Space Technology
Opportunities for physicists

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Introduction

Space technology
The space sector is a vigorous and growing component of the UK economy, comprising more than 200 companies that directly employ around 25,000 staff, indirectly employ 60,000 more and generate a turnover of £7 bn a year.

Long lead-in times for major projects have helped to make the sector resilient to recession. In fact, it’s expected that the sector’s turnover will double in size over the next nine years, growing to £14 bn by 2020, and giving a major boost to the British economy.

There is a good reason behind that expansion. From home insulation, disaster response, and satellite navigation, to high-spec medical equipment, space technology has made a vast array of vital modern technologies possible. Increasingly, satellite-based research also plays a crucial role in widening our understanding of the Earth’s climate and the way that human activity impacts on climate change.

The space sector is one of the most highly skilled parts of Britain’s industry and economy. It is also seen as a key industry in Europe. Talented and highly trained scientists and engineers underpin the success of the sector, and physicists who have recently left full-time education or are further along in their careers have a major contribution to make.

I am therefore delighted to introduce this guide to space technology, and I urge any physics graduate looking for a challenging career to seriously consider the opportunities that space affords.

Prof. Sir Peter Knight KB FRS CPhys FinstP
Introduction

Who this booklet is for
This booklet is aimed at physicists with an interest in entering the important and expanding space sector. It will be of primary interest to graduates starting out on their careers but we also hope that it will be of use to physicists at later stages in their working lives.

While space research and technology help us to understand more about the universe and aid the development of physics, physics itself is essential to the development of the technology. The demand for extremely high performance, endurance, and reliability in space technology adds to the physics challenge.

What this booklet includes
This booklet includes a brief overview of the key sectors of the industry, looking at:

- Space science and research, including exploration of the planets, their moons and the asteroid belt.
- Space-based applications, including satellite navigation, telecommunications, meteorology and Earth observation.
- Space engineering, including manned and unmanned space flight.

There are also case studies of the working lives of five physicists employed in various areas of the space sector, and information on skills, qualifications, salaries, and graduate schemes.

We’ve included advice on getting into the sector and getting on once you’re in it. And there’s a short history of how space exploration and technologies have developed since the 1950s. Finally, there are contact details of major companies and agencies working in the sector.

We hope that you find this booklet informative, interesting and accurate. If you have any comments please contact Vishanti Fox, careers manager at the Institute of Physics, on 020 7470 4800 or e-mail members.careers@iop.org.
Opportunities in space research
Space science and research aims to broaden our knowledge of the universe. Space scientists study the origin, evolution and future of the cosmos, the nature of the Sun, the formation of the solar system, the beginnings of life on Earth, and the possibility of extra-terrestrial life.

In addition to ground-based observational instruments, space scientists use unmanned automated spacecraft such as the Hubble space telescope, as well as landers and rovers, to relay information from space, or from other planets or moons, back to Earth. The spacecraft need to be designed with enormous care – once out in space, the possibilities for repair or redesign are very limited.

Space research is a mix of disciplines and includes the following.

**Pure research**
Astronomers and astrophysicists are engaged in pure research in a number of universities around the world, including Leicester, Southampton, Cranfield, MIT, Caltech and Technical University of Delft. The academics at these institutions and elsewhere use extremely high-spec instruments to study celestial bodies and widen our knowledge of the physics of the universe.

**Principle investigators**
These are the senior scientists who oversee the whole of a research project and have the best understanding of what the instruments being used are ultimately capable of.

**Mission specialists**
Mission specialists assist academic astronomers and astrophysicists in the best use of instruments, and in the preparation of proposals for the use of instruments.

**Payload specialists**
Payload specialists define new instruments to gather data for use by the academics and researchers.

Opportunities in space-based applications
Much of the technology that we take for granted today, from weather forecasting to mobile phones, depends ultimately on space technology. Physics plays a central role in managing and further developing these technologies. Here we look at some of the space-based applications that, as a physicist, you could get involved in.

