Science In a Social CONtext

SPACE, COSMOLOGY AND FICTION

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Space, Cosmology and Fiction

JOAN SOLOMON

ASSOCIATION FOR SCIENCE EDUCATION
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Introduction

The study of space may seem as far removed from the problems of society as it could be, but this is not so for three quite separate reasons. In the first place, because the stars and planets are so remote, people have always used their faith and imagination as well as their science for interpreting them. Secondly, they have inspired fiction, stories in which our current social problems can be seen in a new and dramatic setting. The third reason is more strictly contemporary. Through the use of satellites we are now entering a space age in which the concerns and pressures of society can move outwards, beyond the earth itself.

The first part of this book is concerned mainly with the biggest confrontation between science and religion in all history – the story of Copernicus, Galileo and the church. This enables us to think about the nature of scientific explanation, about freedom, censorship and personal belief, all of which concern us today. From this beginning we follow some of the scientific discoveries and measurements which led to modern cosmology and the Big Bang theory.

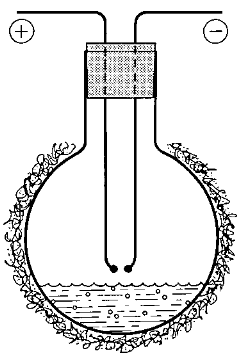
The last two sections are about space exploration, early rockets, the race to put a man on the moon, and the space probes which travel the solar system and beyond. Science fiction has been taking us beyond the Earth to worlds peopled in imagination. Now that our satellites promise to improve transworld communication and threaten new realms of warfare, reality may be catching up on fiction.

1 Early Views on the Universe

CREATION MYTHS

Almost every human society has developed its own story of creation based on what was thought to be most significant in life. For the ancient people of Mesopotamia, who depended upon the flood waters for their agriculture, it was the powers of water, mist and sea which 'gave birth' to the living world. For the biblical Hebrews, creation happened at the command of a spirit – God. For the Athenians, at the time of the philosopher Plato, creation was pictured as a coming together of the elements in perfect numerical proportions. Each story tells us something important about the society which invented it.

One modern view, based on experiments with electrical discharges inside a sealed flask containing inorganic gases and liquids, holds that creation may have happened as a chance result of lightning in the ancient atmosphere.



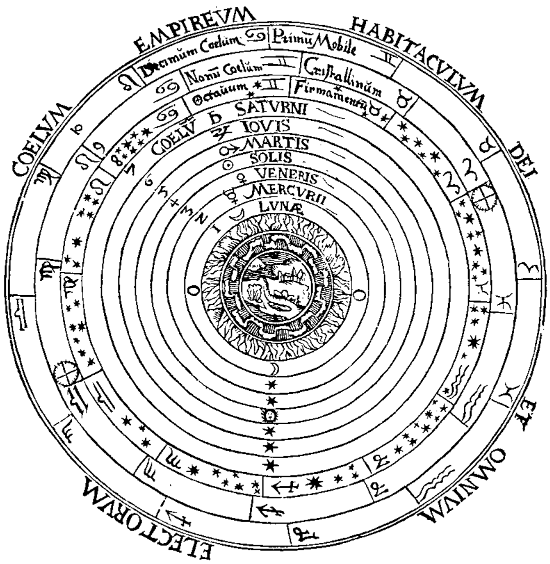
An experiment to mimic 'the creation' of amino-acids, essential components of all living creatures.

What does this tell us about modern ways of thinking?

Do you think that such experiments can prove how the creation of life came about?

Do they establish a mechanism and make useful predictions like other scientific theories?

By the thirteenth century the combined authority of ancient learning (Aristotle and Ptolemy) and that of the contemporary church (St Thomas Aquinas) had established a 'model' of the universe which was to last unchallenged for several centuries.



The mediaeval model of the universe.

This model pictured the Earth at the centre of a nesting set of 'crystal spheres'. The spheres, which still figure in some Christmas carols, were made of hard, everlasting material, and were invisible to mortal eyes. Each moved round at its own unchanging speed; only the central Earth remained at rest. It may seem strange to us because we have been taught another theory in which the Earth moves round the sun, but can you prove it wrong?

It matched the simple 'facts' of observation in several ways:

The Earth seems unmoving under our feet.

