French-based international fusion physics centre ($20 billion). His own projections for the first interstellar probe and manned starship were in the range one trillion and twenty trillion US dollars respectively. The interstellar probe mission had the prospects of discovery, prestige and inspiration. The first manned starship mission had the prospect of settlement in other stars systems.

Ceyssens offered his thoughts on geopolitical scenarios relevant to deep space exploration. Three broad futures were sketched out: one in which world governments tended to integrate into a unified global governing institution, one in which the current situation of several major power blocs continued and one where political institutions were eclipsed by non-state actors such as multinational corporations, with the implications of each of these alternative scenarios being discussed.

In conclusion he said that the greatest benefits to the human race when pursuing the interstellar goal were the spirit of global co-operation that it would require, the exploratory mind-set it creates and the need for larger scale, long term thinking.

The session rounded up with a discussion on the presentations with a chance for more involved questions of the speakers. It was announced that the speaker's presentations would be written up as papers and submitted to the *Journal of the British Interplanetary Society* for peer review and, hopefully, the publication of a special issue dedicated to this meeting.

Attendees were treated to a scrumptious dinner put on by British Interplanetary Society staff.

Project Dragonfly

Kelvin Long and Rob Swinney bring news of an exiting new technical project from I4IS, presented at the Philosophy of the Starship symposium.

At I4IS' recent Philosophy of the Starship symposium (see previous article) a rather special new project was announced as part of an interactive discussion workshop: Project Dragonfly. This is a concept for a laser-sail propulsion system that could be tested on the ground and then scaled up to Cubesat-based architecture as a proof-of-concept for scaling up to an actual deep space mission. Dragonfly will become the flagship project of the I4IS.

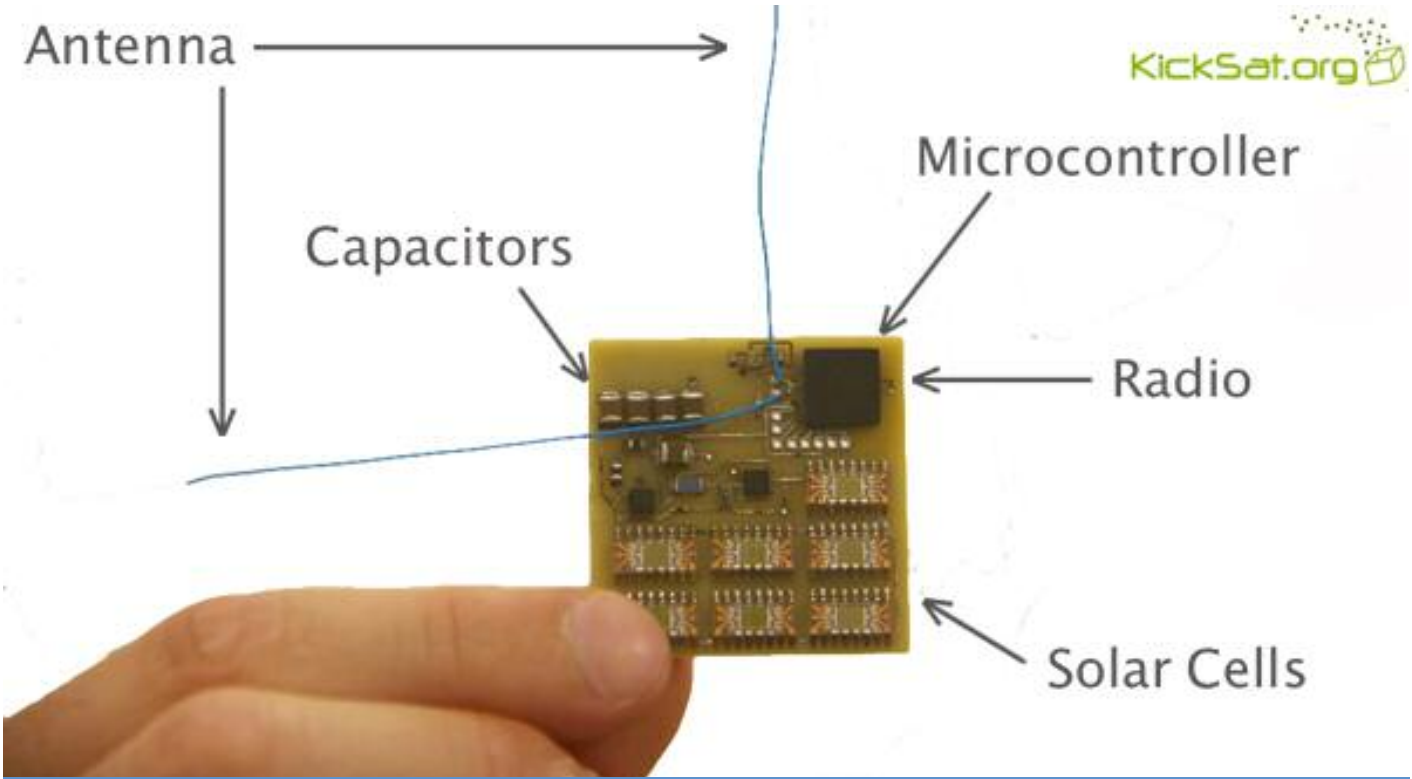
The original proposal for doing this study came about from discussions between Gregory Matloff, Andreas Hein, Kelvin Long and Rob Swinney. The technical basics of laser sail propulsion physics formed part of Long's introduction at the workshop, including how to calculate basic problems such as the sail loading, characteristic acceleration, lightness number and escape velocity on a basic solar sail. He also gave examples of sail materials with their different maximum temperatures, densities and reflectivities – for a sail material the more reflective it is, the better.