**Earth observation and environmental monitoring**
Earth-observation satellites observe the Earth from orbit to monitor the environment and the atmosphere, and assist with cartography. Their distance from the Earth generally ranges from about 600 to 36 000 km, depending on their application. Military reconnaissance satellites work on the same principle.

Earth-observation satellites generally use two sorts of orbits: low Earth orbit (LEO) and geostationary orbit (GEO). LEO satellites orbit at an altitude between 160 and 2000 km. Sun-synchronous LEO satellites pass over every latitude point on Earth at the same local time. This ensures that the data they collect is always at about the same local sun angle, making it easier to correlate images taken on different orbits.

In contrast, geostationary satellites at an altitude of about 35 800 km and with zero inclination, remain in the same position in space relative to an observer on the ground. They can therefore monitor a particular portion of the Earth’s surface continuously.

As the name suggests, meteorological or weather satellites primarily monitor the weather and climate. Meteorologists can use the pictures and
Opportunities in space-based applications

data from GEO weather satellites together with those from a number of LEO Earth-observation satellites to develop their predictions of future weather conditions. As well as cloud formations, however, weather satellites can also collect an enormous amount of environmental information, and are crucial in tracking the effects of pollution, sand and dust storms, forest fires, changes in the polar ice caps, and the shores of oceans.

Physics is important to the study of reflectivity of optical and radar signals and their propagation through the atmosphere. Physicists are often involved in the design and manufacture of radar, microwave, UV, gravitational, and optical instruments aboard satellites used for Earth observation and meteorology. They may also take part in the development of the complex computer simulation models that make use of satellite and terrestrial data to predict future weather patterns.

**Satellite navigation (global navigation satellite systems)**

Satellite navigation systems give autonomous geospatial positioning with global coverage. They work by enabling small electronic receivers to determine their longitude, latitude and altitude using radio-transmitted time signals from satellites. Global coverage is achieved by 20 to 30 satellites spread between several orbital planes.

At the time of writing, the USA’s Global Positioning System is the only fully operational satellite navigation system to achieve continuous global coverage. However, Russia is currently upgrading and replenishing its GLONASS global satellite navigation system and China is expanding its regional Beidou/COMPASS navigation system. The ESA/European Union’s Galileo system has already launched, carrying payloads designed and constructed in the UK.

The satellite navigation sector is a rich source of employment for physicists. They are commonly involved in the analysis of radio signal propagation through the atmosphere, and in the design and construction of atomic clocks, antennae, and inertial navigation systems.

**The UK Space Agency**

The UK Space Agency was formed in April 2010 to take responsibility for the British government’s policy and budgets for space.

As part of the Department for Business, Innovation and Skills, the agency describes itself as “leading the UK’s civil space programme in order to win sustainable economic growth, secure new scientific knowledge and provide benefits to all citizens.”

Its remit is to:
- Give a focus for civil space policy and programmes across the government.
- Manage a number of space projects and programmes.
- Work with government departments, research councils, industry and academia to ensure the effective and growing exploitation of space.
- Manage the UK’s relationship with other space agencies and trans-national organisations such as ESA.

The agency has an annual budget of £220 m.
For more details go to [www.bis.gov.uk/ukspaceagency](http://www.bis.gov.uk/ukspaceagency).

**Telecommunications**

Modern communications satellites (comsats) use a variety of orbits, including geostationary orbits, Molniya orbits, other elliptical orbits, and low (polar and non-polar) Earth orbits.

Communications satellites provide a platform for fixed telecom services. They are also used in mobile applications such as communications to cars, ships and planes, as well as TV, radio and hand-held devices.
These crucial applications mean that telecom satellite technology is big business, and is by far the most mature business application of space technology. The world market for the development and launch of telecom satellites is currently worth about £2 bn per year, but the yearly revenue earned by these satellites is almost three times as much.

**Space weather science**
The monitoring of space weather, including sun spots and solar flares, has many practical applications. Large solar flares and coronal mass expulsions can disrupt electrical power distribution grids on the Earth and damage satellites in orbit. Aeroplanes in high-latitude regions can have their communications and GPS navigation systems disrupted. Getting an early warning on when such events are likely, even if only a few minutes or hours in advance, can make a big difference.