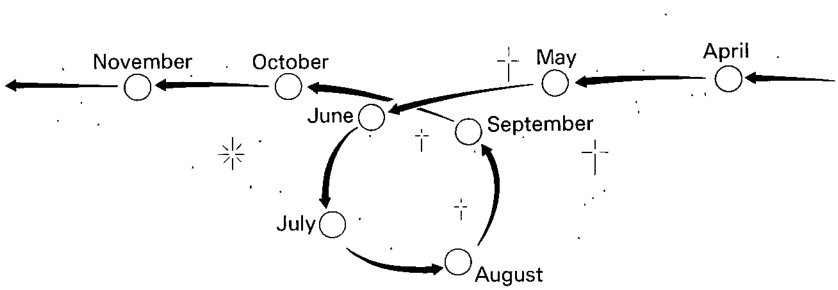
The sun, moon, and planets seem to move across the sky.

All the constellations of stars remain in exactly the same patterns as they swing across the night sky, just as if they were fixed to an invisible sphere.

The system had certain features which had become mixed up with religious teaching. By the sixteenth century the church had added the following points:

> The hand of God turned the outer sphere, 'the Primum Mobile', which kept the whole system moving.
>
> Only the Earth at the centre is imperfect. The rest of the universe is perfect, without blemish and unchanging.
>
> Where Jesus Christ lived and died was the centre of the universe.

The system had some difficulties. The planets do not always seem to move regularly across the sky; sometimes they seem to move backwards for a while before going on again. The model had to introduce more spheres to copy this effect. Little spheres were imagined to roll around on the surface of other spheres. The model became more complicated and by the sixteenth century there were fifty spheres in all. Calculations based on it became difficult and clumsy but it was possible to predict the positions of the sun, moon and planets accurately.



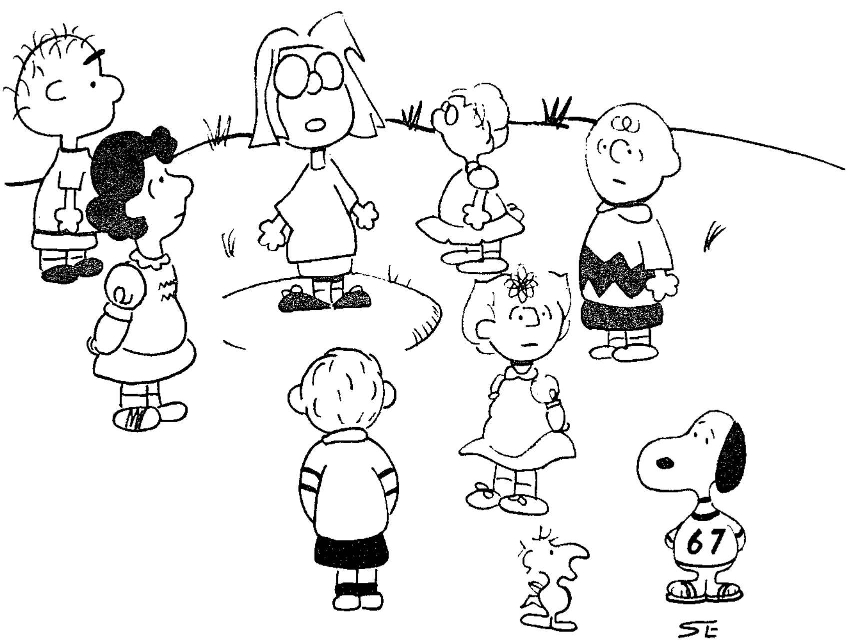
Successive positions of the planet Mars. How do we now account for this loop?

TROUBLE WITH THE CALENDAR

For some time there had been growing concern that the calendar had fallen out of step with observation. Easter is defined by the full moon and the spring equinox, so it became easy to see that the calculated Easter Sunday was not the 'real' one. Since almost all educated men were within the church at this time, it was a pope who suggested new calculations should be made, and it was a clergyman, Nicholas Copernicus, who produced the new system for correcting the calendar.

Copernicus was a Pole who had been educated in Italy and worked in Prussia (East Germany) for most of his life. As a young man he had made some practical observations on the size of the moon but his real interest lay in Mathematics. In order to set the calendar to rights, Copernicus decided to adopt a totally different model of the universe with the sun at the centre, instead of the Earth, round which all the planets circled.

Copernicus was not the first man to have this idea of a sun-centred universe. Some of the ancient Greek philosophers, including the famous Pythagoras, had the same idea, and there were even a few contemporary Italian scholars who suggested that the Earth, although still at the centre, might be rotating on its axis. This would account for the daily movements of the stars and planets. To the vast majority of people living at this time, however, Copernicus's theory would have seemed totally new and probably absurd. They were unlikely to hear about it. Copernicus intended his book for mathematicians; he recommended his new model because it made calculations on the calendar much easier to do.



