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Introduction

David Raitt, ESA

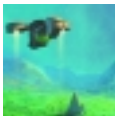
The idea that perhaps science-fiction (SF) literature contained innovative technological ideas that could possibly be brought to the point of development with either today's technology or technology that is just around the corner was the driving force behind a recent European Space Agency (ESA) study entitled "Innovative Technologies from Science Fiction" (ITSF).

The main objectives of the study were to review the past and present science-fiction literature, artwork and films in order to identify and assess innovative technologies and concepts described therein which could possibly be developed further for space applications. In addition, it was hoped to garner imaginative ideas, potentially viable for long-term development by the European space sector, which could help in predicting the course of future space technologies and their impact.

THOMAS THIEMEYER

Those involved in the study (scientists, engineers, SF writers, laymen) reviewed and brain-stormed on the technologies in SF literature and came up with a list of technologies which an expert team is assessing to see whether they might be worthy of greater in-depth evaluation. Some technologies might be judged unfeasible, some might have already been tried before and found not to work. However, new tools and techniques are being developed all the time and what was not possible several years ago might be possible today. Indeed, the study has already suggested a couple of promising areas for further investigation. Many of the concepts, technologies and devices thrown up by the study are contained in this brochure, together with artists' conceptions of these ideas.

Science-fiction literature, artwork and films are full of descriptions of space technologies and systems – often just pure imagination, sometimes based on some semblance of fact. Early science-fiction authors, artists, and illustrators described space concepts and spacecraft based on the limited scientific knowledge available at the time, whereas more modern writers generally portray the same basic systems as used in real-life space flight in their literature and art, even though artistic licence is often employed. It still gives them the opportunity, however, to promote their ideas, which may not otherwise be possible through more formal scientific evaluation processes.



Novel ideas clearly play an important role in science and technology, even when they do not have an immediately testable aspect, and writers predicted satellites and spaceflight well before they were actually possible. For instance, man has dreamed, and explored ways, of going to the Moon for centuries (take Cyrano de Bergerac in the 1650s), but it is only in very recent times that the technologies and infrastructure were in place to actually make it possible. It should thus be feasible to identify some new ideas in SF capable of convincing engineers to work seriously from such imagination. One has only to look at the past, where concepts described by Jules Verne, for instance, or Arthur C. Clarke and many others, have subsequently been developed or rediscovered.

Although early writings were often wildly inaccurate in many areas, some of the predictions made did come to pass and some of the systems and technologies described were subsequently successfully developed. Examples include ultra-high-velocity projectile launchers (1865); retro-rockets (1869); planetary landers (1928); rocket fins for aerodynamic stability (1929); vertical assembly buildings (1929); clustered rocket boosters (1929); EVA, pressure suits, life-support tethers (1929); construction of orbital space stations complete with living quarters using material ferried up and regular service visits (1945); satellite communication, with the satellites in geostationary orbit (1945); solar- and light-sails (1920, 1951, 1963); multiple-propellant storage tanks (1954); streamlined crew modules for atmospheric entry (1954), and so on.

Another example of a technology mentioned in the SF literature is that of the space elevator. This concept was first mooted in 1895 by a Russian scientist, looked at again some 60 years later by another Soviet scientist, studied further by an American physicist in 1970, and became the subject of an SF book by Arthur C. Clarke in 1979. NASA has recently completed a detailed study of the concept of space elevators and concluded that in possibly 50 years or so, this method of cheap transportation to geostationary orbit could become a reality. In fact, both NASA and ESA are looking at quite a few concepts in the advanced-propulsion area, some of which have been described to a greater or lesser extent in the SF literature.

In any discussion about the future of technology, it is difficult to determine exactly when a technology might be taken up and become ubiquitous. There are plenty of technologies that have taken (and still do take) many years to be accepted and deployed. Equally today there are many technologies in existence that could never have been conceived of one hundred years ago or even fifty. This phenomenon allows writers to put ideas or dreams down on paper that are not immediately dismissed as irrelevant either by the layman, engineer or scientist and which may perhaps ultimately bring the seemingly fantastic inventions into reality.

Science fiction can thus be used to stimulate thoughts and ideas that could perhaps be turned into a more realistic scenario with the eventual development of new innovative technologies not as conservative as those currently used in the space field. In fact, Hugo Gernsback, founder of “Amazing Stories” magazine in 1926, noted that science fiction was socially useful precisely because it inspired research and inventions.

On the other hand, we also have it in ourselves to develop technologies for their own sake, as well as for some ultimately useful purpose, including exploration. Inventors often invent things or come up with concepts that have no immediate or obvious application or a use outside a narrow specific domain and it requires a leap of imagination

DAVID HARDY

by someone else to turn that invention into a useful product elsewhere. This is where spin-off from space technologies comes into its own, and why it can take so long for some ideas or technologies to reach the marketplace.

A pioneer or dreamer will still have his dream regardless of whether the technology is actually available to make it a reality (take Dick Tracy and his two-way wristwatch radio for instance in the 1940s - that has only become a reality today, 60 years later with miniaturisation); and equally an engineer or inventor will still create a machine regardless of whether there is a defined use for it or not (take some of the developments in the robotics field, for instance). The application and selling of that idea often comes much later. On the other hand, innovative engineers can certainly take a dream or an imaginative idea and bring it to reality.

The study on innovative technologies for space applications emanating from science-fiction literature, art and films is something that is new and original for ESA and it could have important consequences for the use of existing and the development of new technologies. It is an in-depth look beyond the actual borders of science and techniques, and it deals with exciting concepts that might be worthy of eventual consideration for ESA's long-term space programmes and be explored in the decades to come. Quite apart from the potential contribution to future technological progress in space activities, the study and its description, categorisation and evaluation of technologies should offer a stimulating perspective to the science-fiction community at large, and provide science-fiction authors with fresh ideas and trends.

There have always been explorers and pioneers – it is a basic, not only human instinct – from animals in search of new pastures, from prehistoric man who crossed continental divides in pursuit of food and to find new places to live, and to people in our own times who have sailed the oceans and traversed the land in search of adventure. Where would we be today without the great explorers of the past?

So we have an in-built need to explore new places – especially the tiny pinpricks of stars in the night sky – simply because they are there and we are curious. For the purposes of such exploration, we have a need for new or improved technologies. Given that we have this built-in desire to explore, we will eventually develop the technologies to do this, when the real need is there and when other enabling technologies and materials become cheap enough or feasible enough to do so. This may take years or even centuries to achieve – but looking at the ideas and concepts of the past, which may have been forgotten or overlooked because they were not in mainstream science and technology, is certainly a worthwhile exercise and they may just give us a kick-start.

A Touch of Science in Your Fiction...

Jean-Claude Dunyach, Science-Fiction Author

Translated from the French by P. Ailleris, ESA

Without wanting to give a precise definition of "science fiction" (please God let me refrain from this temptation!) we can, however, underline that a science-fiction story is supposed to contain at least one scientific component – idea, theory, invention, paradox – which is intimately interwoven into the tale. In fact, the adherents of classical science fiction even claim that a science-fiction story can only be told through a link with this scientific component, which should generate the story, provide its originality and contribute to its resolution.

When I use the word "science", I embrace all sciences: nuclear physics as well as linguistics or anthropology, the cognitive sciences and the human sciences, the mathematical sciences or the aesthetic theories. The important aspect is that there should be a reasoning and a corpus of rules or axioms, a way to justify or to comprehend the world.

HUBERT DE LARTIGUE

I want to return to this notion of science intimately mixed with fiction. We can use fiction as a scenery, as an image generator, as a catalyst of situations. Where does the limit lie between science fiction and the rest ? It is sometimes difficult to be precise. Romeo and Juliette simply relocated to another planet is not really science fiction. Romeo and Juliette transcended – or twisted – by the fact that Romeo is an android or that Juliette is an extra-terrestrial entity trapped within a virtual Verone is not necessarily science fiction either – unless and except if the incorporation of the scientific component compels us to understand the story differently.

We can normally recognise science fiction if the underlying scientific idea generates a metamorphosis or a renewal of the story. The movie "Outland" (with Sean Connery) is a Western which takes place in a space station – an OK Corral in Space, if you prefer. The faint science-fiction aspect (here the space station) helps to add some striking images and to renew the scenery. It has no other purpose whatsoever and the same movie could have been filmed in a different epoch and in a different locality. Other Westerns exist that support this point. "Blade Runner", on the contrary, is indisputably science fiction, because the scientific idea of the "replicant" (or artificial human) compels us to comprehend differently the very notion of humanity.

In a science-fiction work, the science is not only there for embellishing things. It is the magic wand that can transcend the story!

The Allure of Vinyl Space Suits

Billy Boy, Tanagra Foundation*

Traditionally in science fiction, the majority of space-suit-clad astronauts of both the male and female variety wore fantasy outfits. Glistening, skritchy[1] space people became luscious creatures which made us all want to go into outer space. These rubbery costumes can only be considered as the "poetry" of space suits, as "real" ones, with their tested and safety-oriented protection, look a big, bulky bore.

[1] skritchy – the sound that plastic rubbing against itself makes

The shimmering materials, so beautifully enhanced by four-colour comic-book print ink, and the twist of a trained illustrator's hand, evoked gleam and glitz, evoked stretch jersey and wet-look vinyl.

BILLY BOY*

Within the svelte image of science fiction, as the genre-oriented entertainment is geared to excite the mind and ultimately the libido, the space suit takes on a glamour and allure of great importance. Vinyl space suits are nearly as important as the slightly ripped strapless, skin-tight sheath dress and matching high heels pumps is to the genre, a regulation outfit for female victims of robots and monsters when they are being carried away to somewhere alien.

Ultimately tight, shiny and "futuristic" in appearance, the science-fiction space suit is a joy to behold, an inspiration in itself. Flash Gordon, Buck Rogers, and a host of cult figures mesmerised us with their varnished and lacquered second skins, and undisturbed hairdos... making space travel seem so glamorous and so easy.

If you have ever been inside a clean vintage 1930s or '40s Pontiac or Chrysler "Airflow", you will know the feeling. Breathe in that chunkiness, that smell of early synthetic materials, the dazzle and weighty comfort; well, science-fiction space suits evoke all the same sensual tactileness and appeasement of the soul.

HUBERT DE LARTIGUE

A Few Thoughts about Ideas and Images in Science Fiction

Patrick Gyger, Maison d'Ailleurs

Film Poster by Byron Haskin, 1955

Science fiction is not a genre that tries to predict the future, nor does it pretend to imagine concepts that will actually happen, and only occasionally can technologies that science fiction describes be considered as innovative.

Science fiction – mostly so-called "hard science SF", i.e. the form of imaginative literature that uses either established or carefully extrapolated science as its backbone, according to writer Allen Steele; as opposed to "speculative fiction", which focuses mostly on social changes – may use science in a speculative way and try to extrapolate what might be done with a specific technology.

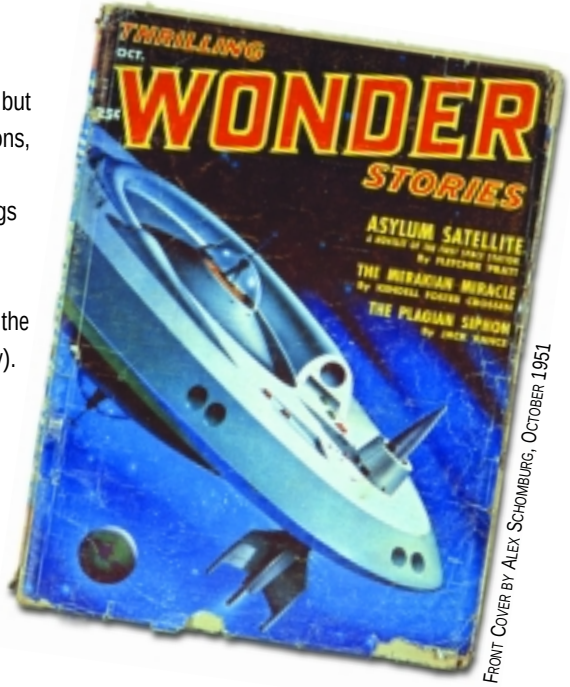
Still, science is always used as a narrative tool in science fiction: most of the time, technologies are imagined in order to make the story progress or to put the characters in a given situation that couldn't happen without it. For instance, the book "Dune" by Frank Herbert describes (among other things) the colonization of a sand-covered planet. The author wants to express how the protagonists evolve in that arid environment without any contact with the outside world. Therefore, Herbert has to "invent" a piece of apparatus that allows people to live with a minimum amount of water in the desert – hence, the “stillsuit”, a device conceived to recycle body fluids.

Board-game cover. Illustration by E. Serre (c. 1905), inspired by Albert Robida

Furthermore, science fiction prepares us to accept new ways of using technologies; it gives us the urge and the motivation to master them. Science fiction, as a very rational genre, is often about the beauty of science and its accomplishments. It can then work as an inspiration for scientists. So, as famous science-fiction writer Charles Sheffield wrote: "Science fiction and science fact swap ideas all the time." Thus a dialogue between science and fiction does indeed exist.

Science fiction is therefore not only a literature of ideas, but also of images. From Cyrano de Bergerac to Dan Simmons, writers have – with often rich descriptions – evoked extraordinary landscapes, prodigious inventions or beings without peers. Drawings and engravings can represent striking scenes from the text and thus came naturally as enrichments to science-fiction novels (see, for instance, the genial Albert Robida at the beginning of the 20th century).

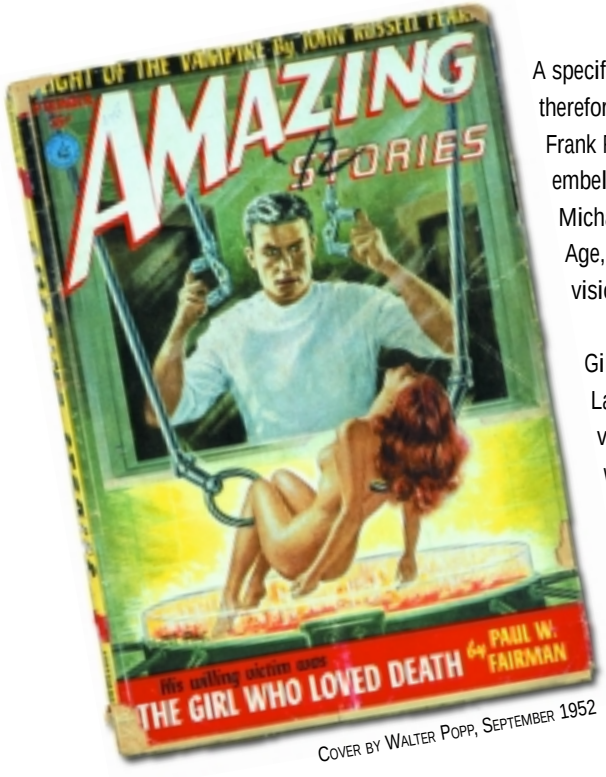
From the end of the 1920s, the spread of colour printing and the appearance of pulp magazines devoted exclusively to science fiction (like “Amazing Stories” or “Thrilling Wonder Stories”) allowed illustrators to play a more and more important part in the science-fiction community.