Long then discussed chipsat technology. Chipsats are small printed circuit boards that are embedded into a silicon substrate, integrated with solar cells and carrying their own dipole antenna. These devices are currently a first generation technology but they have much potential to evolve in capability and performance fairly rapidly over the next decade. Typically a chipsat might be only 25 micrometres thick and one centimetre squared in area. Long described how he and another researcher, Richard Osborne, had performed calculations on a chipsat that had a solar sail deployed with it. A range of calculations were shown with solar sails from 20 grams up to 40 grams in mass and over a range of sail reflectivities, pressures and sail loadings. Escape velocities of several hundred metres per second are plausible, in particular when using a sail area of nine centimetre squared, which would be powered by an input of approximately one watt of solar energy. This concept had been named Watt Intensity Solar Propelled (WISP) Sprites.

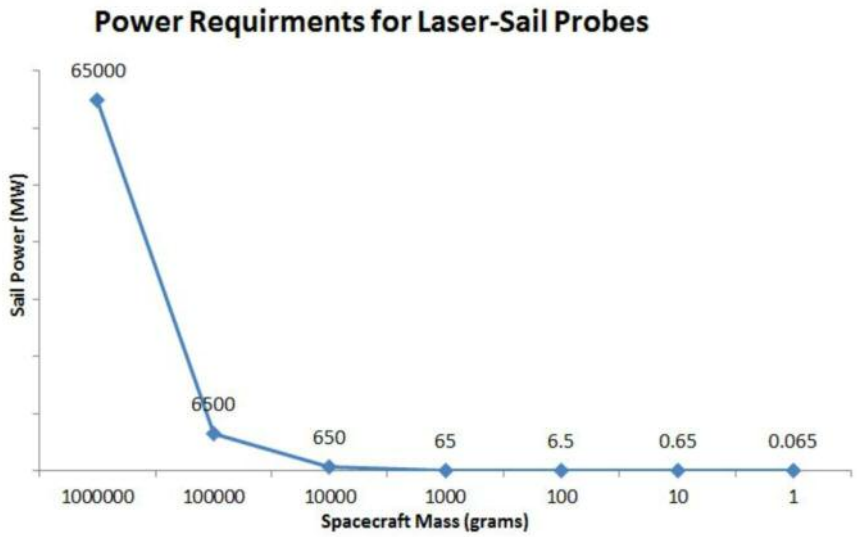
The problem with any solar sails though is that as you move away from the Sun the solar pressure will reduce with the inverse square of the distance. Laser sails can mitigate this. The size of the laser beam's spot will get larger as you move away from the source and this was an important parameter to be able to calculate. Even with a lens aperture of 10,000 kilometres in size, if it was pointed at the nearest stars some 270,000 astronomical units distant (one astronomical unit, or AU, is the average distance between Earth and the Sun, around 149.6 million kilometres), the angular spot size would be around ten kilometres because of beam dispersion.

Oort Cloud mission

In 1999 Geoffrey Landis and colleagues held a workshop to examine possible laser driven sail missions as part of an interstellar roadmap. The results of this work were published in a paper titled 'Beamed Energy Propulsion for Practical Interstellar Flight' (JBIS, 52, 1999). This included a Kuiper Belt mission to 100 AU carrying a 200 kilogram spacecraft of which 66 kilograms would be the payload mass. Accelerated by a 0.1 giga-watt beam



An example of chipsat sprite.