'You know her trouble – she's pre-Copernican – thinks she is the centre of the universe.'

Copernicus completed his first manuscript by 1509 but did not publish it through fear of ridicule. It was circulated privately and a summary of his ideas became known to the pope who asked to see a complete work on the subject. Almost reluctantly Copernicus agreed and in 1543, when the author was already on his death-bed, his book *On the Revolution of the Heavens* was finally published.

MATHEMATICS OR HERESY?

Would the pope and cardinals of the church be hostile to Copernicus's theory? Not only did it seem to contradict common sense, but it was also against religious teaching. The church was powerful and there was not, as yet, any scientific knowledge different from religious knowledge. The truth about the universe was a matter of religious faith.

In order to protect Copernicus's book from possible criticism of this sort, a professor of theology, Osiander, wrote a preface to it, explaining that this was just a mathematical idea, not a 'true cause' of the universe. This meant it was rather like a simplified diagram on paper – it does not resemble the real thing, but it helps us to make calculations.

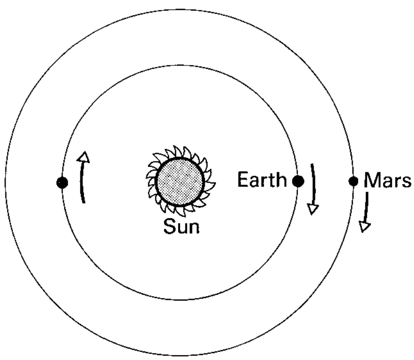
> '. . . I have no doubt that some learned men have taken serious offence because the book declares that the Earth moves and that the sun is at rest in the centre of the universe . . . but if they are willing to examine the matter closely, they will find that the author of this book has done nothing blameworthy . . . For these hypotheses need not be true, or even probable . . . Let no one expect anything certain from Astronomy, lest he accept as the truth ideas conceived for another purpose and depart from this study a greater fool than when he entered it.'
>
> *Osiander's preface.*

It is always difficult to understand people's ideas when they are from another time and different from your own. If you read the passage carefully you will see that Osiander wanted to protect the contemporary faith in religious truth and certainty, no matter what new ideas the mathematicians and astronomers might produce. He may also have been afraid.

What Copernicus himself believed is hard to know. He never read Osiander's preface, but he described his sun-centred system of the universe with an enthusiasm which does not sound much like cold mathematical theory.

> 'In the middle of all sits Sun enthroned. In this most beautiful temple could we place this luminary in any better position from which he can illuminate the whole at once? He is rightly called the Lamp, the Mind, the Ruler of the Universe . . . So sits the Sun as upon a royal throne, ruling his children the planets which circle around him.'

At first there seemed to be little evidence that Copernicus's theory might be right, so it was not dangerous to the Church. It is true that it made the occasional retrograde, or backwards, motion of the planets easier to understand. The Earth moves faster in its orbit than does Mars, for example, so you can see from the diagram that, when they are both on the same side of the sun, Mars will appear to move backwards. But people were quite used to the complicated Ptolemaic explanation for this.



Why Mars seems to go backwards (as seen from Earth).

It is true that the two inner planets, Mercury and Venus, always seem close to the sun. Mercury is hard to observe because it is so near the horizon at sunrise and sunset. Venus is called the morning and evening star because it appears close to the sun.

On the other hand the Earth feels stationary. If you throw a stone up into the air it does not fall behind you as it might if the Earth were moving. To most people, including Martin Luther, the idea that the Earth revolved about the sun seemed ridiculous. Two events took place which were to be important for the coming conflict between science and the church.

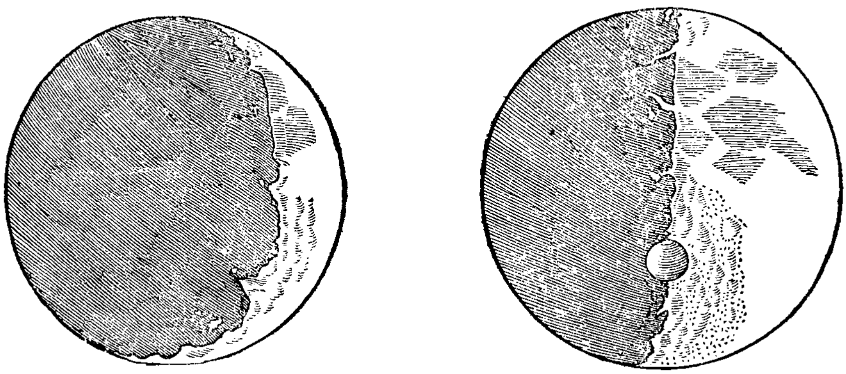
First the theory of Copernicus was taken up by a runaway monk turned philosopher called Giordano Bruno. He argued that there was no need for a crystal sphere to hold the stars; they might stretch outwards into space at any distance from the Earth. What was worse, Bruno suggested that each star might be a world of its own with different races of men and different gods. What sounds like simple science fiction was taken to be serious heresy; on his return to Italy, Bruno was seized by the holy inquisition, tried, convicted, and burnt at the stake in 1600. This event did not make the church feel more favourably disposed towards Copernicus's theory.