Front Cover by Alex Schomburg, October 1951

A specific tradition of pictorial art related to the genre has therefore formed, developed through the talent of creators like Frank R. Paul or Virgil Finlay. Later on, illustrative art went on to embellish the covers of paperbacks: Chris Foss, Tim White and Michael Whelan take over from the illustrators of the Golden Age, rendering on paper their futuristic, dreamlike and startling visions.

Gilles Francescano, Jeam Tag, Philippe Jozelon, Hubert de Lartigue, Manchu or Thomas Thiemeyer: their graphic styles vary, as do the techniques they use. But all, through their works, make us breathe the atmosphere of distant planets and believe in new horizons. These are whole universes that await us...



Cover by Walter Popp, September 1952

The Exploration of Space by Artists and Writers

Arthur Woods, The OURS Foundation

Throughout history, artists have traditionally accompanied explorers on many of the great voyages of scientific and geographic discovery. Space exploration is the greatest voyage of discovery ever undertaken and artists have been at the forefront from the beginning.

Before the flight of the first aeroplane, before the launch of the first rocket, both literature and art began the exploration of space and have progressed ever since. From the first use of the telescope in 1610, astronomers recorded what they observed by making drawings. The first science-fiction novel written by a scientist was by the German astronomer Johannes Kepler in 1615. Called "Somnium", it is a tale about a voyage to the Moon and acknowledges that the Earth's atmosphere does not extend infinitely. In 1870, Emile Bayard illustrated Jules Verne's "Around the Moon", a sequel to his classic novel "From the Earth to the Moon", with woodcut illustrations. At about the same time, James Nasmyth's illustrations were the first space landscapes to appear in a non-fiction book, "The Moon". Before Yuri Gagarin or John Glenn orbited the Earth, artist Chesley Bonestell was depicting what life would be like in orbit and which kind of space vehicles would be used. Since then, many space artists have explored places or concepts that were too distant, too technologically advanced or too dangerous for human beings to explore directly.

Art and literature about space have not only been an integral part of space exploration since its beginnings, they have also played a vital role in its development as well. The primary way of introducing the general public to ideas about space exploration has been the fictional images and scenarios created by visual artists and writers. Such artists and writers lay the foundation which makes future space activities understandable by the general public. Stimulating the public's imagination and excitement about space exploration has also helped to secure the necessary political and financial support for the national civilian space programmes. Indeed, science-fiction films are arguably the most popular and financially successful art forms of all time.

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Many space scientists and engineers began their careers in the pages of a science-fiction novel or in seats at the movie theatre. In the past 50 years of space exploration, artists have helped these space professionals to visualise their plans and projects and to give form to their developing technologies.

Inspired by the beauty and wonder of the cosmos and by the implications of humankind leaving its ancestral home planet, today artists are creating new art forms and techniques appropriate to human expansion in this new environment. Some have already realised artistic projects beyond Earth's atmosphere and others are gaining experience in weightlessness with parabolic flights. As the images in this brochure attest, this new generation of artistic space explorers are busy preparing their art, themselves and the public for the greatest voyage of discovery ever undertaken.

Summary of Science-Fiction Concepts

The Innovative Technologies from Science Fiction (ITSF) study conducted for the European Space Agency reviewed past and present science-fiction literature, artwork and films in order to identify and assess innovative technologies and concepts described therein which could possibly be developed further for space applications, and to gather imaginative ideas that might have potential for long-term development by the European space sector. It should be noted that the study was not exhaustive and that it barely scratched the surface of the vast reservoir of science-fiction literature and films. Nevertheless, the study has covered many of the major concepts mentioned in the literature.

Altogether some 50 fact sheets and 35 technical dossiers covering some 250 concepts and technologies were generated as a result of the study. In addition, artists submitted over 50 space-art images which they believed encapsulated the essence of many of the ideas found in science fiction.

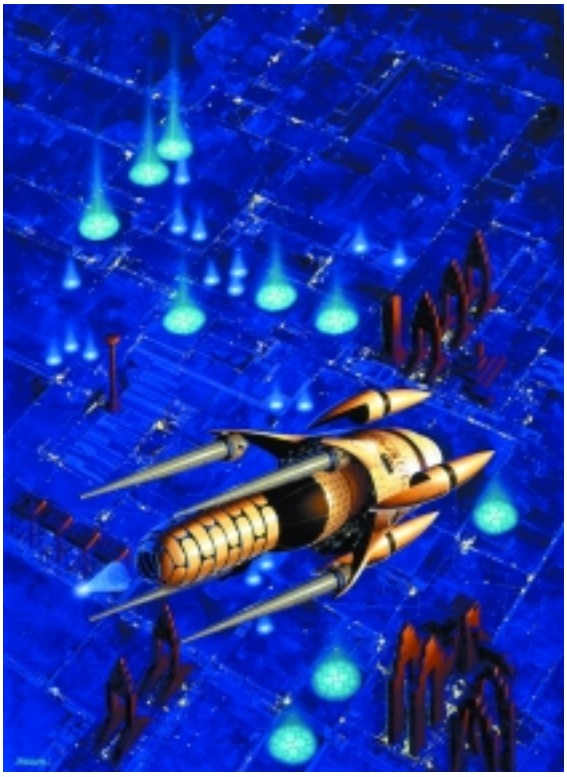
Many of these ideas, technologies and concepts have been distilled into the summaries contained in the following pages. Examples of science-fiction books and films are included to give the context and many of the images submitted as part of the ITSF study are used to illustrate the subjects. It must be emphasised that these concepts are pretty much the ideas of visionary and imaginative individuals, and it will be a long time before any of them can be turned in realistic and practical developments and actually used.

Further details about the study, together with the fact sheets, images and sources, can be found at http://www.itsf.org.

David Hardy

Propulsion Techniques

Perhaps the most critical factor in any attempt at space travel is propulsion. The distances we must travel are enormous, the speeds we can reach are puny, and it is very expensive. NASA's Space Shuttle costs $1 billion to launch and can travel at an amazing 27 800 kilometres per hour. However, it would take the Shuttle five and a half days to get to the Moon. Getting to the nearest star is all but impossible with today's technology – hence the interest (not only in science fiction) in more exotic methods of spaceflight.



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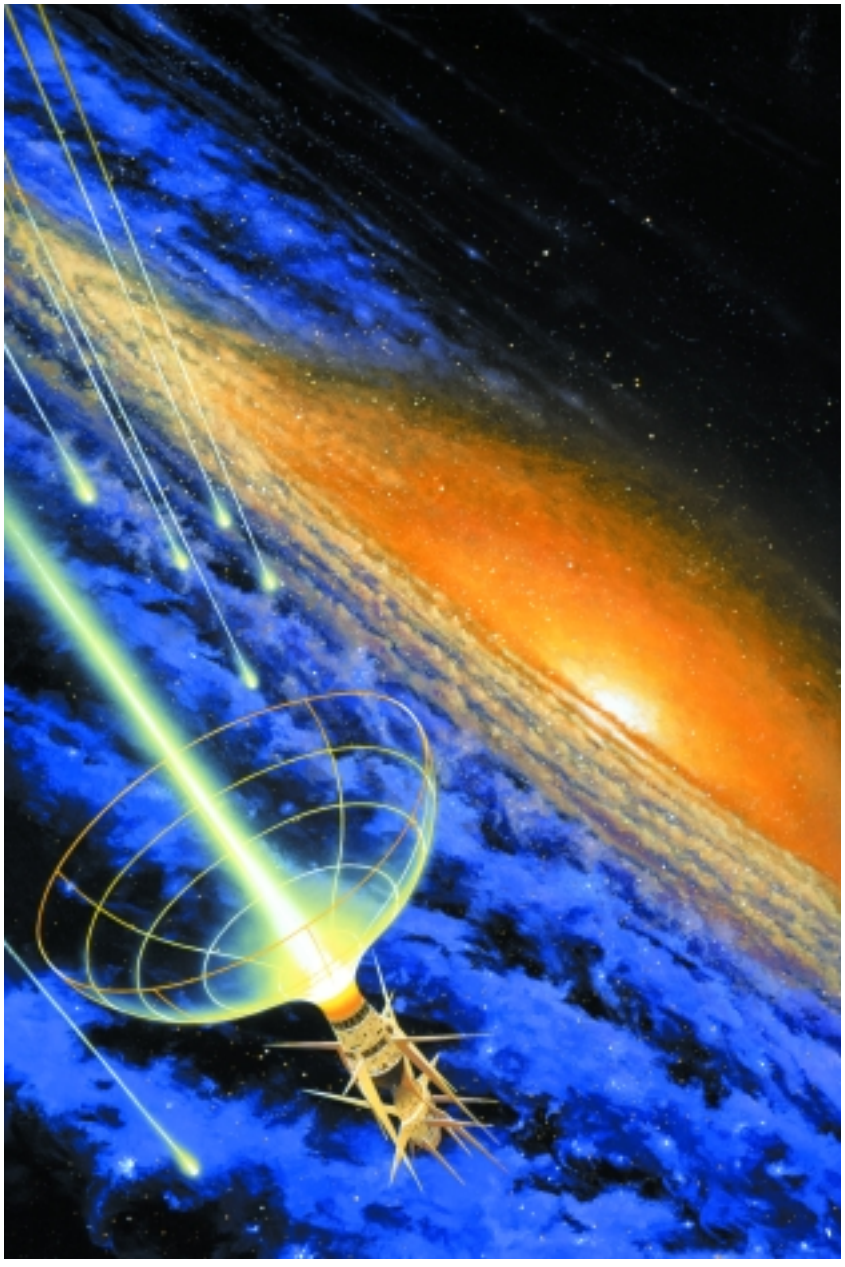
JEAM TAG

Much more advanced technologies are based on systems that do not require reaction mass, the stuff that pushes the rocket forward. The control of gravity is very popular here. David Weber describes a powerful drive in "Path of the Fury" (1992). Each ship can generate a small black hole in front of itself. As the ship falls toward the hole, the hole is moved by the ship – thus the ship continuously falls and accelerates. The concept of building lighter space vehicles with larger fuel tanks has nearly reached its limit. New engines with new fuels will be required to explore our own Solar System more fully and develop permanent outposts in space. Going to the stars will require a great leap in the conversion of known science into usable tools.

Ram Scoop Devices

To cross the gulfs between stars – even between next-door neighbours like Sol and Alpha Centauri or Barnard's Star – a very fuel-efficient method of travel is needed if the vessel is not to be just a huge fuel supply with a tiny ship added to it. Robert Forward in his 1995 book "Any Sufficiently Advanced Technology is Indistinguishable from Magic" sets a reasonable velocity for an interstellar craft at 10% of the speed of light. If exploration should go further, to Epsilon Eridani or Tau Ceti, for instance, then 30% of the speed of light should be the goal as an attainable velocity. These velocities are within the limits of those of the "fuelless" craft, light sails and ramjets.



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The ramjet or ram scoop is a device that uses a powerful magnetic field to collect interstellar hydrogen during flight. The greater the speed, the more efficient the collection will be.

The Bussard ramjet was proposed by R.W. Bussard in 1960. The original vehicle collects charged particles from interstellar space using a large magnetic scoop, and funnels them to the onboard H-He fusion reactor, where they are converted to fuel. According to Bussard's calculations, a 1000 ton starship with a 100% reactor efficiency, which collects fuel from a medium with 1 charged nucleon/cubic centimetre would accelerate almost indefinitely at 1g. In a year the craft would reach the speed of light and in the subjective lifetime of the crew it would also reach the end of the Universe. The diameter of the scoop would need to be 100 km for this 1000 ton vehicle, if it is to move through a space medium with a density of 1000 atoms/cm^3.

The top speed of a Bussard ramjet is theoretically very close to the speed of light, but practically it may be hindered by the density of interstellar matter, the drag of the magnetic field and the braking of the incoming protons. The advantage of Bussard ramjets is that they do not need to bring fuel along with them. The downside is that the ramjet will not work from a standstill, but needs a velocity of 4-6% of the speed of light to get the right flux of charged particles to work.

Poul Anderson ("Tau Zero") and especially Larry Niven ("Tales of Known Space") use ramjets extensively in their science-fiction novels. Here interstellar hydrogen

was trapped in nets of electromagnetic force, compressed and guided into a ring of pinched force fields, and there burned in a fusion fire. The maximum velocity of Niven's ramjets is reached when the speed of interstellar hydrogen coming in matches the speed of the exhaust at a significant percentage of the speed of light. In a chase between two ramjets in the "Ethics of Madness", both ships accelerate out of the Milky Way. In Niven's tales of the Man-Kzinn Wars there are many early encounters between ramjets and the alien ships. The earliest ramjets were unmanned, but later versions carried a crew and were often modified to increase thrust by the use of anti-matter/matter reactions. Most of these manned Bussard ramjets in Niven's stories have two stages of propulsion. The first stage is a laser-propelled light sail launch or a more ordinary rocket launch, and when the right percentage of the speed of light is reached (about 4-6%), the ramjet kicks in. One of the ramjets encountered in Niven's Man-Kzinn Wars carries its own supply of anti-matter, but scoops interstellar hydrogen to feed the matter/anti-matter drive using a standard Bussard ram scoop. This should increase the thrust enormously, and a fusion reactor would not be needed since heat is produced from the matter/anti-matter reaction alone.

Niven also considers the dangers of the powerful magnetic field to living organisms and puts some limitations on the use of Bussard ramjets. Modifications of the original ramjet concept include charging incoming neutral particles using a laser, getting the ramjet to ram speed using a light sail, boosting the thrust of the craft by anti-matter/matter reactions, using an accelerator as an alternative reaction-mass drive – the last concept could be enhanced using fusion or anti-matter catalysation. An onboard or Earth-based laser could be used to heat the incoming plasma in the ramjet to further increase thrust.

The multi-cycle Ram Augmented Interstellar Ramjet (RAIR) is an idea conceived by Alan Bond in 1974. Like the Bussard ramjet, the RAIR scoops up interstellar matter using an electromagnetic collector. The RAIR consists of a fusion-powered electromagnetic accelerator running through the core of the ship. Matter ahead of the ship would be ionised with a laser and collected. Collected matter would not be burned as fuel, but only used as reaction mass. The accelerator is thus used to create a ram flow.