The power requirements of laser-sail probes. The greater the mass,

and assuming a sail diameter of one kilometre and a lens diameter of one kilometre, it would reach a cruise velocity of around 100 kilometres per second after around five years. The team also looked at an Oort Cloud mission to 10,000 AU. With the same spacecraft masses but using a 100 kilometre diameter lens, the spacecraft would be powered by a one giga-watt beam, accelerating to a cruise velocity of around 3,000 kilometres per second (one percent of light speed) and reaching the destination after around 18 years. Finally, the team had looked at an interstellar flyby mission to 4.2 light years, but this time using a total spacecraft mass of 100 kilograms and a payload mass of 33 kilograms. The sail diameter would again be one kilometre but the lens diameter would be 200 kilometres. Driven by a 25 giga-watt power beam, the spacecraft would reach a cruise velocity of 30,000 kilometres per second (ten percent light speed) and arrive at its stellar target after only four decades of travel time.

It was back in 1984 that the American physicist and interstellar pioneer Robert L Forward published his novel *The Flight of the Dragonfly*. The story featured a mission to Barnard's Star, 5.9 light years away, to visit a double planet called Rocheworld. The starship was named Prometheus and was propelled using a laser-sail propulsion system powered by a 1500 terawatt beam, needing a 100 kilometre diameter lens to accelerate the starship to twenty percent of the speed of light. It then used a 300 kilometre diameter deceleration lens. The total sail circular diameter was 1,000 kilometres and was constructed of aluminium. According to Forward's calculations, the starship takes barely half a century to reach Barnard's Star.

Around the same time Forward published a paper entitled 'Roundtrip Interstellar Travel Using Laser-Pushed Light-sails' (Vol 21, No.2, J.Spacecraft, March-April 1984). Forward developed the initial architecture for a laser-sail based system that would push spacecraft to interstellar distances. The laser power system used a 1,000 kilometre diameter lightweight Fresnel zone lens that would propel a one-way interstellar fly-by probe mission using a 1,000 kilogram, 3.6-kilometre diameter light-sail, accelerated at 0.36 metres per second squared by a 65 giga-watt laser system to 11 percent of the speed of light, flying past Alpha Centauri after 40 years of travel time. Forward also developed rendezvous mission scenarios but these won't be discussed in this article.

Forward's 1984 paper represented a breakthrough in approaching the interstellar challenge and, indeed, the 1999 Landis paper carried on from this earlier work. In addition many advances in lasers and sail technology have occurred since the 1980s, leading to the potential for improved design and mission performance. This includes using sail materials such as beryllium, or sails based on refractory oxide dielectric materials, which have a higher melting temperature.

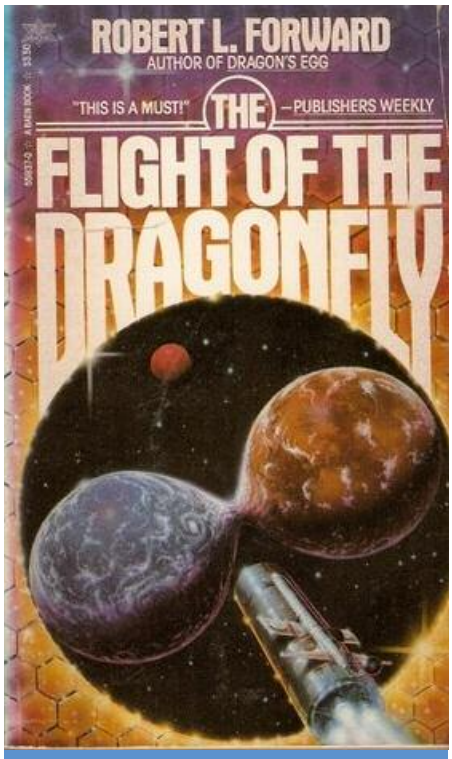
Defining the Dragonfly

With the fundamentals out of the way, the next step was to introduce Project Dragonfly. The exact parameters of the project had not yet been defined, but some initial requirements were drawn up so as to constrain the workshop discussions. The probe has to be propelled by laser-sail methods. It has to be demonstrated in a ground laboratory test experiment to validate the sail material, the physical basis of propulsion and performance. It has to be scalable to cubesat architecture and therefore the costs have to be sufficiently small, of order a hundred thousand dollars. The overall design and architecture has to be scalable to an interstellar mission, to a local star or brown dwarf system.

The deep space or interstellar mission has to be capable of transmitting communications data back to Earth (including health data during the cruise phase of the mission), including images of any exoplanets and scientific data about the local system that could not be obtained from long distance observations. The deep space mission has to be realisable within a decade from today and the total spacecraft design, build and utilisation has not to exceed millions of dollars.