Around the same time the Danish astronomer Tycho Brahe was making careful new observations. He discovered a new star (a nova), and a comet which travelled straight through one of the places where there was supposed to be a hard crystal sphere. Tycho Brahe immediately concluded that the spheres did not exist and that the planets revolved quite freely without 'the hard machinery of the heavens'. There were now new facts and theories in astronomy.

GALILEO'S DISCOVERIES

Galileo Galilei was a lecturer in mathematics at the university of Padua, near Venice, when he first heard about the new Belgian invention which made distant objects look close. He promptly set about grinding lenses to make his own telescope. At the third attempt he produced one with a magnifying power of about thirty times, and turned it on the sky. It was little better than a pair of modern fieldglasses and required patience and skill to use. Galileo never saw the rings of Saturn as more than curious bulges on its surface and he reported a 'vaporous sphere' around the moon which must have been due to optical errors in his lenses. Others found his telescope unconvincing, but to Galileo it brought a series of revelations which he interpreted on the Copernican system.

The moon was a wonderful sight and Galileo, who was skilled at drawing, made beautiful sketches of its mountains, craters and seas. He



Galileo's sketches of the moon.

watched the shadows of lunar peaks move slowly across the moonscape as the sun's rays stretched across its surface. This was no perfectly smooth celestial orb but a rough, real world very like our own.

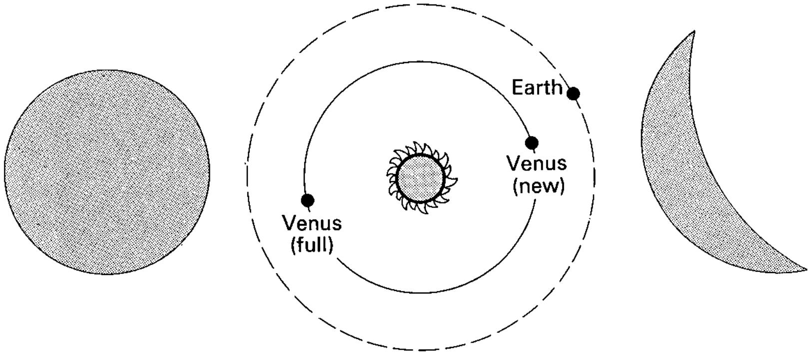
He examined the Earth-shine on the dark surface of the crescent moon and correctly deduced that our world, like the moon, shines with reflected sunlight and is not dark and motionless as the Ptolemaic supporters had taught.

He discovered the four largest moons of Jupiter. He was able to watch their complete revolutions around the parent planet as it slowly drifted past in its large orbit round the sun.

Galileo published these results in 1610. They raised local argument in the university of Padua, including public debates and demonstrations. Some of Galileo's opponents refused to look through the telescope because it was the 'source of error' and perhaps heresy; but Galileo was optimistic that he could convince everyone – the cardinals and the pope himself – by his arguments and his discoveries. On three separate occasions he travelled to Rome to try to win official support for the Copernican theory.

Meanwhile he made two more important discoveries with his telescope.

He watched the planet Venus go through phases, rather like the moon. When Venus is on the same side of the sun as the Earth it appears as a crescent – 'new Venus' – and quite large. But when the planet is beyond the sun on the other side of its orbit it appears round – 'full Venus' – but smaller because it is further away.



Venus as seen from Earth.

This was one of the best pieces of evidence that Galileo had collected so far, but it did not seem to change many opinions. He also saw sunspots which enabled him to prove that the sun too revolved on its axis.

By now Galileo had moved from the comparative freedom of the Republic of Venice to Florence, in the Duchy of Tuscany, where he made his home. He could feel the opposition to his ideas growing, both around him and in church circles in Rome. There was a risk that the pope might make an official pronouncement that the Copernican theory was heresy and not to be taught. In 1615 he wrote a long public letter to the Duchess of Tuscany; it was like an election manifesto, explaining his position and defending, as best he could, the right of scientists to hold what theories they believed to be right.