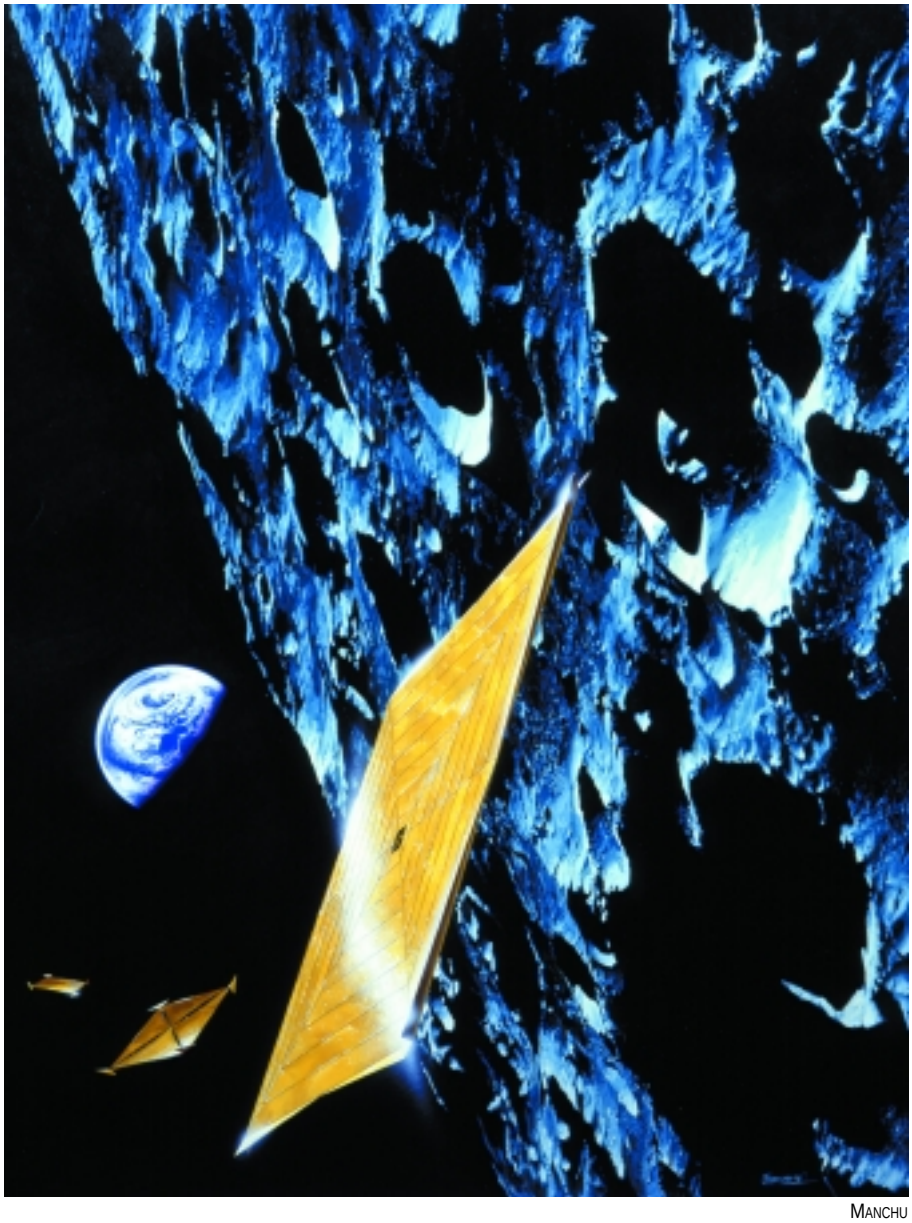
Laser-assisted ram scoops are also mentioned. An onboard laser could be used to heat and accelerate the plasma in the ram tube, maybe triggering fusion pulses. This could be used to enhance thrust, giving the craft greater accelerative power. The laser would need a fuel supply, though. Another alternative uses an Earth-orbit laser to beam energy to the craft, in the way of Niven's light-sail-launched ramjets. But instead of using the beam for push, the craft focuses the beam to heat up the incoming ion stream. This would increase thrust and acceleration power, but the effect of the laser would decrease with the craft's increasing distance from it, much in the way of the limitations of light sails.

Limitations of ram scoops include the fuel, since it is not known whether sufficient molecules would be available. Another major problem is the ram-scoop braking effect. Magnetic fields tend to catch particles, which resist the inward funneling of the scoop. Thus the craft would push a wide cone of matter in front of it, in effect braking it. Ramjets would also be large. NASA's model is a 45-year mission to Alpha Centauri, using a 3000 ton craft with a 650 km-diameter ram intake. Science-fiction writers often mention magnetic fields extending many thousands of kilometres. Of course, interstellar craft that carry their own fuel would be much larger.

Solar- or Light-Sails

The idea of leaving the engine of a craft behind and using the endless fuel supply of solar or star light seems like a great way of reducing the mass of a craft. The obvious disadvantage is the dependence on a high flux of photons to give the craft the needed acceleration. For interstellar travel, light-sail craft have to depend on extremely large-scale constructions such as huge solar-power relays around Mercury and enormous Fresnel zones in the outer Solar System.

Since light applies pressure to surfaces, the stream of photons can be used for propulsion in a near-frictionless environment. This concept is the background for light (or solar) sails. It is a method of space travel that negates the need for onboard fuel. Sails using the solar wind or only the light from stars are less efficient at larger distance from the Sun. In science fiction, solar sails are encountered from the 1920s, with early models being giant, multiple-sail craft. In other works, light sails are used to propel ramjets up to ram speeds. To increase efficiency, ground based lasers can be used to push the craft – using monochromatic light increases the reflectivity of the sail material and gives more acceleration. The efficiency decreases with distance, but much slower than if the craft was riding sunlight alone. The laser beam can be refocused by gigantic Fresnel zones. Light sails will have enormous areas, but the craft will carry no fuel or bulky engines. Alternatives to light sails include microwave sails, particle sails, magnetic sails, and laser or solar thermal or electrical propulsion.



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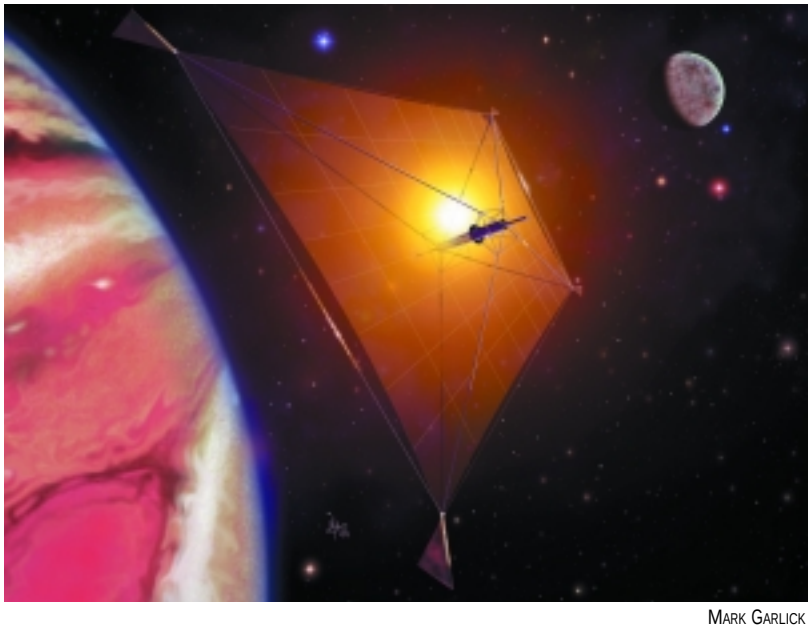
Basically, the light sail is a use of James C. Maxwell's discovery in 1873 that light reflected in a mirror applied pressure to the mirror. Since photons according to Einstein have mass then, by using the rather low friction coefficient of space, a craft is able to travel from A to B without having to carry bulky propulsion devices and especially without the need for onboard fuel. This is a large plus in terms of logistics. The fuel is supplied from nearby stars or by high-power lasers.

Arthur C. Clarke wrote “Sunjammer” in the early 1960s, but one of the earliest sources of light sails is a compilation of works by Cordwainer Smith, the name under which Dr. Paul M. A. Linebarger wrote science fiction in the 1950s. In this story the first manned interstellar ships are propelled by light sails. The smallest, earliest sails were only about 5000 km^2. They were made of “tissue metal” – probably a fine mesh to give lightness to these enormous sails. Each ship carried many sails, and was steered by the manipulation of the sails much like sail-carrying ships today. Larry Niven is a later science-fiction writer who uses light sails extensively in his “Tales of Known Space” setting, where they are a way to propel a vessel to speeds where ram scoops can be used. These light sails are almost always pushed by giant lasers, placed either on tracks on Mercury, or on asteroids in the belt between Mars and Earth. In one story, “The Mote in God’s Eye”, written with Jerry Pournelle and set in Pournelle's own universe, the first encounter with an intelligent alien species is in the form of a meeting with a laser-pushed light sail.

There are several types of light sails – in the basic model the craft uses only light from stars to generate push. This is the model used by Cordwainer Smith. Acceleration is only provided as long as the light is intense, that is in the inner parts of solar systems. In those areas, light sails may be a cheap and efficient way of getting about. Acceleration is low, and the maximum speed is usually guessed to be about 25% of the speed of light. As the distance to the photon source increases, so does the efficiency of the light sail needed to sustain significant acceleration. There might very well be a point where a sail’s degree of push is countered equally by the friction of the incoming interstellar matter in the craft’s path.

The simplest form of light sail is a big circle or square with the craft dragged along on wires. This model is used in Robert Forward’s “Rocheworld”, where buckling of the sail occurs, but with no great concern from the crew. The danger of having the sail flap around or collapse in the fluctuating photon stream from the Sun seems to be a problem considered only in the real world, where ways of reinforcing the sail with poles seem popular.



MARK GARLICK

Other forms of sail include the laser-powered light sail, where a giant laser or system of lasers bombards the sail with monochromatic light. This is favourable since it is easier to create efficient reflectors of monochromatic light compared to reflectors of ordinary sunlight composed of a spectrum of wavelengths. To be effective, the laser will have to be enormous and have its beam focused before the light reaches the sail. The laser-powered solar sail is seemingly the only way of getting a light sail to be effective on interstellar journeys. Larry Niven's early “Tales of Known Space” have giant laser batteries on Mercury, surrounded by a loose net of solar collectors.

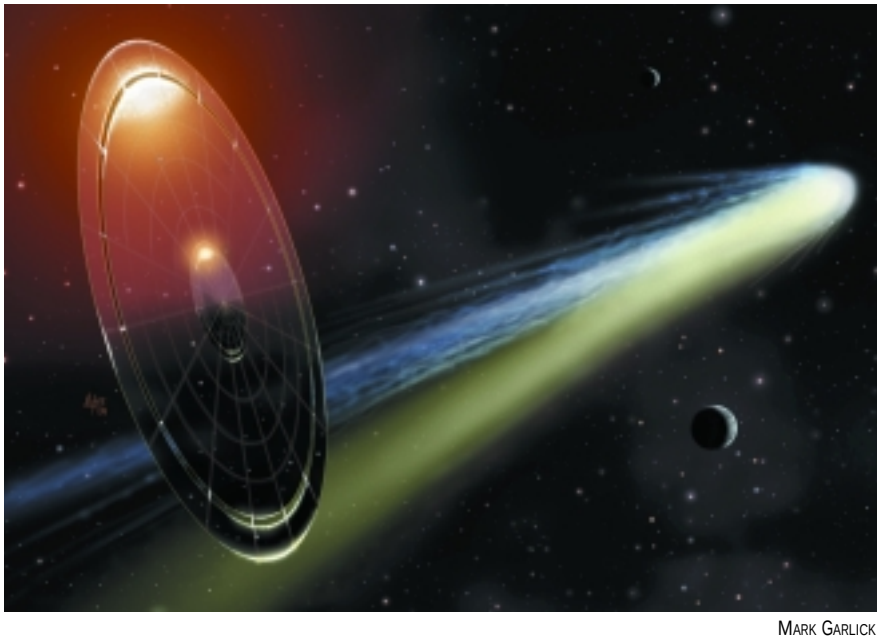
One proposal by Robert Forward involves a lens the size of Texas (a Fresnel zone) placed between Saturn

and Neptune, which focuses the lights from several thousand solar collectors in orbit round Mercury. These solar-pumped lasers will have a collective power of 65 GW. The light sail itself is a two-stage one, where the large outer sail is slightly bowl-shaped. It will be separated from (but very likely still connected to) the inner sail, upon arrival at Alpha Centauri (or Barnard's Star?). The large outer sail then focuses the laser beam back onto the inner sail, thus braking the craft. The downside to laser-powered light sails is the tremendous laser power needed to propel the craft over interstellar distances.

Alternatives to light sails have been proposed. The microwave sail is also an idea from Robert Forward. A tiny spacecraft, the Starwisp, is propelled by microwaves transmitted from a solar-powered satellite in Earth orbit. The craft would be mostly a 1 km diameter mesh sail covered with microcircuitry, weighing only a few grams. The beam power should be 65–100 GW, pushing the 4–5 g craft to 20% of the speed of light, using a Fresnel-zone type lens to focus the microwave beam.

Particle sails are not exactly sail craft, but still use the concept of catching a beam from a ground-based emitter to gain acceleration. The beam in this case is a stream of heavier, slower particles like protons, emitted from a fusion reactor as plasma. The beam would disperse quickly, but the push gained could be up to 1000 g propelling the craft to 1/3 of the speed of light before the effect dissipates. The beam-projection limitations would make interstellar missions a one-way venture.

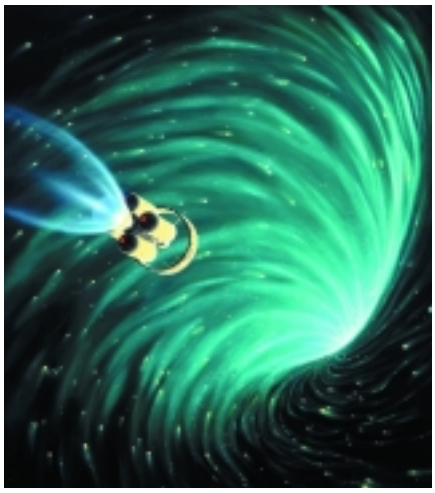
The magnetic sail is a use of Lenz's Law (flux will attempt to remain constant in a electrified wire loop). The loop should be made from superconducting wires, and will expand to a circle when powered. The craft will be attached to this loop. Charged particles meeting the loop or magsail at other angles than parallel to the magnetic field will transfer some of their momentum to the field and thus push the craft. A magsail weighing 36 tons could receive accelerations of 0.0001 m/s^2 to 0.009 m/s^2 varying with the orientation of the sails. The mag loop is very small compared to a standard light sail, being only about 10 km in diameter.



Mark Garlick

Solar sails are very close to being non-fiction. The Russians have conducted the Znamya tests of light thin-film applications in space. The tests seemed to be for Earth-surface illuminatory purposes, but were also a test of alternative propulsion methods. In the United States, a light, bowl-shaped object was lifted 20 m using a laser beam. In Europe, ESA and DLR have developed solar-sail technology small enough to be carried into space and light enough to enable efficient sailing. A 20 m x 20 m model consisting of aluminium-coated sail segments with carbon-fibre-reinforced plastic hooks has been manufactured and tested.

Warp Drives



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The concept of warping space-time as an advanced propulsion technology is a very common one in science fiction; probably the best known example is found in “Star Trek”. This technology would allow faster-than-light travel, and, maybe even more relevant for astronomy, represent a powerful window to the Universe both in terms of space and time. Ranging from Star Trek’s “Voyager” pilot episodes to Larry Niven’s “The Mote in God’s Eye” and R.J. Sawyer’s “Starplex”, warping is one of the most common ways of circumventing the enormous travel times which would otherwise render science fiction a very boring genre.