**Radiation science**
The lack of atmosphere in space means that galactic cosmic rays and solar flares pose severe radiation risk to electronics, materials and human beings, and proper shielding needs to be designed to ensure the safety of astronauts.

Physicists have a major role to play in designing and building shielding and hardening devices, and in predicting the path of cosmic rays and their impact.

**Spacecraft engineering**
The design, construction and operation of vehicles for spacecraft and space missions is complex, challenging and high risk. The extreme conditions of space – including the risks of radiation, lack of atmospheric pressure, massive temperature changes, the need to get the maximum possible payload and the restrictions on mass – make astronautics a big scientific and engineering challenge. Materials science, radiation science and propulsion play a key part.

Because of the complexity of the field, teamwork is important. Space engineering is conducted by teams of engineers, each one specialising in their own field. There needs to be a careful balance struck between abilities, performance, available technology and costs.

**Manned space flight**
It is now a little over 50 years since the first man was sent into space – Yuri Gagarin. Only Russia (then the USSR), the USA, and China have directly put humans in space. However, the European Ariane-5 rocket was conceived as a manned launch vehicle and ESA has been involved in manned spacecraft such as the Columbus Space Laboratory.

**Space tourism**
Manned space flight is perhaps the most glamorous and visible branch of space engineering and space flight, and one that’s not yet reached its full potential. Once a platform for prestige in the Cold War, manned space flight now looks set to offer business opportunities, with space tourism on the brink of becoming a mainstream commercial activity.

Virgin Galactic is a well publicised player in this market. Meanwhile, KLM Royal Dutch Airlines is planning to operate a two-seater Lynx suborbital spaceship for space tourism. The vehicle is currently being developed by XCOR Aerospace of California. The Russian space agency Roscosmos is also a major player.

**Opportunities in enabling technology propulsion**
For the foreseeable future, rocket propulsion will be needed for all space-flight missions, whether manned or unmanned. The propulsion requirements for almost every flight are different, requiring rockets with different levels of thrust, operating durations and other capabilities.

To date, the rockets used for space missions have used a variety of technologies, including liquid propellants, solid propellants, a hybrid combining
Opportunities in enabling technology propulsion

Focus on Ireland

Ireland’s involvement in the space industry has expanded enormously in recent years.

Space-based industry is currently worth more than €20 m to the Irish economy and the space sector offers a growing number of employment and research opportunities for physics graduates.

About 70 Irish companies have participated in European Space Agency programmes since 2000. Irish companies and researchers were involved to the tune of €5 m in contracts for the Herschel Space Observatory and the Planck Surveyor Satellite for ESA.

The Institute of Physics is active in Ireland and supports Irish physicists working in the space sector. To find out more, e-mail shelia.gilheany@iop.org.

Simulations and testing

Because of the expense of space flight and the difficulty of repairs in space, it’s necessary to test satellites, launch systems and their components extensively on the ground under simulated conditions. The physical hardware needed to simulate the vibration and acceleration experienced by a satellite during launch, and the chambers needed to simulate the vacuum and radiation environment of space, are sophisticated systems that continue to be improved with new developments.

The software simulations used to predict the environments that a satellite will experience in space are constantly being modified and improved, as are the simulations of a satellite’s behaviour in these environments.

Orbital mechanics

Orbital mechanics is the application of the science of ballistics and celestial mechanics to the practical problems of space flight. It deals with spacecraft trajectories and manoeuvres, including the influence of celestial bodies on spacecraft.

Orbital mechanics is therefore at the heart of space mission design control and operations.

Materials

The question of the best materials for the manufacture of spacecraft is absolutely central to space engineering. New materials with very specific properties are invented, or existing ones are modified to improve their performance.