> 'To commend that the very professors of astronomy themselves see to the refutation of their own observations is to enjoin something that lies beyond any possibility of accomplishment. For this would amount to commanding that they must not see what they see and must not understand what they know. I am referring at all times to merely physical propositions, and not to supernatural

things which are matters of faith . . . And to prohibit the whole science would be but to censure a hundred passages of Holy Scripture which teach us that the glory and greatness of Almighty God are marvellously discerned in all his works and divinely read in the open book of heaven . . . the intention of the Holy Ghost is to teach us how one goes to heaven, not how heaven goes.'

The letter was as long as a small book, but it did not succeed; few clergymen of the time were ready for the kind of intellectual freedom that Galileo demanded.

The powerful Cardinal Bellarmine thundered back the position of the church in a letter to one of Galileo's supporters:

> Copernicus's theory is only to be taken as a mathematical idea, not as reality.
>
> All the bible is literal, God-given truth, as interpreted by the church. A man would be as much a heretic if he believed that the sun does not 'move across the heavens', or that Abraham did not have two sons, as if he denied the virgin birth of Christ.
>
> It is common and easy to believe that the truth is different from the evidence presented to your eyes. For example, if you set out to sea in a ship, it is the shore that looks as though it is moving away. That does not deceive you: you know that the ship is moving and not the shore. Why not do the same in astronomy?

How do you think that Galileo would have answered these points?

CHALLENGE AND PERSECUTION

An official committee of church theologians decided against the Copernican theory and Galileo was privately warned by Cardinal Bellarmine neither to teach nor discuss it in any form. For a few years this silenced Galileo, at least on this topic, even though he had been wanting for a long time to write a book explaining his views on the two possible systems of the universe – those of Ptolemy and Copernicus.

Seven years later, the pope died and one of the cardinals who had always been friendly to Galileo was elected in his place. Galileo immediately travelled to Rome to speak with him. He was well received and given permission to write his book, just so long as he did not try to disprove the older Ptolemaic theory which the church supported.

Slowly Galileo began to write his great work in the form of a dialogue. Two of the characters supported the Copernican view and discussed all the telescopic evidence that Galileo had collected. The third character, Simplicius, presented the church's view. In 1632 his famous *Dialogue Concerning the Two Chief World Systems* was finally published.

Galileo.

The church's reaction was prompt and fierce. Galileo's own courageous words in the preface, '. . . I have taken the Copernican side in the discourse . . .' proved only too true. The rather pathetic character Simplicius, who was to have been the church's mouthpiece, is steadily convinced by Galileo's arguments throughout the book. Perhaps it was hardly surprising that the printer was ordered to suspend all sales. Galileo himself, now almost seventy and continually ill, was ordered to

Rome to stand trial before the holy inquisition. His pleas of age and illness were ignored and he made the long journey painfully in a litter.

Twice during April 1633 Galileo was examined by the inquisitors and refused to change his views. Only when the Pope ordered more severe treatment did the old man give way. Dressed in the white shirt of a penitent he knelt on the floor of the monastery while the document of his recantation was read out. In it he promised to believe that the Earth was stationary, and in everything that was taught by the Holy Church. He 'abjured and cursed' the heresies of the Copernican system which were 'errors and contrary to Holy Scripture' and signed his name to the sentence. It was a public humiliation for all the world to see.

After a few months Galileo was allowed to return home to permanent house arrest in Florence. He was forbidden to teach or publish any more books. More misfortunes struck him: his eldest daughter died, he became ill and lost the sight of both his eyes. Nevertheless his will had not been broken. By dictation he wrote a superb book on physics and mechanics, *The Two New Sciences*, which was smuggled out of the country to Holland for publication.

The great creative period of Italian science died with Galileo in 1642, but in northern Europe his works were widely read and from them sprung a new growth of science.

IDEOLOGY AND CENSORSHIP

This has not been the only occasion in history when science has come into conflict with official ideology. In Nazi Germany, the relativity theory was pronounced to be 'non-Aryan' physics and discouraged. For a while genetics suffered an even stronger prohibition in Soviet Russia (1948–1964) because it was thought to be in conflict with the official programme for raising new strains of crops. In some states of the USA it is against the law to teach the theory of evolution in school unless the same length of time is devoted to teaching the biblical view of creation.

The persecution of Galileo is still the most notorious of all these incidents. The whole weight of the church's authority was set against the Copernican theory of the universe; they suppressed his book, forbade anyone to teach his ideas and were ready to torture and imprison those who disobeyed. For a while the church seemed to be claiming the right to dictate what scientists should believe about science.