In the “Star Trek” world, the primary propulsion system used by most faster-than-light interstellar spacecraft is the warp drive. The system used by Federation starships employs the controlled annihilation of matter and anti-matter, regulated by dilithium crystals, to generate the tremendous power required to warp space and travel faster than the speed of light.

A warp drive is basically a mechanism using exotic matter with negative energy density for warping space-time in such a way that an object could move faster than light. In 1994, Miguel Alcubierre worked out a space-time geometry which describes such a warp drive. The warp in space-time makes it possible for an object to go faster than the speed of light while remaining on a time-like curve.

Rodenberry takes full advantage of the concept of the warp drive in his “Star Trek” odyssey to transport us to the edges of our Universe. In the “Avatar”, Poul Anderson shows how humankind could travel between stars by using the exotic relativistic effect of massive rotating cylinders on the space-time metric surrounding them, as predicted by the Theory of General Relativity. The latter allows us to consider some orbits around a massive rotating cylinder which are “instantaneously” connected to other orbits around another massive spinning cylinder located at an arbitrary distance from the first cylinder. From a technological point of view, the main problem is, of course, to build a network of such rotating cylinders spread throughout the entire Universe.

MANCHU

From the physics perspective, the relationships between space and time in a particular region are confined by the realms of General Relativity. A basic example is a “wormhole”, which could use exotic matter to causally connect two distant locations in space. A hypothetical spaceship could enter one “mouth” of the wormhole and exit from the other very distant “mouth”. Although the travelling issue is certainly the most inspiring aspect, wormholes, if they exist, could prove to be astonishing tools for seeing (in a broader sense) other and older parts of a remote Universe.

Ion Drives

An extension of current technology is explored by Edward Gibson (a US Astronaut) in his novel “Reach” (1989). His spacecraft uses an ion drive to accelerate atoms of mercury to 1% of the speed of light and throws them out of the back. The drive does not use that much fuel, but it does use a lot of electricity (which can be provided by solar panels or nuclear reactors).

Tim White

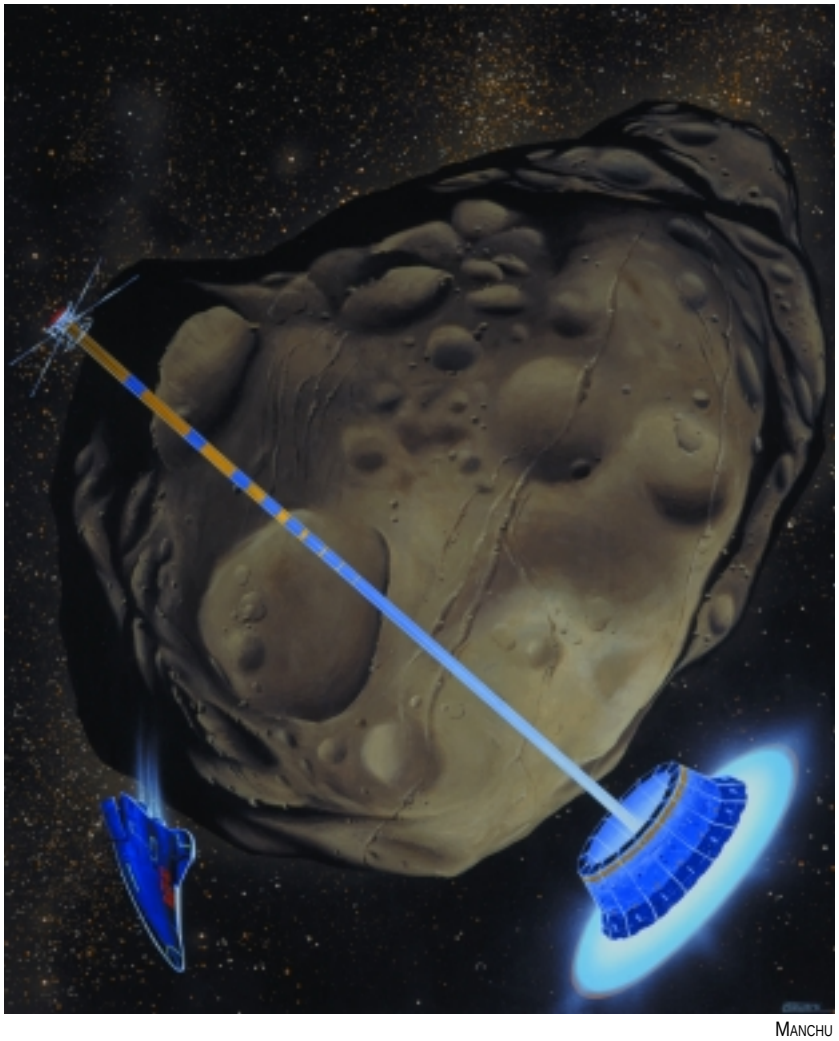
Cutting-edge technologies are extended by Paul Pruess in “Starfire” (1988) and David Mace in “Nightrider” (1987). Science knows that causing two atoms to fuse into a single atom generates a large amount of energy. These two authors describe propulsion systems where controlled fusion reactions are used in place of the chemical reactions in modern rockets. The advantage here is that fuel is used much more efficiently – you can go faster with less fuel.

More advanced technologies have also been considered. A ship could theoretically move by firing an extremely powerful laser. Individual photons, though of very, very low mass, move very quickly. This is an extension of the ion drive using smaller and faster-moving particles. This idea was explored by Larry Niven in “The Warriors” (1988).

Anti-matter

Anti-matter is explosive stuff! In a scientific sense, it is the opposite of the normal matter which comprises both us and our surroundings. Every type of particle in nature is thought to possess its own anti-particle – which will have the opposite charge to the particle itself. Originally theorised to exist by scientists in the first half of the 20th century, the fact that a matter/anti-matter reaction releases a hundred times more energy (per mass of fuel) than even the most powerful nuclear reaction quickly brought it to the attention of the science-fiction genre. "Star Trek" is probably the most obvious example of the basic use of anti-matter in science fiction. Star ships of the Federation use stores of anti-matter as their source of fuel, so that their ships are powered by a matter/anti-matter reaction.

Sometimes the use of anti-matter was as straightforward as being the ultimate rocket fuel, for example in the anti-matter rocket starships in Peter F. Hamilton's "The Nightsdawn Trilogy" (1990s). On other occasions, anti-matter has been viewed as the natural successor to nuclear reactors as the source of power of the future, a prime example being the "Starship Enterprise" from the 1960s television show "Star Trek" (not to mention its sequel series and film spin-offs). The "Enterprise" contained a central reactor core which powered the entire ship in which matter and anti-matter were mixed, releasing enough energy to boldly go where no-one had gone before!



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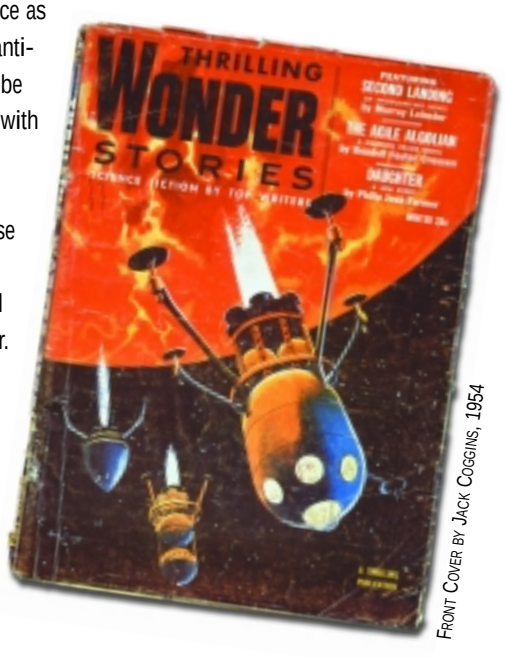
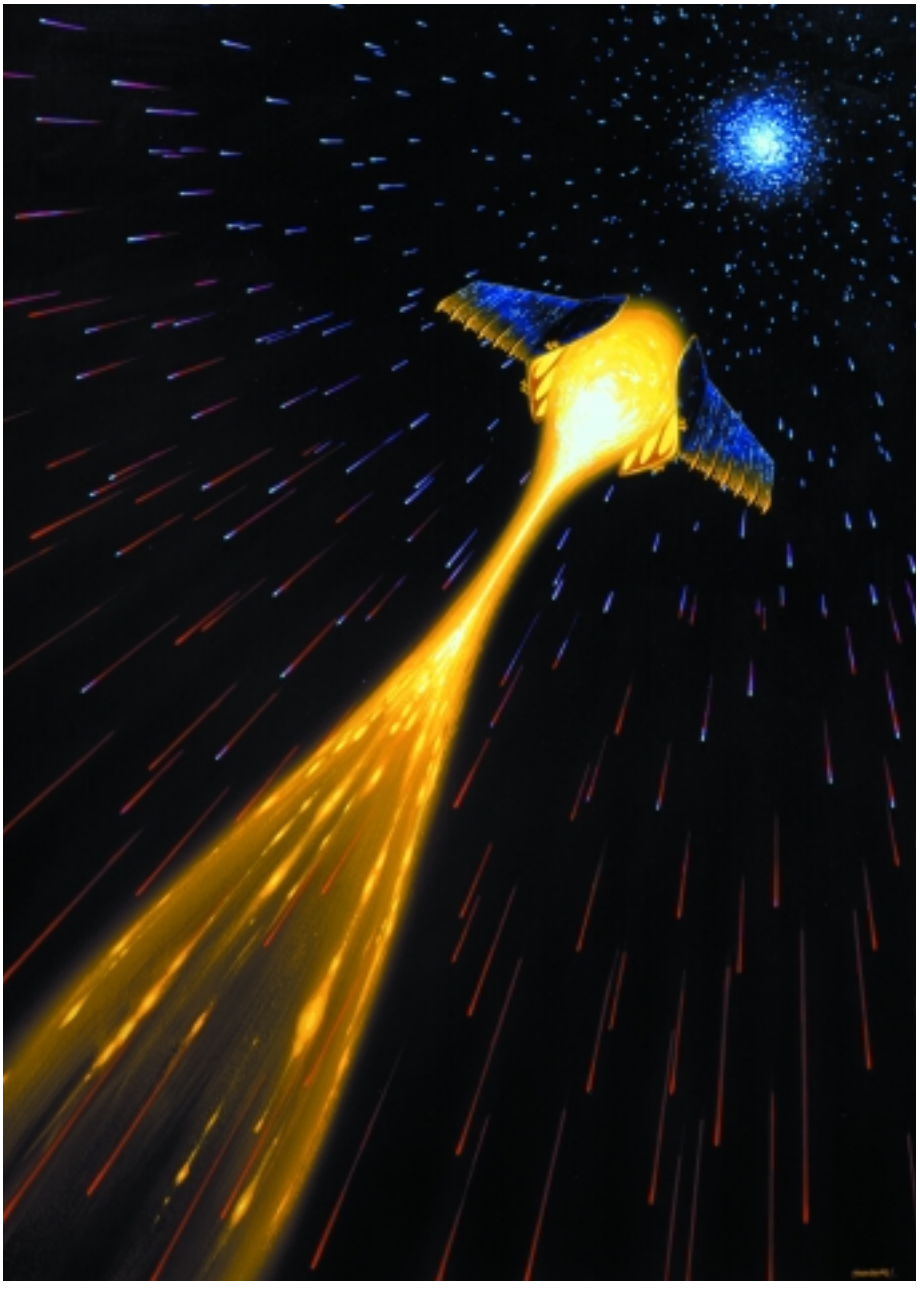
Some science-fiction authors have even asked what-if questions about anti-matter. In the book "Traces", Stephen Baxter explores the idea that anti-matter might exist in space as large chunks of "anti-ice", which could be mined and mixed with large volumes of normal water to provide, in the case of the story in question, an awful lot of steam power.



FRONT COVER BY JACK COGGINS, 1954

Fusion Drives

Many of the interstellar spaceships that leave Earth in science-fiction literature and reach out to explore the unknown make use of a fusion-drive propulsion system. The fusion drive, also known as impulse drive, is a propulsion system that works on the classical Newtonian reaction principle and is used for subphotonic flight (i.e. velocities less than the speed of light). The propulsive medium is composed of electrically charged particles, which are compressed and accelerated to the speed of light before they leave the spaceship's propulsion system.



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The term fusion drive arises because the particles being accelerated are a byproduct of the fusion reactors, which are used to produce the energy for the spaceship. As the "fuel output" of the fusion reactors is limited, additional "fuel" – often in the form of Bismuth atoms – can be injected into the propulsion system if more thrust is required. This system is then often introduced as the spaceship's "afterburner". Fusion drives are used in the "Star Trek" series, "Star Wars" movies, "Perry Rhodan" novels, and in many other science-fiction books, computer games and films.

Although humanity has not been able to utilise the enormous power of the fusion reaction for energy generation, a fusion-drive system might not be so far off. Fusion reactors have one major problem: they have to hold the plasma particles together long enough for several fusion reactions to be established, generating enough energy to sustain the heating and confinement of the plasma. A fusion drive would also need to support several fusion reactions, but it does not need to be as efficient as a fusion reactor, as the main purpose of the fusion reaction is to heat up the plasma particles to extremely high temperatures. As the temperature of the plasma particles increases, the velocity with which they are streaming out of a magnetic nozzle increases also, thus creating a very effective propulsion system.

Pellet Propulsion

Having been developed from nuclear-weapons research, pellet propulsion could have a stunning application for the high acceleration of interstellar-travelling vessels, for instance. Its premise is simple: every few seconds, a fission nuclear bomb is released from the starship and detonated a short distance behind it. The vessel is equipped with an enormous metal pusher and shielding plate attached to the ship into which vaporised debris from the explosions slams.

Back Cover of "Amazing Stories" by James B. Settles, June 1942

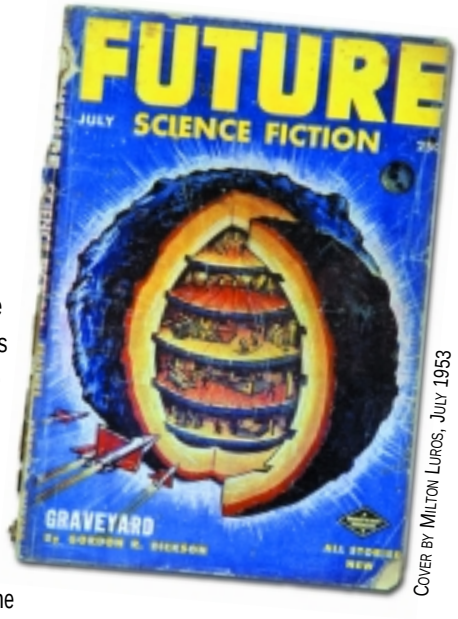
The idea of such an "atomic drive" was a science-fiction cliché by the 1930s, but it appears that Stanislaw Lem and Frederick de Hoffmann conducted the first serious investigations of atomic propulsion for spaceflight in 1944. The research culminated in the "Orion" project whereby a prototype vehicle was propelled to an altitude of 100 m by six detonations in a ground test in 1959 in the United States. At a time when the US was struggling to put a man on the Moon, science-fiction authors and a group of visionary engineers had laid out the propulsion technology for interplanetary and even interstellar travel. The project was later cancelled for political reasons.