Space hardware not only has to function reliably with little opportunity for repair, it also has to survive in extreme conditions, and have the least possible weight. Not only must these materials survive, they must do so without releasing any materials that could adversely affect the sensitive instruments, telescopes, solar arrays, and thermal surfaces.

As a result, the development of materials with satisfactory mechanical characteristics and low outgassing in extreme temperatures is an important area in the space field, as is the development of test equipment and processes that will ensure that the proper characteristics have been achieved. It is little wonder that extensive testing of materials and components is needed prior to space missions.
Technology transfer
Often, the materials have properties that ensure they find a niche in everyday life on Earth. The household lubricant WD40 and hypothermia blankets are good examples. ESA has a system of business incubators that provide seed funding for start-up businesses with a convincing business plan.

Careers information
Skills and qualifications
As one might expect in such a high-tech area, more than 70% of employees in the space sector are degree qualified. However, PhDs are not strictly necessary for space careers outside academia. Many contractors working in practical fields will start with a bachelor’s degree and move on to a masters later in their careers.

As well as academic qualifications, physicists working in the sector will need high attention to detail and a good aptitude for teamwork.

To make the most of your potential, you’ll also need to be prepared to work outside the British Isles and develop your language skills. Space is very much an international sector, and British physicists would be at a definite advantage with European languages, especially French, German and Italian.

Job websites devoted to or including, the space sector include www.space-careers.com, www.hespace.de and www.brightrecruits.com.

Salaries and conditions
Graduate schemes
Graduate starting salaries begin at around £25 000 to £30 000 a year. An experienced physicist working in the international sector could expect to earn £80 000 a year or more.

A lot of work in the space industry is done on a contract basis, and physicists are likely to get a “foot in the door” after a stint of working as a contractor or through a contracting company.

ESAs Young Graduate Trainee (YGT) programme offers recent graduates a one-year non-renewable training contract designed to give valuable work experience and to prepare for future employment in the space industry or research.

Young graduate training opportunities provide hands-on experience in all ESA activities, but mainly those in the engineering and scientific fields. On occasion, however, there are also opportunities in support areas such as finance, contracts, public relations, and human resources. Graduate trainees work as part of a team under the supervision of an experienced specialist or “mentor”. Go to www.esa.int/esaMI/Careers_at_ESA/SEMRSSXO4HD_0.html for more details.

Astrium’s Graduate Development Programme is a two-year programme designed to support graduates with less than two years’ postgraduate professional work experience. Its purpose is to provide a framework to guide and support graduates through the first stage of their career development.

Those involved will be based mainly in Portsmouth, Stevenage or Friedrichshafen in Germany. However, participants may get the chance to do rotational placements in France, Germany or Spain. Go to www.astrium.eads.net/en/gdp/ for more details.

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“The main challenges of my job are managing complex, often novel, technologies and manufacturing processes to produce equipment that gets one chance to work. We do not usually get the opportunity to go back up there and fix things if they go wrong.”
Case study: Mark Chang

Age: 39
Job: Chief optics engineer
Company: Surrey Satellite Technology Ltd (SSTL)
Studied: PhD in Astronomy Instrumentation, University of Durham

In the UK there is a very small community of technical engineering managers who pull together the concept, requirements, design, manufacture and verification testing of optical instruments for space-borne platforms.

My particular expertise lies in multispectral cameras and spectrometers for low Earth orbit satellites, both for scientific Earth observation and astronomy. I am the chief optical engineer at my firm, which means that I am responsible for the company processes related to optical payload production.

There is a lot of variety in what I do and the people that I work with. With ESA projects I am involved in a lot of document generation, because of the high level of analysis, testing and tracking of all phases in instrument production. With commercial projects I am much more hands-on, guiding the design and interfacing of the payload through review meetings.

I spend a lot of time in face-to-face meetings and in teleconferences and videoconferences. Systems engineers are customer- and external subcontractor-facing roles. I am able to be hands-on too because there is always practical work to be done.

I work across all disciplines because I have to hold together the overall system-level view. At times I have to delve into the detail of engineering, with the support of expert teams, in order to handle specific problem areas.