After some of the initial thinking behind Project Dragonfly had been discussed, Long talked about the excellent microwave beam experiments previously performed by James Benford and colleagues as an example of what could be done ('Flight and Spin of Microwave-Driven Sails: First Experiments', Proc.Pulsed Power Plasma Science, IEEE, 01, CH37251, p.548, 2003). He also referred to the existence of 100 kilowatt and 100 megawatt Gyrotrons for comparison of what was possible. To contrast this, 0.1 milliwatt and two-watt lasers were passed around the room, both hand held devices.

Long said that part of the dual purpose behind Project Dragonfly was to help move interstellar studies towards an experimental validation regime, instead of just theoretical paper studies. He invited



Robert Forward's 1984 science fiction novel.

discussion and critique on the proposal and wanted the workshop attendees to help design the parameters for both the theoretical and experimental programme of work. Long described a five phase approach to the problem that saw ground-based vacuum chamber testing, followed by low Earth orbit technology demonstrators utilising cubesat mission architectures (see the Institute's Project CATSTAR, featured in issue one of *Principium*). This would be followed by near-space demonstrators, perhaps around the Moon, Mars or deep into the Solar System. Next would come an actual mission to the outer reaches of our Solar System, passing the Voyager and Pioneer probes, exceeding a distance of 150 AU and maybe even going as far as the Oort Cloud between 1,000–10,000 AU. The fifth and final element would be the launching of a Dragonfly mission into deep space, beyond one light year or 63,000 AU and towards the stars.

Discussion

Richard Osborne pointed out the constraints on the communications and power systems of such a mission, suggesting that optical lasers rather than radio may be better. Bob Parkinson added that for both optical and radio the signal to noise ratio was not good. Martin Ciupa proposed we look at novel materials like graphene that have unique properties and were near-term technology. Kelvin Long referred to some of the recent graphene sail calculations performed by Dr Gregory Matloff that indicate graphene as a definite option. One of the workshop attendees pointed out that such a mission needed to grab people's imagination and doing something more near-term first like a transfer mission around Mars may be the way to go. Stephen Ashworth discussed his own proposal for a Lunar Cycler mission that may be easier to achieve.

Gerry Webb bought up the important regulatory issues surrounding cubesat technology. He discussed the limitations, including altitude, on cubesats that were over a certain cost margin. He suggested that 520 kilometres may be the maximum height for a cubesat and that there were space debris issues to consider. However, a geosynchronous mission may be the alternative said Bob Parkinson. It was generally agreed that the costs of any deep space mission would exceed $10 million. Martin Ciupa discussed possible funding options, including crowd sourcing, philanthropists and investor-based routes. The business case for such a mission would also need to be made. Other issues discussed at the workshop included power-beaming ideas, marketing pitches, managing the dust particle risks, sail stability and what happens when the payload gets to the destination.

The initial phase of the project will be to define the likely tradespace for where such a mission would be plausible, although it is thought that an interstellar precursor version of Dragonfly would have a payload mass in the range 1-1,000 grams (utilising chipsat and nanosat technology) and would require 10-1,000 mega-watt power levels. The limiting factor on the mission is likely to be the power and communication systems and the team already has some novel solutions for addressing this by using swarms of laser-propelled probes, a flight of Dragonflies, interconnected by their own equivalent of a wireless network. This will be discussed in later reports.

For the project, extensive calculations will be required and work has already begun on the development of a comprehensive laser-sail physics code, written in FORTRAN, to aid such work. The accompanying chart shows the results of using the 1984 Robert Forward laser-sail architecture, applicable to both a mission to Centauri A at 272,000 AU and also into the Oort Cloud at 10,000 AU. In both these missions the probe is accelerated at 0.37 metres per second squared for a one year beaming phase, before reaching a cruise velocity of 11,280 kilometres per second or 3.76 percent of the speed of light. The interstellar mission would be completed in 115 years and the Oort Cloud mission is 4.7 years. The results in the chart are shown for a wide range of vehicle masses, from one gram up to 1,000 kilograms and the results show the sail power requirements for those different masses. Somewhere in this multi-dimensional tradespace is the optimum design point for the Project Dragonfly reference missions and this will be one of the team's first tasks to work out.

Meanwhile, we hope that the interstellar community is excited by the arrival of another technical project, Project Dragonfly, which can help to push forward just one of the propulsion options for the future. We can only hope that the pioneer Robert Forward would have been proud of our efforts and by making the attempt we continue to honour his memory.