Manchu

Another modification would be to use other forms of pellets, e.g. nuclear particles accelerated by magnetic fields or through a mass driver. By positioning fuel pellets along the trajectory of the vessel, the launch mass could be drastically reduced.

Colonization of Space

Space Stations and Space Colonies

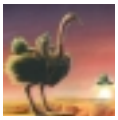


Cover by Milton Luros, July 1953

Most space stations in science fiction serve predictably as stopovers for travellers, laboratories, factories, or military bases. But some envisioned facilities offer intriguing ideas for builders and residents of future space stations. Arthur C. Clarke's "The Lion of Comarre" (1948) proposes a space station as the headquarters for a world government, Michael Moorcock's "The Fireclown" (1965) creates an orbiting monastery, Patricia A. McKillip's "Fool's Run" (1987) designs a space prison, and Dean Ing's "Down and Out in Ellfive Prime" (1980) offers a comfortable home for the elderly. Space stations could protect endangered species, as in the film "Silent Running" (1971), or house bio-engineered creatures, like the dinosaurs recreated in Robert Silverberg's "Our Lady of the Sauropods" (1980). For tourists, science fiction suggests space hotels, satellite casinos, World Fairs, and summer camps for youngsters. Innovative space activities include zero-gravity dancing, as in "Spider" and Jeanne Robinson's "Stardance" (1979); exotic sculpture, as in Fritz Leiber's "The Beat Cluster" (1961); and "flying" with artificial wings, as in Konstantin Tsiolkovsky's "Beyond the Planet Earth" (1920).

Tim White

Moving farther into the future, science fiction imagines space stations as essential homes for humanity should Earth become uninhabitable, as in Thomas M. Scortia's "Earthwreck!" (1974). Arguing that space life represents the next logical step in human evolution, Bruce Sterling's "Schismatrix" (1985) depicts strange new forms of humanity evolving beyond Earth, while Terry Greenhough's "Thoughtworld" (1977) suggests that psychic powers might increase in space. Space stations themselves might evolve to become generation starships travelling to distant stars, as in Don Wilcox's "The Voyage that Lasted Six Hundred Years" (1940); or series of orbital stations might be connected by cables to Earth and each other to form an immense inhabited ring around the planet, as in Clarke's "The Fountains of Paradise" (1979). Clearly, when writers imagine what humanity might someday do with space stations, the sky is not the limit!



Biospheres

PHILIPPE JOZELON

As the environmental conditions on other celestial bodies are harmful to life, artificial habitats are vital at least in the early phases of colonization. Given the biological needs of plant and animal life and the limited resources available, it seems only natural that a number of advanced high-tech features will be needed to support early settlers. These include solutions such as using piezoelectric plastic membranes for outer hulls, which create electricity from wind on the surface of Mars, and another layer capturing radiation, or constructing entire cities by using lightweight aerogel structures instead of rigid domes. During the Biosphere-II experiments, about 80% of the food supply was provided by locally grown crops; this percentage will need to be increased substantially for long-term expeditions.

A long-term vision of a biosphere is the so-called “Dyson sphere”, originally proposed in 1959 for an advanced civilisation to utilise all of the energy radiated by their sun. It is an artificial sphere the size of a planetary orbit. The object would consist of a shell of solar collectors for habitats around the star, so that all or at least a significant amount of energy will hit a receiving surface where it can be used. This would create a huge living space and gather enormous amounts of energy. Another version of the Dyson sphere is a “ringworld” (also the title of a novel by Larry Niven), which is a band of matter along the ecliptic of a planet that would require less material, although the mechanical stress would be even greater.

JEAM TAG

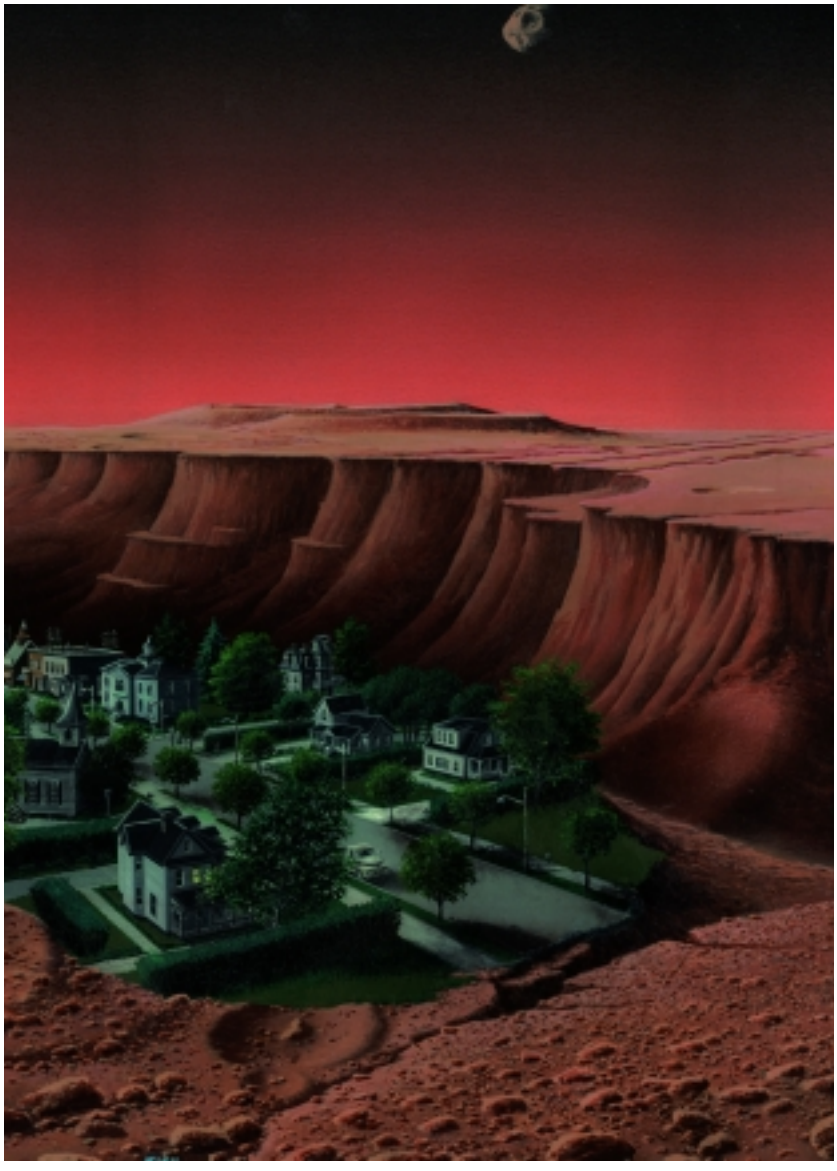
The science-fiction novel “Red Mars” by Kim Stanley Robinson gives the regolith as an example of a biosphere. The first habitats were just simple barrel-vaulted chambers, which were covered by 10 m of sandbagged regolith to stop radiation and to allow the interiors to be pressurised to 450 mbar. They used indigenous resources to get their building materials; for example, bricks were made of clay and sulphur from the regolith. Later, more sophisticated materials and structures were used. The novel “Red Mars” does not give too much detailed information about the structure of the biospheres, but there are other science-fiction novels and movies having biospheres/ecosystems as a central theme. For example, “Silent Running” (1971) has the hero Lowell Freeman looking after plants in giant space greenhouses. Back on Earth, all the trees have long vanished. When orders are received from Earth to destroy the greenhouses, Lowell cannot go through with it, but cannot persuade his three colleagues to help him save the plants, so he makes other "arrangements". “Starlost” (TV series, 1973) was all about people living in a spaceship for generations until they forget they are on a spaceship. Besides the Mars trilogy, Kim Stanley Robinson also wrote “Icehinge” and “Antarctica” – both of which have closed biosystems as important elements.

An ambitious experiment in Cornwall, England is perhaps the earthly forerunner of a biosphere in space. The Eden Project consists of several geodesic domes (known as biomes), which are enormous greenhouses specially constructed to house and grow many of the world’s plants.

Colonization of Other Planets

Colonization of other planets is a common theme in science fiction. Many stories describe what happens when something goes wrong in the colony – which is something to keep in mind! Some techniques are disturbingly simple and possible today, but without the potential for great success. Some techniques may be possible in just a few years.

The most realistic technique for colonizing our Solar System comes from Stephen Baxter's novel "Titan" (1997). Using a single US Space Shuttle, two old Apollo command modules, and some additional equipment cobbled together, five scientists travel to Saturn's largest moon, Titan. Whilst not the safest or most effective method for colonizing another world, it does have the advantage of being feasible right now. Another nearby colonization effort is described in David Drake's novel "Surface Action" (1990). He describes a technique for colonizing Venus by terraforming it. Using small asteroids and comets, the atmosphere of Venus is altered and seeded with Earthly life (bacteria, algae, etc.). A novel that deals exclusively with colonization and the problems that could be faced by colonists is "Legacy of Heorot" (1987) by Larry Niven, Jerry Pournelle, and Steven Barnes. There are detailed descriptions and logical reasoning for the equipment and techniques used by the colonists.



Jeam Tag

Extraterrestrial colonization is not going to be a programme undertaken lightly. Yet, the need for space and the potential safety for humans as a species lead us to the conclusion that colonization will have to happen. However, the colonists will have to be lavishly equipped and supported for their efforts to be successful.

Back Cover of "Amazing Stories" by Frank R. Paul, October 1941

Long-Duration Spaceflight

VIGNETTE VIELLEMARD, 1901

As we too often forget, the marvels of science used in science-fiction stories are not limited to the domains of physics or technology, but also include products of life science. As an example, imagine mankind has finally located the ready-to-colonize, Earth-like planet it has always dreamed of. This planet is orbiting a nice little star, a bunch of light years away from our blue planet. The interstellar ship is ready, but there is just one little problem. As faster-than-light travel is not available in this not so hypothetical universe, the trip will take between fifty and one hundred years. The members of the crew will be more than eighty when they reach their destination. Life science can easily solve this first problem by giving human beings a longer life expectancy.

GILLES FRANCESCANO

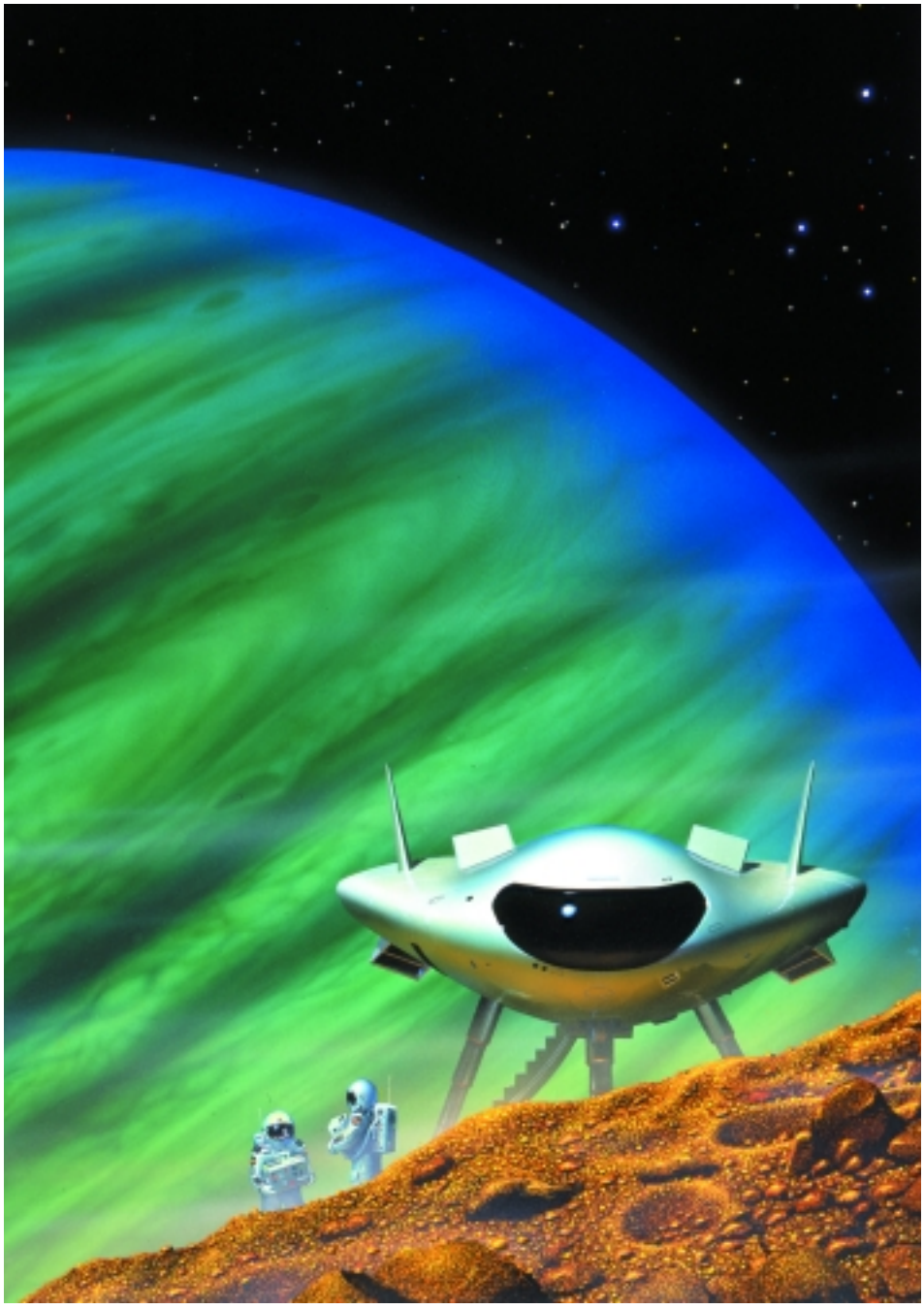
However, even a science-fiction writer would not dare to imagine that the small crew would remain sane after spending a century crammed into a space ship cruising in the middle of nowhere. Once more, life science comes to the rescue. As in the novels “2001: A Space Odyssey” (Arthur C. Clarke) or “The Legacy of Heorot” (Larry Niven, Jerry Pournelle and Steven Barnes), the crew can be put into hibernation or frozen sleep until they reach their destination. In addition to the crew, the frozen cargo of the ship will also include all the plants and animals (embryos) that will be necessary for these new settlers to set up their colony.

Genetic engineering is also a key life-science technique in many science-fiction stories dealing with the exploration and colonization of planets. Most of the time, planets will not be fit for human life. Making them habitable (terraforming them) will be a huge task, and genetically engineered organisms and plants can be key players in the process (see “Le rêve des forêts” by Gérard Klein or “Venus of Dreams” and “Venus of Shadows” by Pamela Sargent). If terraforming is not possible or cannot be afforded, why not use genetic engineering to make human beings fit to live on the planet instead? In the novel “The Seedling Stars” by James Blish, a new species of human beings is created using a mix of genetic engineering and quite mysterious techniques called “pantropy”. These “adapted men” are completely transformed to be able to live on Ganymede, the icy satellite of Jupiter: their blood is made of liquid ammonia, their bones of ice IV, and their breathing cycle is based on the chemistry of sulphur! One danger of such a radical transformation is that the adapted men could be so different that they are no longer human. In the novel “City” by Clifford D. Simak, they become so different that they give up communicating with the good old human species.