As a chief engineer I work with other disciplines’ chief engineers and the company overall chief engineer to coordinate the production of all of our projects within short timescales.

I am based in Sevenoaks, Kent, although I spend about 20% of my time at our head office in Guildford or travelling to clients around Europe.

I fell into my current field after pursuing a path in astronomy instrument design at university. I was always interested in optics (my favourite question is “what is colour and why is it so beautiful?”) and I studied physics at bachelor’s level and applied optics at master’s level at Imperial College.

I took an MSc to give myself the time to find a venue to enter astronomy as an instrument maker, which I found at the University of Durham.

I had the wonderful opportunity to be sponsored through my BSc and MSc by e2v. I spent one year in-company prior to the degrees and every summer and Easter vacation with them.

I started with a PhD in astronomy instrumentation at the University of Durham, and went on to work in IT. I went to the USA and became involved in space-based optics, which opened the door to working with SSTL.

The main challenges of my job are managing complex, often novel, technologies and manufacturing processes to produce equipment that gets one chance to work. We do not usually get the opportunity to go back up there and fix things if they go wrong.

I love the interaction with experts of all sorts, from all technical disciplines to management experts. The variety keeps you from dull routine, and there is always some new challenge to be addressed.

The space sector is going from strength to strength and has proven to be resilient during the recession. Space-based Earth-observing systems are going to be more important. It is an exciting and demanding field. Although it is difficult to find employers in the UK, European technology in this area is growing and advancing rapidly and the future is bright.
“For me space was a childhood passion that ensured that I challenged myself continuously.”
Case study: Jose Pizarro

Age: 37
Job: Systems engineer
Company: European Space Agency
Studied: MSc Space Systems Engineering, Technical University of Delft

The area that I work in comes under the generic title of system engineer in the ESA Technical Directorate. I use my physics knowledge to support programmes in manned space flight and robotics, navigation and consultancy.

The job varies a lot, from brainstorming with industry to technical reviews of new projects and feasibility studies. I also work on installing simulator equipment and training astronaut instructors on its use.

I’m based at ESA’s technology centre ESTEC in the Netherlands. Some weeks I can be in my office reviewing documents or working in the labs. Others I can be out at industry sites working closely with them. But one of the best times is when you get to go to a launch site to see something that you’ve worked on being launched.

I started in the space business writing instrument simulators for the European Southern Observatory. From there I worked in Darmstadt, Germany, on a satellite visualisation tool, then went to ESTEC in the simulations section.

Soft skills
The way that I found my first foothold in the industry was by having a range of other skills that complemented my physics background, such as software, languages and people skills. This combination allowed employers to see that I would not be just a one-trick pony.

Even though I did not graduate with the highest of marks it was my adaptability and life skills coupled with my knowledge of physics and optics that ensured that I already had a position and was working at the European Southern Observatory before graduating.

What held me in good stead was a commitment to continuous professional development, which meant that I was able to achieve chartered physicist status after four years’ practical industrial experience. Later in my career I was able to complete a masters at the Technical University of Delft.

For me space was a childhood passion that ensured that I challenged myself continuously. This allowed me to set high goals that at the time did not seem achievable but enabled me to push myself.

Everyday impact
The space industry is a manufacturing and research industry that day to day the public does not realise is there. It makes an impact every day on all of our lives, from TVs to mobile phones, from the weather forecast to the maps in your car’s satnav system.

The next 10 years will see a rapid commercialisation of space, allowing today’s graduates to become the entrepreneurs of tomorrow.
“Because I run my own company there is also the extra task of marketing and understanding customers’ needs and desires. In fact this may be the most important task of all. Without this understanding or empathy you won’t really deliver what a customer wants.”
The main core of my work is in ion propulsion and related spacecraft engineering. I provide expertise and consultancy services to spacecraft projects that use ion propulsion. My expertise covers all aspects of ion thrusters, in particular gridded ion thrusters. This can be design, development, testing and control.