Most people think that the church was wrong. They argue that Galileo, and all other scientists, should have complete freedom to construct any theory to explain natural events and to teach this theory, whether or not it is in conflict with firmly held beliefs of the church or citizens. Some are against all forms of censorship, especially in science which, they claim, is not about moral issues but about facts and observations.

Are you against all censorship (even for sadistic or racist propaganda)?

Are there subjects on which you might want to suppress the findings of scientific research (experiments to change the characteristics of a human foetus; finding out whether one race is intellectually superior to another)?

Should scientists' beliefs influence what research they do (chemical warfare)?

Is science academic and neutral, or concerned with moral issues and personal beliefs?

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2 Scientific Cosmology

GRAVITY MOVES OUTWARDS

Neither Copernicus nor Galileo had given serious thought to what kind of force made the planets circle round the sun and the moon round the Earth. That was the achievement of Isaac Newton in the seventeenth century.

Newton assumed that it was the same force which causes an apple to fall off a tree that makes the moon orbit the Earth. He made careful calculations to back up his theory. It was a universal law. It could be used for planets, stars, comets, or a child tripping over on the ground.

This was a new idea – to suppose that Earthly scientific laws held true for other regions of space:

> The laws of physics which scientists develop to explain happenings on Earth should also be held true for the unreachable objects

> in space. From now on, whether the subject was astronomy or space fiction, there were rigid conditions which had to be met.
>
> The force of gravity could cause all the movement and change within the universe without the action of any god.

This second point was the beginning of scientific cosmologies, theories about how the universe began, how the stars and planets were formed, how they continue to exist, and how they may come to an end.

The first cosmology, based on Newton's law of gravity, was due to a German philosopher called Immanuel Kant who lived about a century later. New and improved telescopes had shown that there were two small luminous clouds in the sky. These were called nebulae; one was in the constellation of Orion, the other was in Andromeda. Kant believed that both were distant star systems forming out of clouds of dust. He believed that they must be rotating under the inward pull of their own gravity. The same power could have caused the formation of stars from primaeval dust and might lead to the regular collapse and destruction of stellar universes into debris from which new stars could grow by the same gravitational process.

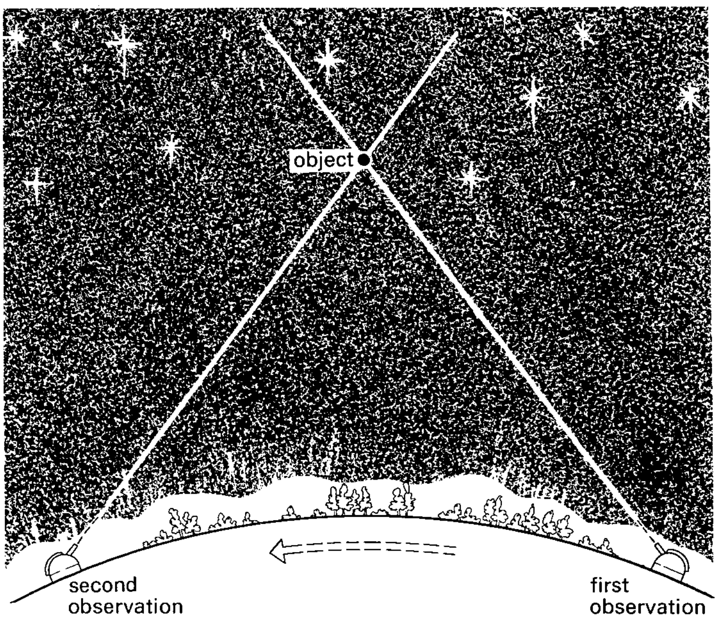
> When we follow this Phoenix of nature, which burns itself only in order to revive again in restored youth from its ashes, through all the infinities of time and space . . . carrying on the plan of Divine revelation . . . then the spirit which meditates upon all this sinks into profound astonishment.
>
> *Universal Natural History, 1755*

HOW BIG IS THE UNIVERSE?

It is possible to measure the distance of our nearest neighbours in space, the moon, the planets and the sun, by taking bearings on them in the same way as mapmakers do. You need two positions for a telescope and a base line between them whose length you know. Only one telescope is necessary because, as the Earth revolves, the position of the observer is changed.

By the time of Copernicus and Galileo this kind of work had been done, although not with same accuracy as we can do it today. But there was still no knowledge about the distance of the stars.