Energy and Power

Space Power

Space power is an absolute necessity in science fiction, just as it is in real-life space travel. The topic covers everything that can serve as a source of power in space, from the simple chemical reactants used by real-life rockets upwards. In “The Legacy of Heorot”, written by Larry Niven, Jerry Pournelle and Steven Barnes in 1989, nuclear fusion is used both in power plants and rocket engines to provide the energy required to cross the distances between the stars. In the television series “Star Trek”, which goes back as far as the 1960s, the even more powerful matter/anti-matter reaction is used as a power source. Greg Bear even used the concept of a technology that could completely convert mass into energy in his book “Anvil of Stars”.



These are concepts involving huge energy outputs, but there are also much more subtle examples of space power to be found in science fiction. Peter F. Hamilton's “Nightsdawn Trilogy” contains the idea of dragging conductive tethers through a planet’s magnetic field to generate electric currents, as well as living ships which are capable of absorbing the diffuse background radiation of space. Perhaps even more unusual is an idea from the late-1990s film “The Matrix”, in which human beings are harnessed as sources of power. “People power” in its most literal sense, one might say!

Tim White

Power Supplies

Future spaceships have to sustain numerous power-consuming subsystems as they fly through space. While the idea of using nuclear power in the form of fission and fusion reactor systems is rather straightforward from today's viewpoint, science-fiction authors have anticipated extremely complex and futuristic energy-generation systems to fulfil the power needs of their spaceships. The power system list found in the literature encompasses fission and fusion reactors, tylium reactors, matter/anti-matter reactors, singularity converters, hyperspace taps and various other systems.

Tim White

The "Perry Rhodan" series of books, for example, features the use of singularity and anti-matter generators, which use a strong gravity field to generate a miniature black hole. While the matter collapses into the black hole, 50% of its mass is converted into pure energy, released in the form of gamma-rays. The singularity generator is superseded by the anti-matter generator, which uses the same principle but cracks the black hole open again (by using a pulsating gravity field). Assuming that the released matter has been converted into anti-matter, the other 50% of the matter, which had been left over in the earlier engine, can also be converted to energy.

The "Battlestar Galactica" series utilises both fusion and tylium reactors, the latter using the exotic material tylium, which contains so much energy that a single reactor can unleash an energy of 1.8 Exawatts. The "Star Trek" series, on the other hand, makes use of a classical matter/anti-matter annihilation process to generate the required energy in the spaceship, while the "Star Wars" spaceships utilise fusion reactors (sometimes with tremendous dimensions, as for example within the "Death Star").

Space Lasers

Front Cover, June 1952

Space lasers in science fiction are tricky things. The reason for this is that there are myriad examples of ray guns, laser weapons and death beams scattered throughout the genre of science fiction. However, buried beneath this race of fictional arms lies a wealth of creative thought dedicated to the use of lasers in space. From the simple use of lasers as directional communication devices, to the use of huge, planet-scale lasers to destroy space debris or even rework the face of a planet or moon, the creators of science fiction have come up with any number of ingenious ways to use laser-based devices. A variation of the solar-sail concept introduced by Arthur C. Clarke in his book "The Wind from the Sun" allows a laser beam to be used instead of sunlight as a means of pushing a light sail. The type of large laser needed for this could also be used to transmit power from one point in the Solar System to another.

Thomas Thiemeyer

Perhaps the most versatile example of space lasers in science fiction is the phaser technology from the "Star Trek" television show and series of films. Although ostensibly a weapon system, phasers end up being used as a heat source on missions to planets, to cut holes in walls to escape hazards, and even as a means of transmitting energy to other locations. This is a good example of how, with a little thought, a basic ray gun can actually be used for many other purposes.

Magnetic Shields

Shields are widely used in science fiction to protect spacecraft and persons – see, for instance, “Maximum Wrap” by D. Galanter. They could be produced by strong magnetic fields. Magnetic shielding against radiation, and the use of magnetic fields as “sails” for real interplanetary missions, are currently under discussion. We can deflect electrically charged objects using electromagnetic fields, leading to concepts for protecting space travellers from cosmic radiation. That's the physics trick we know that resembles the powerful special effects of the Enterprise's shields. Neutral particles and objects cannot be deflected by magnetic shields.

Tim White

In “Star Wars” the strong shields were repeatedly used to shield a planet, a battle cruiser or a space ship. The rebel shield over Hoth had to be lowered to allow the egress of departing ships and the ion cannon shots against the Imperial blockade in “The Empire Strikes Back”. If magnetic shields were used as deflector shields, they would have to be lowered to allow a ship to depart, as the strong magnetic field would interfere with the on-board electronics. Shields in “Star Wars” are usually associated with spacecraft, but there are several examples of devices involving shields on a smaller, personal scale: in “The Phantom Menace”, Federation destroyer droids had built-in ray shields, and the army of the Gungans was also outfitted with portable in-atmosphere theatre shields. Personal magnetic shields could be made using magnetic dipoles or coils. Superconducting coils could generate magnetic fields that are strong, but would have to be actively cooled to work at room temperature, which is a big effort. Strong magnetic fields could also be used like a big sail, catching the plasma naturally found in the solar wind and interstellar medium like a cotton sail catches the wind. Magnetic sails could also be used to accelerate or decelerate a spacecraft on an interplanetary mission.

Computers and Communications

Instantaneous Communications

Although Captain James T. Kirk flipping open a communicator and saying “Beam me up Scotty” has evolved into Captain Picard tapping his chest and saying “One to beam up”, where are we really going with communications systems and the way we interface with them?

Michael Boehme

Boom microphones and earpieces get smaller all the time, but where will this end? According to David Drake in the book “Hammer’s Slammers” (1979) it will end with a small relay device being implanted directly into the chest, transmitting sound through bone conduction and sub-vocalising speech to send messages. William Gibson in “The Nano Flower” (1995) has personal messages delivered in virtual reality by an interactive computer representation of the sender.

Thomas Thiemeyer

These, though, are means of interfacing; what of the mechanics of sending the message? In the collection of stories “Venus Equilateral” (1947), George O. Smith gives us a relay station orbiting the Sun and independently forwarding messages to a colony on Venus. To send messages outside our Solar System, faster-than-light communications are the ideal. It may be a subspace message in the mould of “Star Trek” or “Babylon 5”, but James Blish (“Beep”, 1954) and Ursula K. LeGuin (“The Dispossessed”, 1974) have put forward in different forms the idea of the perfect, ideal, instantaneous communicator – the Dirac communicator and Ansible would link the galaxy together instantly. In “Bleep”, for instance, there is an instant communicator which broadcasts to every receiver tuned to it and attaches a compressed message (the beep) containing every message that ever has and ever will be transmitted.

In the film “Contact” (from Carl Sagan’s novel) an alien message is received on Earth. In order to understand it, massive cryptographic resources are brought in, but a basic premise is that any such message is designed to be decoded. As Dr. Ellie Arroway (Jodie Foster) says, “Mathematics is the only true universal language.”

Wearable Computers

Wearable computers are body-mounted, interactive personal computers (PCs) designed for applications where operators are required to be mobile, keep their hands free, view data in bright sunlight or darkness, and/or keep a largely undisturbed view of the environment while viewing computer or video data. This rugged, full-function computer system will be configured with a head-up display in which the image is projected onto the inner surface of the eyeglass lenses. The unit is designed to maximise the view of the outside environment while the display is in use. The wearable computer includes a voice-recognition system with integral microphone. Accessories such as a wrist-mounted/pocket mini-keypad, roll-up/fold-up keyboard, or data gloves can also be utilised. So, a wearable computer is a PC that can be worn, like tools, clothing and glasses, and interact with the user based on the context of the situation. With head-up displays, unobtrusive input devices, personal wireless local-area networks (LANs), and other context-sensing and communication tools, the wearable computer can act as an intelligent assistant wherever the user is. Other applications for wearables include: communication devices, mobile inventory management, medical assistance and telemedicine, smart appliances and vehicles, and military and optical applications.

TIM WHITE

There are several reasons why such computers will be successful. First of all, there is the sex appeal. Movies like “The Matrix” and “Johnny Mnemonic” (loosely based on a short story by science-fiction writer William Gibson) have made the mirrorshades- and black-leather-wearing antisocial persona appealing. Secondly, the power enclosed in the tiny box, either because of smaller, faster chips or due to being able to access information elsewhere, such as via the internet or world-wide web, allows more processing power and gets more projects done. The Enterprise from “Star Trek” is one such example. The ship itself is the network, and all of the tricorders, data pads, comms. badges and other portable devices access the ship’s main computer to do their job. Thirdly, the wearable computer will offer seamless integration between the user and the technology for increasingly lower cost. The comms. badges from “Star Trek” and “Babylon 5” are worn by aficionados of the television shows already. There are also throat mikes and earpieces disguised as jewelry and other accessories. Tattoos and body-piercing art can also be integrated into mobile computing’s growth, with the ever-smaller devices hidden in earrings, tongue studs and necklaces.

A “wearable” computer taken to its ultimate level is described by Robert L. Forward in his “Rocheworld” series, which started with “The Flight of the Dragonfly” in 1984. In another story, “The Christmas Bush,” jointly conceived by Forward and scientist-writer Hans P. Moravec, there is a futuristic “wearable” computer used mostly for medical diagnostics, communications and housekeeping. William Gibson is the master of seamlessly integrating man and machine. He demonstrated this when he wrote “Neuromancer” in 1984, touching off the cyberpunk movement. Many of his characters displayed technological enhancements à la “The Six Million Dollar Man” or “The Bionic Woman”. But some of them also were able to “jack in” to their computers or the internet directly because they were “hardwired” with technology in their bodies.

We already use cellular phones, pagers, two-way radios and other tiny, portable devices for communication. A wearable computer would incorporate communications with its computing power. The old tricorders in the original “Star Trek” series (1966-68) would be like the cell phone. The communications badges worn on the chest in the more recent “Star Trek: The Next Generation”, “Star Trek: Deep Space Nine” and “Star Trek: Voyager” series and on the hand in J. Michael Straczynski’s “Babylon 5” are examples of wearable computers for communications. But in fact one of the earliest examples dates from the 1940s, when the lantern-jawed comic strip detective hero Dick Tracy used a two-way wrist watch to communicate with his HQ. In the 1980s, a camera was added to the watch so that he could take pictures at the crime scene and transmit them back to base. Nowadays, it is fairly commonplace for wrist watches to have calculators (often solar powered), television, cameras or global-positioning features.

Wearables will be used in the medical profession. Here again “Star Trek” comes to mind with the tricorder and various portable medical devices used by the medical staff. The tricorder is able to scan someone’s body and transport information to the main ship’s computer and then get information back for the doctor to utilise in the field. The holographic doctor in “Star Trek: Voyager” could be argued to be at least a portable computer, as well as an artificial intelligence, as could the character “Seven of Nine”. One of the applications that the company Blue Fire is currently working towards is for the paramedic industry and has the ability to utilise this “tricorder” function by getting data, video and voice to and from databases, hospitals and doctors, which can assist in life-saving in the field.

Optical computing technology is also being considered. In the movie “The Last Starfighter”, the aliens are shown with hydraulic see-through optical pieces that flip back to allow full vision. Cyberpunk master William Gibson best demonstrates the optical technology. In “Neuromancer” and “Mona Lisa Overdrive”, the mirrorshades are often more than just plain glasses, and in “Virtual Light” Chevette Washington steals “a pair of innocent-looking sunglasses.” But, as the story goes on, “these are no ordinary shades. What you can see through these high-tech specs can make you rich – or get you killed.” IBM’s television commercials seen during the Superbowl and the Olympic Games show a tiny acrylic box that is used to see the computer screen. Blue Fire, Xybernaut and many other optical engineering companies are working on true, see-through head-up displays for the wearable computer, much like those in Apache helicopters and high-end cars such as the Cadillac.

Robotics and Cyborgs

Robotics and Automation

Toy from the Maison d'Ailleurs Collection

One of mankind's major skills is the ability to construct and use tools. The silex tools of the stone age have now become complex machines – computers – and we rely more and more on them. It is therefore not surprising that robots and automated machines are omnipresent in the societies of the future imagined by science-fiction writers. This is especially true when the topic of their stories is the exploration and colonization of space.

In many science-fiction novels, the colonization of space by mankind is prepared for by the systematic exploration of stellar systems with automated probes. The most impressive way to conduct this exploration is to use automated, auto-reproducing machines called Von Neumann machines. The idea, present in the novel "The Time Ships" by Stephen Baxter, is to build and send towards the stars a single machine that will be able, once it has arrived at its destination, to start building replicas of itself (at least two) and send them towards other stars (like a computer virus which, once it has infected a machine, will send copies of itself using electronic mail!). Once started, the process will quickly expand. If each machine builds two replicas of itself and sends them to explore other stellar systems where they will also duplicate themselves, the number of stellar systems explored after n generations is roughly 2^n. After ten generations, more than one thousand stellar systems would have been explored and prepared for colonization, whilst after twenty generations this number would reach 1 million. The whole galaxy would be conquered after only thirty to forty generations of machines!

Jeam Tag

Vignette Vieillemard, 1901

The ultimate stage of automated machines is artificial intelligence (AI). Wild AIs tend to be presented as a threat to mankind. As an example, in the novels of Gregory Benford, starting with "Great Sky River", mechanical AIs form a complete, independent order of life (the fifth one) and are actively fighting the biological civilisations for supremacy in the Universe. And, as far as mankind is concerned, the balance is in favour of the AIs which it may have originally created. In this context, it is impossible to avoid the three laws of robotics imagined by Isaac Asimov. Their goal is to make sure that intelligent or semi-intelligent robots will never hurt or be used to hurt human beings. The three laws are: first, a robot will not hurt a human being, or by remaining passive allow a human-being to be hurt; second, a robot must obey orders given by a human being, except if these orders are in conflict with the first law; and third, a robot must protect itself as long as this protection does not conflict with the first or second laws. In his long series of novels and short stories, Isaac Asimov has explored all the consequences of these laws, as well as their possible flaws.

Cyborg Systems

The cyborg concept, first proposed by Manfred E. Clynes and Nathan S. Kline in 1960, to adapt human beings to space environments, has proved a rich resource for science-fiction writers, most notably Martin Caidin whose novel "Cyborg" (1972) was adapted as TV's "Six Million Dollar Man". However, the history of cyborgs in science fiction predates Clynes' and Kline's analysis of the possibilities of a human/technical hybrid by at least two decades. In 1944, "Astounding Science Fiction" magazine published a story by Catherine Lucille Moore which explored the possibilities of a prosthetic body made of "metal rings" and controlled by "electromagnetic currents" generated by a human brain and, in the 1950s, Cordwainer Smith's "The Game of Rat and Dragon" imagined remote devices controlled by human telepaths and guided by cats.