Ion propulsion is a way of creating thrust that uses plasmas. Ions are created and accelerated into space, being made neutral just as they leave, so that the resulting momentum of the particle provides thrust. The advantage is that for very little fuel (a rare gas like xenon) a low magnitude but constant thrust, or a highly variable thrust, can be achieved.

The real selling point of ion propulsion is that it can be done using at least five times less fuel than for standard gas jet devices. Less fuel means a smaller tank so there is more room on a satellite for experiments and hardware.

At the moment I am actually working full-time again for an engineering company as well as doing consultancy in ion propulsion through my own company, so I am busy. My everyday work is a combination of data analysis, writing reports and coming up with results and insights to meet requirements.

Marketing and customer demands
Because I run my own company there is also the extra task of marketing and understanding customers' needs and desires. In fact this may be the most important task of all. Without this understanding or empathy you won't really deliver what a customer wants. And that can mean long antagonistic meetings and having to do more work.

I maintain my own website and when possible I create articles and videos that can help engineers and scientists with sticking points in their project.

So in an average week, I might be looking at solving a particular problem, doing some analysis on data, putting together a report, interacting with colleagues or thinking about marketing.

After my PhD I got a job working in jet engine controller software. After working at that for a year I moved over to England (I'm originally from Belfast) to work on ion propulsion. Following some successes in ion propulsion for QinetiQ, I decided that it was time to think about working for myself. So I left QinetiQ and set up my own consultancy.

Learning new skills
The main challenges are getting customers, then giving them something of value; either real expertise or just help to overcome a technical challenge by showing a different perspective.

I used to enjoy the pure problem-solving activities – the balance of creative, even irrational thinking and methodical testing – and the results it brought; like a thruster actually flying in space. Now I also enjoy the personal interactions more – learning how to communicate and solve people's problems by trying to get to what really worries them.
“I really enjoy the challenge that this role provides, which is always pushing me to learn more and expand my knowledge base. However, sometimes this can leave you feeling as if the learning curve is almost vertical.”
**Case study: Victoria Hodges**

**Age:** 27  
**Job:** Attitude and orbit control system engineer  
**Company:** Astrium Ltd  
**Studied:** BSc physics with satellite technology, University of Surrey

My work is in spacecraft systems design, specifically for the Attitude and Orbit Control System (AOCS), which guides and steers spacecraft autonomously while in space.

Most of my work is carried out at my desk on my PC using various tools and simulators. I focus on coming up with solutions to AOCS design problems, then try to validate these solutions by testing them out on our simulator and write up the results for the customer.

This role doesn’t involve doing a particular set of tasks each day. Instead, you find a problem and try to solve it, as well as other issues that sometimes come up requiring urgent attention from one or more members of the team. I can easily go into the office expecting to spend my day working on one thing and end up doing something quite different if the need arises. So the work is never dull and the environment is dynamic.

**Applied physics**  
As a physics graduate the AOCS role is fantastic because it really allows you to apply your knowledge of kinematics and dynamics directly. Having a physics background is also advantageous when it comes to having a deeper understanding of how the AOCS equipments work, many of which are optical-based sensors.

I really enjoy the challenge that this role provides, which is always pushing me to learn more and expand my knowledge base. However, sometimes this can leave you feeling as if the learning curve is almost vertical. Fortunately though, the people within the team and within the wider AOCS group at the company are very supportive and always willing to help others to understand and learn.

**My career route**  
I suppose you could say I followed the classical route into this area, an interest in space leading to a degree in physics with satellite technology and into the industry. However, my colleagues and I come from a range of disciplines including physicists, mathematicians and engineers. It is this range of backgrounds that enables us to work successfully on our projects.

During my degree I undertook a one-year work placement at VEGA-IT GmbH in Darmstadt, Germany. After that I was offered a place on the Astrium Ltd Graduate Development Programme. The two-year scheme enabled me to join the company and gain experience in many different areas: AOCS, commercial and contracts, future mission studies and systems engineering. Finally, I decided to join the AOCS group at the end of the graduate programme.