On the older Ptolemaic model of the universe all the stars were supposed to be at the same distance, on a remote crystal sphere. If it were true, as Galileo believed, that there was no such sphere and that the stars were at different distances from us, then, by the same method, it should have been possible to see the nearer stars apparently changing their positions as the observer moved. However big the base line was, even using the diameter of the Earth's orbit around the sun, Galileo could not detect the least movement of any of the stars against the background of the more distant constellations. This meant that the stars had to be at immense distances from the Earth. It was a great disappointment for the supporters of the Copernican theory.



Taking bearings or measuring parallax.

By the nineteenth century the best telescopes had become good enough to find and measure this 'stellar parallax' for some of the nearest stars, so it became possible to measure their distance from the Earth; more than 25 million million miles. For these enormous distances it was necessary to have a new measurement of length – the light year.

Galileo had tried to measure the speed of light but it is so great, it can travel about seven times round the world in one second, that he failed. In 1660 Ole Römer made observations on the moons of Jupiter, which Galileo had discovered, and found that the time intervals between the eclipses of one of these moons, as it went behind Jupiter, were not regular. The extra time taken for the light to reach us when the Earth was moving away from Jupiter was making the difference. From this he calculated the speed of light as 186,000 miles per second, or 300 million metres per second.

One light year is the distance travelled by a beam of light in one year . . . nearly six million million miles.

The next question was, are the nebulae really remote systems of stars, and if so, how far away are they? By the end of the nineteenth century it became possible to make out the occasional bright star in the Andromeda nebulae, so perhaps it was a whole collection of stars; but a completely new method was needed to measure its distance away.

During the first decades of the twentieth century astronomers made a special study of variable stars. Many stars, including our own Pole Star, change in brightness over a period of a few days or weeks, and it was soon discovered that the brighter ones changed more slowly than those that were dimmer and probably smaller. When telescopes became good enough to pick out such variable stars in the Andromeda nebulae it was possible to calculate how bright they would have been if they were in our galaxy. Astronomers took into account how faint they seemed and so estimated their distance from us. It turned out that this whole nebula (or galaxy) of stars was a thousand times as far away as the average stars in our own galaxy, some two million light years away.

Andromeda is the nearest galaxy to us. We have now counted millions of others stretching out to distances of many billions of light years. That means that we are seeing them far back in time, billions of years ago, as well as far out in space. In between the galaxies there seem to be great dark spaces containing hardly anything, neither stars nor dust, only the thinnest gas imaginable.

> The universe is empty, for the most part, but here and there, separated by immense intervals, we find other stellar systems, comparable with our own . . . we find them smaller and fainter, in constantly increasing numbers, until we arrive at the frontiers.
>
> *The Realm of the Nebulae (Edwin Hubble, 1936)*

The great Andromeda nebulae.

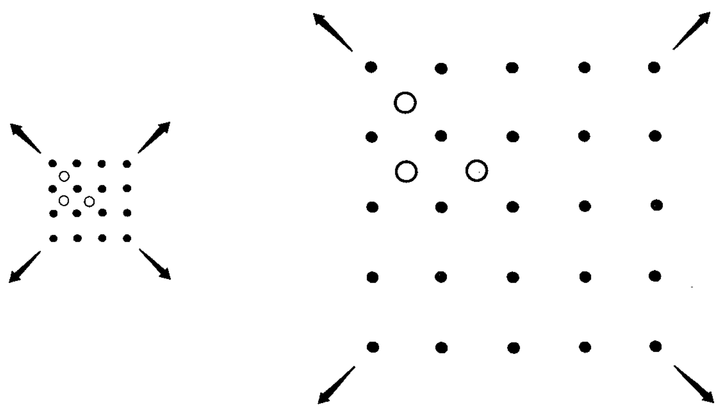
THE EXPANDING UNIVERSE

Edwin Hubble made the first measurements of the distances of the galaxies, but he is best remembered for another discovery. When he examined the coloured spectrum of the light from distant galaxies he found it was shifted slightly towards the red end of the range where the frequencies are a little slower.

What could be the explanation for this? You may have noticed that when a police car goes past sounding its siren, the note is higher as the car approaches and lower as it goes away. If a similar phenomenon was affecting light from distant galaxies then the 'red-shift' would prove that they were all moving away.

Hubble's measurements showed that the more distant galaxies were moving away faster than the closer ones. They retreat about twenty miles per second faster for every extra million light years away. The most distant observable galaxies are going away from us at nearly half the speed of light according to this theory.