By the 1980s, when the idea of direct human interface with computers was being entertained as a serious possibility, the work of the so-called "cyberpunk" writers was littered with imaginery cyborgs. In Tom Maddox's "Snake Eyes", a war veteran called George appears to time-warp into Cordwainer Smith's story when his brain implant, designed to enable instant communication with the systems aboard his space ship, malfunctions to the extent that it forces him to eat cat food. In John Shirley's "Wolves of the Plateau", "brain chips" are a valuable currency.

PHILIPPE JOZELON

Prosthetic devices to enhance and extend the range and function of human vision are probably the most pervasive of cyborg systems in recent science fiction. Engineer Geordie La Forge's "visor" in "Star Trek: The Next Generation" allows him to see in the infra-red spectrum and can be adapted for remote sensing, and in Marge Piercy's "Body of Glass" (1991) and William Gibson's "Neuromancer" (1984) implanted chronometers dispense with the need for watches.

The writers who have also imagined an extension of the virtual-reality principle whereby human consciousness can actually inhabit a virtual body are almost too numerous to mention, suggesting perhaps that the next stage of what Clynes and Kline called "participant evolution" may be cyborg systems that allow us to go into space without leaving our armchairs.

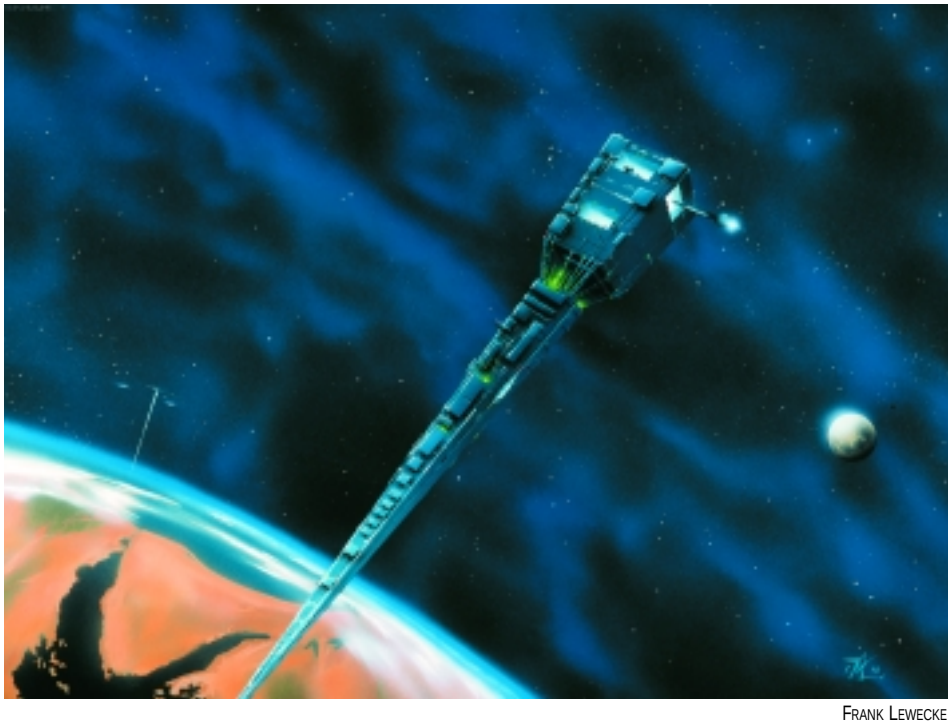
The concept of cyborgs and mutants is a theme often explored in films, including "Terminator", "Robocop", "Universal Soldier" and the more recent "X-Men" where the heroes are children of the atom, homo superior, the next link in the evolutionary chain. Each was born with a unique genetic mutation, which at puberty manifested itself in extraordinary powers: thus one's eyes release an energy beam that can rip holes through mountains; another's strength is both telekinetic and telepathic; and a third can manipulate all forms of weather.

Launch Systems

Orbital Towers and Space Elevators

The concept of an Orbital Tower has appeared in science-fiction literature since the end of the 19th century. The only material strong enough to facilitate such an endeavour from a mechanical-stability point of view would be carbon nanotubes. Another property of the material which can also be used is conductivity, thus leading to significant power production if the tower is put into an orbit around a planet having a global magnetic field.

In 1895 Konstantin Tsiolkovsky, a Russian scientist, looked at the Eiffel Tower in Paris and thought about an orbital tower. He wanted to put a "celestial castle" at the end of a spindle-shaped cable, with the "castle" orbiting the Earth in a geosynchronous orbit. Building from the ground up, however, proved an impossible task (though there are still groups talking about volcanoes as a possible source for a space elevator). It took until 1960 for another Russian scientist, Y.N. Artsutanov, to propose another scheme for building a space tower. In his book “Dreams of Earth and Sky”, Artsutanov suggests using a geosynchronous satellite as the base from which to build the tower. By using a counterweight, the cable would be lowered from geosynchronous orbit to the surface of the Earth, while the counterweight was extended from the satellite away from the Earth. Nine years after Artsutanov, an American physicist, Jerome Pearson, designed a tapered cross-section that would be better-suited to building the tower. He suggested using a counterweight that would be slowly extended out to 144 000 km (half the distance to the Moon) as the lower section of the tower was built. His analysis included disturbances such as the gravitation of the Moon, wind and payloads moving up and down the cable. The weight of the material needed to build the tower would have required 24 000 Space Shuttle trips, although part of the material could be transported up the tower when a minimum-strength strand reached the ground.



Frank Lewecke

Later, Pearson thought about building a tower on the Moon. He determined that the centre of gravity needed to be at the L1 or L2 Lagrangian points, which are special stable points that exist about any two orbiting bodies where the gravitational forces are balanced. The cable would have to be 291 901 km long for the L1 point and 525 724 km long for the L2 point. Compared to the 351 000 km from the Earth to the Moon, that's a pretty long cable, and the material would have to be gathered and the cable manufactured on the Moon.

Several years later, Arthur C. Clarke popularised the idea in his novel “Fountains of Paradise”, published in 1979. The concept of the Space Elevator

FRANK LEWECKE

proposed by Clarke is to construct a rigid connection between a point in geostationary orbit and a planetary surface. The fundamental problem of the last decades has been that no material known to man would be able to withstand the mechanical tensile forces, which would tear the cable apart. Recent developments in the field of nanostructures with carbon molecules indicate that the required physical properties are now within our grasp, thus having the potential for drastically lowering the cost of access to space. The transportation system would consist of a series of “cable cars” moving along the space elevator and then being released into geostationary orbit.

A potential construction strategy could be to move a carbonaceous chondrite asteroid into a stable orbit around our planet. Automatic machines would then process the materials at their source and start producing a cable like a spider. Years later, the cable would reach the ground and the connection between the planetary surface and geostationary orbit would be established. Problems – besides the cost, the difficulty of moving an asteroid (even one just a few kilometres in diameter) and the lack of automatic machines – include dynamical friction when the cable interacts with the uppermost winds in the Earth’s atmosphere, and the periodic gravitational pull of the Moon.

There are a variety of difficulties with the proposal to stretch a rope from the Earth to orbit, which are not solved solely by carbon nanotubes. These materials are very strong and light, but have not yet been incorporated into working plastics with high strengths. One would be concerned that such a plastic (like Kevlar) would be strong only in one direction and therefore might not be as strong as one might expect when made into a rope. A second challenge would be the celestial-mechanics difficulties with Clarke's idea, given that such a construction would be affected by both the Moon and Sun and their tides.

NASA has recently completed a detailed study of the space-elevator concept and concluded that in possibly 50 years or so, this cheap method of transportation to geostationary orbit could become a reality and dramatically lower the cost of getting into space.

Orbital Loops

MICHAEL BOEHME

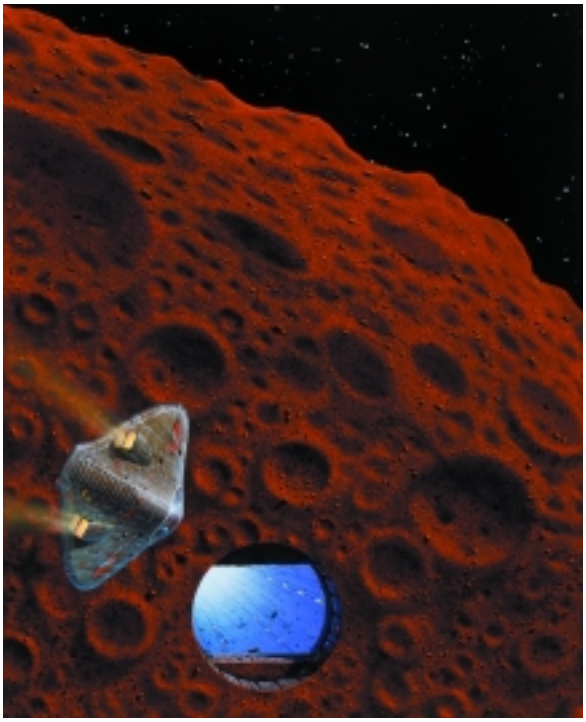
An orbital loop is defined as a ring of satellites and tethers around a planet to change the orbits of the satellites, stabilise them and keep them in a particular orbit. Again, carbon-nanotube research could prove to be the key technology with which to create materials of unprecedented mechanical stability and superb electrical conductivity. In this concept, an endless tether is launched into an eccentric Earth orbit. It is interspersed with winches and a segmented tube. A sounding rocket or a gun carries cargo to the tube. When the cargo enters the tube, it is accelerated by friction to the orbital velocity. Half of the orbital energy is transferred to the cargo, while the other half is wasted as heat. Momentum transfer is provided by electromagnets. The engineering aspects of such an orbital loop have been analysed in detail by the Polish physicist Andrew Nowicki.

MANCHU

If combined with a similar loop system around the Moon, a “slingshot” system could provide a cheap Earth-to-Moon mass-transfer infrastructure. The mass required for an Earth loop would be in the order of 10 000 tons. The maximum tensile forces would not exceed 2 Gigapascal. Potential applications would be the transfer of, for example, Helium-3 from lunar strip-mining bases for nuclear fusion on our home planet.

Resources and Materials

Extra-terrestrial Mining



TIM WHITE

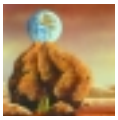
The concept of extra-terrestrial mining is in many ways inescapable when one considers the exploration of space. In essence, it is the idea that resources exist beyond the Earth's atmosphere and there are advantages to be gained by exploiting them.

These advantages can be as mundane as in the "Star Trek" television series (from as early as the 1960s) and films where the use of ram scoops to collect interstellar hydrogen meant that they did not have to carry any hydrogen from Earth. Then there are the moisture gatherers from the 1977 film "Star Wars Episode IV: A New Hope", which collect atmospheric water in a desert world, thus saving costs on importing the vital liquid.

They can also be due to the scarceness of a given substance on Earth, such as in the "Nightsdawn" trilogy, published in the 1990s, by Peter F. Hamilton in which gas giants are mined for the rare helium isotope He-3, a source of fuel for nuclear-fusion reactors. This rareness can even be taken to the point of uniqueness, as in the book "Dune" by Frank Herbert, in which the planet Arrakis is the only known source of the spice Melange, which in turn is the only known substance which makes faster-than-light travel possible. Valuable indeed!

DAVID HARDY

In short, this topic covers everthing from the gas drifting through space to the most fantastic substances conceived by the human mind. Who knows what we will find as we explore the cosmos for real?



Mars Terraforming

Film Poster by Brian Haskin, 1964

Terraforming is the process of changing the climate of Mars to a more Earth-like environment. Starting with "A Princess of Mars" in 1917, Edgar Rice Burroughs wrote eleven novels in which Mars was made habitable by an "atmosphere factory". The first modern terraforming novel was Arthur C. Clarke's "The Sands of Mars" from 1952, which proposed warming Mars by using a nuclear reaction to ignite the moon Phobos.

Frederik Pohl's 1976 novel "Man Plus" and the 1994 sequel "Mars Plus" suggested cybernetically modifying humans to live on Mars. These cyborgs were powered by solar panels and satellite-beamed microwaves. The latter could be used on future missions to power robotic vehicles on the Martian surface. Pohl revisited terraforming in 1992 with "Mining the Oort", in which Oort Cloud comets were harvested for water. While the Oort clouds are 6 – 15 trillion kilometres away, water is also present on near-Earth asteroids and comets. Robotic missions could be launched to study this potential resource.

Michael Boehme

One particularly fantastic terraforming scheme appeared in Greg Bear's 1993 novel "Moving Mars". A machine called a "tweaker", which manipulates matter at the quantum level, is used to move Mars to another star system. But the most ambitious work of terraforming fiction was Kim Stanley Robinson's 1993 – 1996 "Red Mars/Green Mars/Blue Mars" trilogy, which chronicled the "synergic terraforming" of the planet. This floated the idea that only many technologies deployed in a massive industrial effort can succeed in changing the planet.

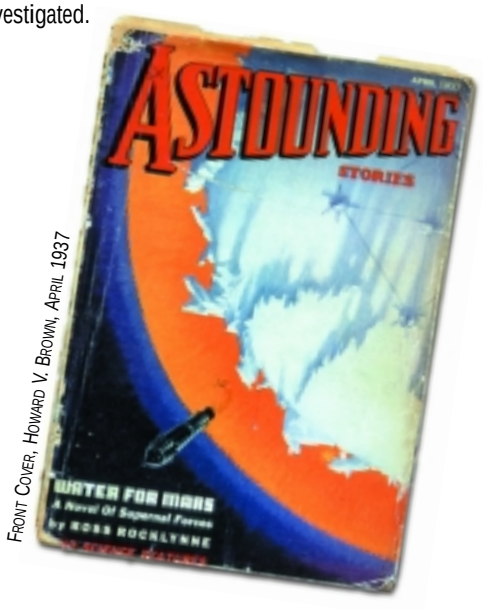
Finally, the 2000 novel "White Mars" by Brian Aldiss was the antithesis of Robinson's trilogy in which the United Nations ban terraforming. The book mentions a "Zubrin Reactor" that uses atmospheric carbon dioxide and stored hydrogen to create methane fuel and oxygen. This was a homage to Robert Zubrin's "Mars Direct" plan for low-cost missions to the Red Planet.

Solettas and Sun-Screens

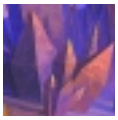
The concept of space-based reflector technology as a method to terraform planets like Mars, enhance food production, undertake local weather manipulation and supply energy is often used in science fiction. This concept is an integral part of many major science-fiction stories, while the underlying concept is not based in science fiction but could be carried out with current technology. In his book "Blue Mars" from 1996 Kim Stanley Robinson writes about solettas – a collection of orbital mirrors – as a tool used to terraform Mars. In "3001: The Final Odyssey" from 1999, Arthur C. Clarke mentions a deployable Sun-screen beyond the orbit of Neptune.

Mark Garlick

The soletta in Kim Stanley's book is used to heat the atmosphere of Mars using the additional sunlight reflected by the mirrors in orbit. In Clarke's book, the Sun-screen is used to provide shade. The science-fiction concepts for terraforming planets, producing large quantities of food and having access to a continuous power supply by using solettas and Sun-screens, are based on a concept that is within the scope of current technology. Solettas made out of deployable structures still challenge material science if the structure is large and a high surface precision is required. Their feasibility still has to be properly investigated.