At this point in time I am quite near the beginning of my career and know that I still have a lot to learn. I am looking forward to the next large piece of work that I have been assigned because, while it is going to be extremely challenging for me, the potential knowledge gain is enormous and will enable me to expand my skill set immensely. Longer term I’m not certain, but in the space sector there are no boundaries!
“There are lots of interesting challenges in my job: understanding what will bring real benefits to clients; managing complex projects; turning real-world problems into problems that can be described mathematically; and solving difficult mathematical problems.”
Case study: Matthew Pigg

**Age:** 30  
**Job:** Consultant and attitude orbit control systems analyst  
**Company:** Tessella  
**Studied:** BSc physics with astrophysics, University of Birmingham

Most of my work is designing, analysing and testing the mathematics that goes into the software in attitude orbit control systems for spacecraft. I also develop simulation models of the sensors and actuators. These models allow the performance of the system to be simulated.

I spend half my time working for Tessella in our Stevenage office and half providing onsite support to one of our clients. A typical day might include interacting with clients across Europe, mentoring junior staff, designing and tuning part of an attitude orbit control system, or identifying innovative solutions to difficult technical challenges.

When I started at Tessella, I was lined up to work on an upcoming research project studying ways to improve how spacecraft autonomously estimate their attitude (i.e. their orientation). My next project covered how to control and guide their attitude as well as how to estimate their orientation. This is the basis of attitude orbit control systems. Once I got to grips with this field, I found the challenges it presented absolutely fascinating and, after nearly 10 years, I’m still learning new things.

I also really like the fact that the skills I am learning are transferable, which has allowed me to apply experience and techniques from the space sector to other industries.

**Into industry**

During my BSc I worked for a major defence company in all of my university vacations. This experience really helped me get a job at Tessella in 2001. I considered staying in academia after my degree, but the experience of working in industry in my vacations really encouraged me to go straight into industry.

There are lots of interesting challenges in my job: understanding what will bring real benefits to clients; managing complex projects; turning real-world problems into problems that can be described mathematically; and solving difficult mathematical problems.

**Interacting in the real world**

The part that I enjoy the most is talking with and helping others. In my job I get to help people at a range of levels, from junior staff to senior clients. I also enjoy the fact that what I’m working on will be used in the real world. The launch of missions that I’ve worked on is always a great reminder that my work has a real application.

In the future, I expect to be managing larger teams and I hope to be recognised as a technical expert in my field. I also hope to work on more new and interesting projects.
10 tips on getting into the space sector…and making the most of it once you’re there

• The industry is becoming more and more competitive as the profile of the UK space sector is growing. So try to gain some work experience within the industry during your degree. Not only will this help you to decide if this is the right industry for you, but it will also give you a real head start when it comes to applying for graduate positions – Victoria Hodges, Astrium

• If you’re still a student, try to get work in your vacations and not just six weeks over one summer. I fitted in 15 weeks per year, which meant that I had a lot more on my CV when I left university than most. With high competition for the best jobs, such experience can really make you stand out – Matthew Pigg, Tessella

• Be prepared to travel, because this is very much an international field with a lot of national prestige tied to it – Mark Chang, SSTL

• Be polite and don’t burn your bridges. The space industry is a small world and you’ll often encounter the same people again as your career progresses – Jose Pizarro, ESA

• Keep adaptable. For the interesting projects you have to be willing to go where the work is. In the same way that physics is multifaceted, you should be too – Jose Pizarro, ESA

• It’s not often talked about but empathy and understanding of what a customer really wants is as important as successful experimentation, development and testing – Michael Corbett, Corvos Astro Engineering Ltd

• Try to get involved in space societies and go along to the annual UK Space Conference. This will enable you to find out more about the opportunities available – Victoria Hodges, Astrium

• A high level of technical skill is required, so do not lose your taste for continuous learning – Mark Chang, SSTL

• Go for it and work hard. It’s very competitive and the most interesting work requires a really strong academic background – Matthew Pigg, Tessella