Let the flight of the Dragonfly begin.

Starship Century

Starship Century is a ground-breaking anthology of science and science fiction edited by James Benford – a leading expert on space propulsion – and Gregory Benford, an award-winning science fiction author and physicist.

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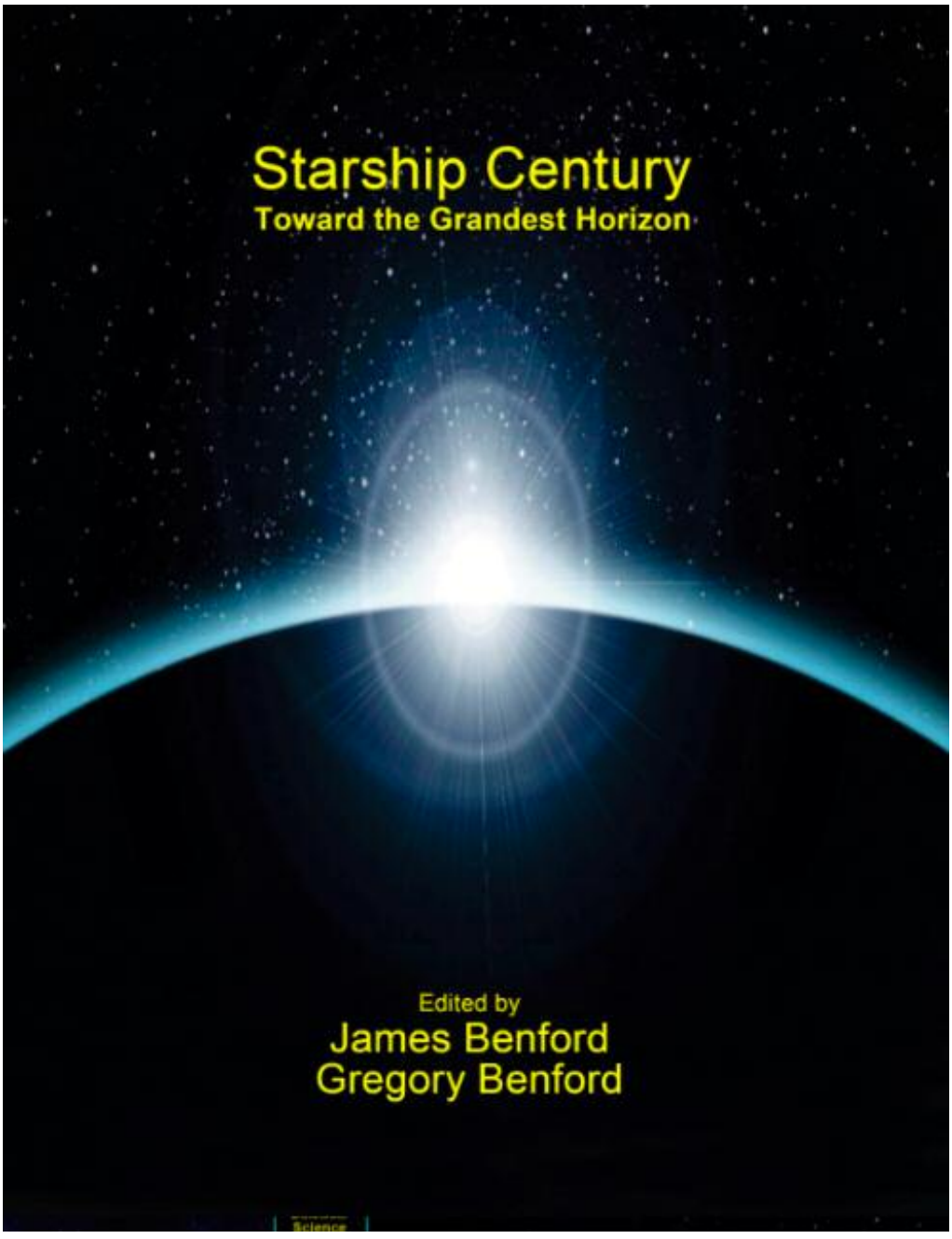

Mission Statement

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.

Vision Statement

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.

Values Statement

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.

Front cover: Project Dragonfly, art by Adrian Mann www.bisbos.com.

Back cover: The star-forming region IC 2944, which is 65,000 light years away in the constellation of Centaurus, shows dark clumps of dust and gas being eroded by the ultraviolet radiation of nearby stars amidst a background of fiery red emission nebulosity. Image: ESO.

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