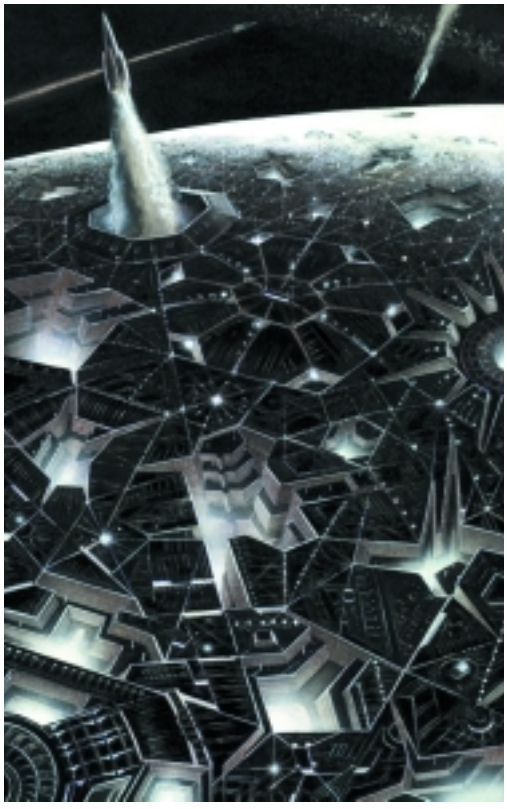


Front Cover, Howard V. Brown, April 1937



Advanced Materials

The concept of advanced materials in science fiction pre-dates the emergence of materials science as a discipline in its own right by quite a number of years. As far back as the 1920s and 30s, in the “Skylark” series of books, E.E. “Doc” Smith was speculating on the uses of neutronium (a super-dense material comprised solely of neutrons), the substance now thought to make up the astronomical bodies known as neutron stars. Neutron stars, however, were only discovered in the late 1960s, by which time science fiction had moved on to even greater things. The television series “Star Trek” introduced us to anti-matter, something that although scientifically postulated was not to be significantly produced until the late 1990s. Even comic books got in on the act, a prime example being the substance Adamantium, the mysterious alloy in “Marvel” comics which made the hero Wolverine's bones unbreakable.



Jeam Tag

Thomas Thiemeyer

More recently, the continued growth of the biological sciences has led science fiction to focus on the possibility of hi-tech bio-materials. From the creature-machines of Peter F. Hamilton's “Nightsdawn” trilogy to the biological computers of David Cronenberg's film “eXistenZ” and even the biological spaceships of the TV series “Farscape” and “Babylon 5”, science fiction continues to produce amazing ideas and concepts for futuristic materials. One might even say that these advanced bio-materials are to wood and animal hide what a material strong enough to sustain an elevator to space would be to a simple piece of string. But fullerene tubes are that strong, and they actually exist!

Other Technologies

Nanotechnology

The concept of nanotechnology was already introduced in 1959 by Richard Feynman at the annual meeting of the American Physical Society. Feynman stated, "*the principles of physics, as far as I can see, do not speak against the possibility of manoeuvring things atom by atom. It is not an attempt to violate any laws; it is something, in principle that can be done; but in practice, it has not been done because we are too big.*" The idea was stunning but did not receive the appropriate attention until the 1980s, when K. Eric Drexler, who also coined the term “nanotechnology”, delivered a paper on molecular manipulation. This paper triggered further studies in the field of molecular nanotechnology, which is now seen as an anticipated technology based on molecular machines able to build objects to complex atomic specifications. The possibilities that had been identified include molecular manufacturing systems able to construct computers smaller than living cells, devices able to repair cells, diamond-based structural materials, and additional molecular manufacturing systems.

Given its possibilities, nanotechnology is widely used in the science-fiction genre. It is an integral part of such science-fiction movies as “The Fifth Element“, “Terminator 1 and 2“, “Matrix” and “Star Trek”. The latter features nanorobots, called "Nanites", which are described in the book "Star Trek Science". In addition, “Star Trek” utilises nanotechnology for medical proposes. Nantotechnology also forms the core of various computer games.

François Rouiller

In the book "Trader's World" by Charles Sheffield, rather detailed descriptions of various technological gadgets are given. One of these is a crystal spy dragonfly, which is assembled by a bottom-up approach. Its brain is synthesised in a complex way, being grown out of a crystal by nanotechnological means. Nanotechnology also makes a second appearance in the novel, in the form of the "Dulcinell Protocol", which is a nanotechnological supplement to the immune system, increasing its performance by an enormous degree. The being, which makes use of the Dulcinell protocol, has improved recovery from wounds (in terms of time and quality of the repair) and is even able to survive a radiation dose that would be lethal under normal circumstances.

Probably the best description of a future world dependent on the extensive use of nanotechnology is “The Diamond Age” by Neal Stephenson. This book describes Shanghai in the middle of the 21st century, where nanotechnology is used for every possible application, such as to build up muscles, to purify water and air, to provide the population with free food from public matter compilers, to store data and even to manufacture a whole island. All of the nanotechnology devices in Stephenson's book relate closely to Drexler's concepts, such as the rod logic nanocomputer, but Stephenson goes further than Drexler, as he is willing to show us the possible dangers of nanotechnology, such as voice-activated nanoprojectile launchers or "nanobiological warfare".

Virtual Reality and Telepresence

Virtual reality, telepresence and remote viewing are regarded as the most promising tools for visualising and transferring complex information. Taking into account that space operations per se need such tools, science fiction offers a wealth of impulses in how to further these assets. The experience of a teleoperator (e.g. medical specialist) could be superimposed on a local robot or human, guided by force fields or a teleoperated exoskeleton. Remote operations, for example strip-mining on a lunar base, are often called “the next best thing to being there”. Increasing the sensory input for the operator is called “augmented reality”, which includes, for example, measurements of physical properties such as radioactivity that a human would not be aware of.

The potential for spin-offs is obvious wherever humans have to encounter dangerous environments like hot zones of nuclear power plants, sub-sea mining, etc. A great many of such augmentations might take place not only in the hardware, but mainly in the software field. Virtual reality can be fairly easily processed by artificial intelligence systems which filter unnecessary information and come into existence as virtual agents. However, some authors warn of the potential dangers of depending solely on “Virtual Augmented Realities”. In societies where modern production conditions prevail, all of life presents itself as an immense accumulation of spectacles in a broader sense: everything that has directly lived has moved away into a representation.

Science fiction also predicted tele-operation, with the term “waldo” coined by Robert A. Heinlein in his 1942 novel "Waldo", which was adopted when the technology came into existence later. In “Waldo“, a crippled genius living in a zero-g home in orbit around Earth finds that he may need his fellow humans even more than they need him. Heinlein's description long predated the telepresence gadgets now common in high-radiation environments, on research submarines, and aboard the Space Shuttle. No article about telepresence and virtual reality would be complete without mentioning Wiliam Gibson’s “Neuromancer” published in 1984. Computers suddenly had a cool but dangerous new dimension - Gibson called it “cyberspace”.

Gilles Francescano

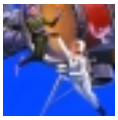
There has been much enthusiasm generated when it comes to telepresence, tele-operation and virtual reality in general – in the “Asteroid Man” by R.L. Fanthorpe (1960) or Robert Sawyer’s 1999 novel “Daily Life in the Year 3000”. However, there are several dangers to telepresence and tele-brought realities which are also discussed in science fiction. In “Society of the Spectacle“, Guy Debord raises a number of postulates why and how telepresence and virtual reality start to influence our society in a negative way. The science-fiction film “Telepresence” focuses on the people who populate a small military outpost, one of several scattered among thousands of asteroids. The group fights the enemy by “telepresencing”, utilising remote attack robots linked to the soldiers by cerebral cortex implants. At a certain point, people begin to realise that their implants have started to mutate and therefore have a significant impact on their off-duty lives, leading to increased aggressiveness. In the short story “The Next Best Thing to Being There”, Mike Combs describes the problem of a remote operations base at the Lunar South Pole. The tele-operators there who are operating the robots by means of augmented reality have an increased sense of aggression.

Space Tethers

A space tether is a long cable, constructed of thin strands of high-strength fibre used to couple spacecraft to each other or to other masses, and providing a mechanical connection that enables the transfer of energy and momentum and can be used as a form of space propulsion. Konstantin Tsiolkovsky first conceived the idea after seeing the Eiffel Tower in 1889 – he then turned it into a giant tower extending out of the atmosphere, anchoring a "celestial castle" in geosynchronous orbit. Almost 100 years later, Arthur C. Clarke gave the concept of the space elevator greater public awareness and Robert L. Forward furthered the ideas in his books. In 1973, Mario Grossi suggested flying a wire from the Space Shuttle, which would act as an antenna emitting low-frequency radio waves, allowing the Shuttle to "trawl" the atmosphere and collect data. In 1975, Jerome Pearson suggested a tapered-cross-section tether, stronger than a straight strand, with a counterweight extending halfway to the Moon.

HUBERT DE LARTIGUE

There are two general categories of tethers: Momentum-Exchange Tethers, which allow momentum and energy to be transferred between objects in space; and Electrodynamic Tethers, which interact with the Earth's magnetosphere to generate power or propulsion. Space tethers can be used for a diverse range of applications, including studying plasma physics and electrical generation in the upper atmosphere, space elevators, orbiting or deorbiting of space vehicles and payloads, planetary exploration, and mining of asteroids. In the century since their conception, space tethers have not been fully utilized. As the convergence of materials and technology continues, however, there will be numerous opportunities to use tethers in space.



Personal Transportation Devices

Front Cover, Walter Popp, Spring 1954

The idea of somehow counteracting gravity is one of the great science-fiction dreams: it is gravity that kept us earthbound for so long, and even now the force required to escape the gravity well of Earth or any other celestial body is the main factor that makes spaceflight so difficult and expensive. R.L. Forward in his 1995 book "Any Sufficiently Advanced Technology is Indistinguishable from Magic" and H.G. Wells incorporated into science fiction the theme of antigravity. Antigravity is a generic word to designate the control of gravitational fields produced by massive bodies (like planets). In his book, "First Men in the Moon", H.G. Wells introduced the idea of screening the Earth's gravitational field by using an imaginary material call "Cavorite".

In science fiction a huge variety of personal transportation devices are used: from antigravity devices that counteract the effects of gravity on the body, to faster-than-light transportation, to teleportation. In "Fantastic Voyages" written before the mid-19th century virtually all modes of transport were facilitating devices. John Wilkins, fascinated by ideas of novel means of transportation, had discussed submarines, flying machines and land-yachts at some length in "Mathematicall Magick" (1648). Concepts like the space-gun in Jules Verne's "From the Earth to the Moon" (1865-70) and the antigravity device in H.G. Wells' "The First Men in the Moon" (1901) were heavily discussed. In "Air Wonder Stories", H. Gernsback was writing about the topic in 1929. In "Star Trek", the Heisenberg compensator somehow miraculously overcomes the difficulty.

The faster-than-light (FTL) starship had arrived before the end of the 1920s, as had the ultimate in personal transport, the antigravity-belt featured in the Buck Rogers stories by Philip Francis Nowlan. According to Relativity, the velocity of light is limiting: no matter how objects alter their velocity relative to one another, the sum of their velocities can never exceed the ultimate constant c, the velocity of light in a vacuum. FTL drives of various kinds are so useful in avoiding the inconveniences of Generation starships that many writers of science fiction insist on clinging to the hope that the theory may be imperfect in such a way as to permit an exploitable loophole. "Faster than Light" (1976), a theme anthology edited by Jack Dann and George Zebrowski, includes, as well as the stories, several essays combatively arguing the case. A small rocket like the one used in the comic and movie "Rocketeer" to allow the hero fast movement has already been tested on Earth. It proved inconvenient, as the maneuvering is complicated. Yet flying cars like in "Back to the Future" have been built and function. The next problem will be to adjust driving laws to these science-fiction-inspired personal transportation devices!

Cinzano Advert by Michel Simeon, circa 1960

Appendices

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ESA and the ITSF Contractors

The European Space Agency (http://www.esa.int)

The European Space Agency (ESA) provides for and promotes, for exclusively peaceful purposes, co-operation among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and operational space applications systems.

For over 30 years, the Member States of ESA (Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and Canada which also takes part in some programmes) have worked together and pooled their resources to open up new pathways in space exploration and the development of advanced technologies for the nations of Europe.

ESA's Convention lays out the task of defining and putting into effect a long-term European space policy that allows Europe to become and remain competitive in the field of space technology. ESA also endorses a policy of co-operation with various partners on the basis that pooling resources and sharing work will boost the effectiveness of its programmes. ESA's European space plan spans the fields of science, Earth observation, telecommunications, space-segment technologies (including in-orbit stations and platforms), ground infrastructures and space-transportation systems, as well as microgravity research. Its role also takes in co-ordinating the Agency's own work with the national programmes of its members, so that they can be progressively integrated within pan-European programmes.

FRONT COVER, JUNE 1937

ESA, which is basically a research and development organisation, also has an industrial policy that encourages competition and ensures that each member country will, for the investment it makes, enjoy a fair financial return and a fair share of the technological spin-offs. Apart from the scientific programme, which is directed more towards basic research aimed at widening our knowledge of space, the Earth and its environment, ESA's work results in industrial development, operational products like the launchers of the Ariane family, and applications satellites such as ECS, Marecs and Meteosat, which are managed by commercial companies (Arianespace, Eutelsat, Inmarsat and Eumetsat).

Maison d'Ailleurs (http://www.ailleurs.ch)

The Maison d'Ailleurs (the House of Elsewhere) is a non-profit foundation created in 1976 in Yverdon-les-Bains, Switzerland, by the French encyclopaedist Pierre Versins. It is the only public museum in the world dedicated to science fiction, utopia and extraordinary journeys. It explores the main themes of science fiction (space travel, psi powers, future cities, etc.) and each year puts on exhibitions of the major artists in the field (H.R. Giger, W. Siudmak, Caza, J. Fontaine, etc.).

Maison d'Ailleurs also serves as a research and documentation centre with its unique collection of more than 60 000 items, a constantly growing research library comprising some 40 000 books in 40 languages, and thousands of objects related to science fiction and utopia (paintings, illustrations, posters, movies, games and toys, etc.) The richness of the museum's collection attracts specialists, scholars, students, journalists, writers, curators and the like from all over the world, and publishers and artists often rely on its huge iconographic database for their work.

LAURENT DUBOIS

The OURS Foundation (http://www.ours.ch)

The OURS Foundation is a non-profit cultural and astronautical organisation founded in 1990 in Switzerland, the primary purpose of which is to introduce, nurture and expand a cultural dimension to humanity's astronautical endeavours. This task will be manifested through the identification, investigation, support and realisation of related cultural, astronautical, humanitarian, environmental and educational activities, which may take place both on and off planet Earth, and which are deemed beneficial to the development and advancement of human civilisation in this new environment. The OURS Foundation has been responsible for organising space cultural events both on the Earth, including the IAF Congresses in Oslo, Turin, and Melbourne, and aboard the Mir space station in 1993 (Cosmic Dancer) and 1995 (Ars Ad Astra on EuroMir'95), etc.

COSMIC DANCER (OURS FOUNDATION)