• Having another language helps even if it is only to say thanks for the coffee. It shows your people and team skills in an international environment – Jose Pizarro, ESA
Most people think of the Space Age as starting with the launch of the Soviet Union’s Sputnik artificial satellite in October 1957. But manned space was a frequent theme in science fiction stories long before that. In *From Earth to the Moon*, published in 1865, Jules Verne contemplated a long-range cannon that could launch people in a capsule into space where they would circumnavigate the Moon and then return to Earth, eventually landing in the ocean from where they would be recovered by waiting ships. And the use of communication satellites was first proposed by the British physicist and author Arthur C Clarke, in a paper he published in 1945.

Sputnik-1 was launched in the midst of the Cold War, with the USA and the Soviet Union both trying to develop a functioning satellite. America launched its first successful satellite, Explorer-1, on 31 January 1958, three months after the USSR had launched a second satellite carrying a dog called Laika.

**Space-based applications**

The Explorer-1 satellite was outfitted with a Geiger counter-based experiment to measure cosmic rays. The flight led to the discovery of the two belts of trapped particles now collectively known as the Van Allen belt and other discoveries. But perhaps the most important development concerning satellites was in their use for communications.

The first satellite launched that was capable of receiving, storing and returning signals to another location on Earth was the USA SCORE satellite. In 1960 the first Courier active repeater satellite was launched. The design of the Courier payload was a precursor of the architecture of most communications satellites in use today.

**Watching the Earth – and other planets**

Satellite communications has become a relative economic powerhouse as far as the use of satellites is concerned, but it was soon recognised that there were many other important applications to which satellites could be directed.

**The British connection**

The UK began launching sounding rockets in 1957. There were four launches of the British Black Arrow rocket between 1969 and 1971, leading to the successful orbital launch of the Prospero satellite. The UK is currently heavily involved in flagship programmes of the European Space Agency such as Galileo and GMES, and British companies such as Astrium and SSTL are pre-eminent in satellite design and manufacture. The recently formed UK Space Agency controls the government’s space budget and policy.

As early as April 1960, the USA launched the first of a series of Television Infrared Observation Satellite (TIROS) satellites. TIROS-1 mapped cloud coverage and returned images to Earth. Cloud mapping provided information that allowed weather predictions of much greater accuracy.

The same technology that can monitor Earth from an orbiting satellite can also be used to monitor other planets. Space probes have sent back close-up pictures of all of the planets visited to date. The NASA New Horizons spacecraft that was launched in 2006 is expected to reach Pluto in mid-2015.

The Hubble Space Telescope and other astronomical satellites have provided many thousands of photos taken in many different wavelengths that have helped us to understand the origins of and the ultimate demise of stars, have confirmed the existence of and helped us to understand black holes and quasars, and led to theories of dark matter and dark energy.

**A human in space**

In April 1961 the USSR launched a Vostok capsule into space containing Yuri Gagarin, the first human to be put into space. Less than a month later, in May, US Astronaut Alan Shepherd was launched into space.
The Apollo programme followed, with Neil Armstrong and Buzz Aldrin landing on the Moon on 20 July 1969.

It wasn’t long, however, before many other countries began to develop their own space expertise. In Europe, the first national space agency was the French National Centre for the Study of Space (CNES) established in 1961. In 1964, two multinational European organisations were formed: the European Space Research Organisation (ESRO), tasked primarily with the development of scientific satellites; and the European Launcher Development Organisation (ELDO), tasked as its name indicates to develop a European satellite launch vehicle.

ESRO and ELDO were joined together in 1975 to form the European Space Agency (ESA). In 1969, Germany established the German Research and Development Institute for Air and Space Travel (DFVLR), which was renamed the German Research Institute for Aviation and Space Flight (DLR) in 1989.

The British National Space Centre (BNSC) was established in 1985, but has since morphed into the UK Space Agency. Italy established the Italian Space Agency (ASI) in 1988.

All of these national space agencies are still active, both developing technology for national space endeavours, and providing funding and oversight to ESA for co-operative European space programmes.
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