This continual opening out of the universe in all directions was not unexpected. Eight years earlier Albert Einstein had published his Theory of General Relativity and it had seemed then that gravity might make space-time expand outwards. If the space between the galaxies itself were stretching it was hardly surprising that the galaxies embedded in it seemed to be moving away from one another.



Imagine you are at one of the little circles. All the dots will appear to be moving away from you.

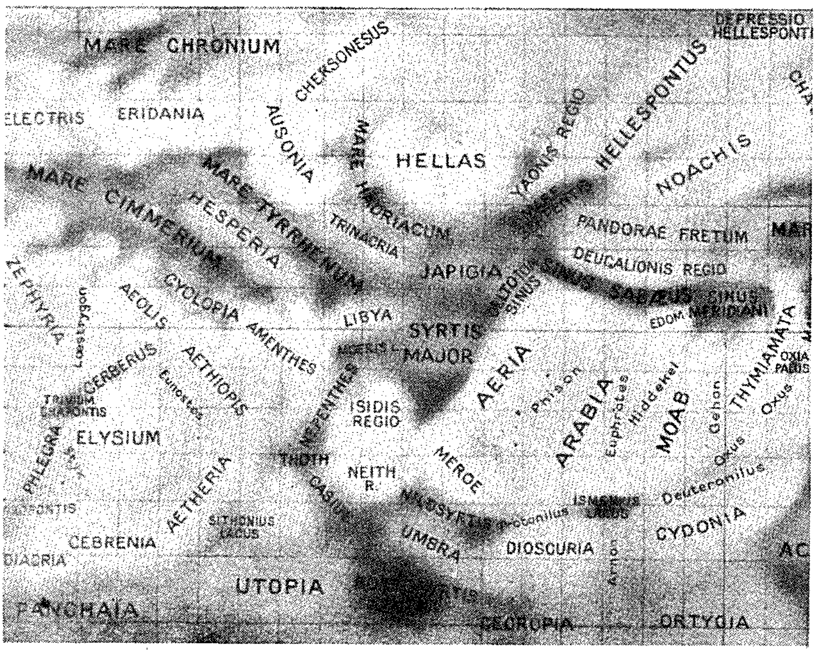
These new discoveries gave rise to new cosmologies. If all the galaxies were moving outwards, with the fastest being furthest away, it suggested that they may all have begun at the same point in space and time in one great explosion. This is the Big Bang Theory, first put forward by the mathematician Georges Lemaitre in 1927. It is interesting that this scientific cosmology, which imagines something like a violent moment of creation about twenty billion years ago, was first proposed by a clergyman.

There have been other modern cosmologies, including one called the Steady State Theory, in which the matter from which the stars are made is thought to be continuously created. Astronomers have attempted to decide between rival theories by making predictions like forecasting the number of radio galaxies (systems detected by the radio waves they emit) in distant regions of space. Experiments carried out so far seem to favour the Big Bang Theory, with claims that faint echoes of the original 'bang' can be picked up.

SCIENCE FICTION CATCHES UP

In 1877 the Italian astronomer Schiaperelli announced that he had seen some channels, 'canali', on the surface of the planet Mars. This observation was repeated by the American astronomer Percival Lowell who spent his professional life drawing the surface details of this planet. His telescope, situated in the clear air of Arizona, was good enough to pick out the large dark patches, the biggest craters, the polar ice caps, and even a dust storm which temporarily blotted out all detail. Lowell's maps are criss-crossed with fine straight lines which he supposed to be vegetation watered by artificial canals which had been constructed, so he thought, by intelligent Martians (in fact his telescope was not good enough to resolve such fine detail even if it had been present).

Opposite *These illustrations show identical regions of the Martian surface mapped (1) from telescopic photographs taken in 1969, and (2) from telescopic drawings compiled at the Lowell Observatory in 1905, during Percival Lowell's lifetime (note the canals).*


MARE CHRONIUM
DEPRESSIO HELLESPONTI
CHERSONESUS
ELECTRIS
ERIDANIA
AUSONIA
MARE HADRIACUM
HELLAS
YAONIS REGIO
HELLESPONTUS
NOACHIS
MARE CIMMERIUM
MARE TYRRHENUM
HESPERIA
TRINACRIA
PANDORAE FRETUM
DEUCALIONIS REGIO
SINUS SABAEUS
SINUS MERIDIANI
EDOM
JAPIGIA
ZEPHYRIA
Laestrygon
AEOLIS
CYCLOPIA
AMENTHES
LIBYA
SYRTIS MAJOR
AERIA
Phison
ARABIA
Euphrates
Hiddekel
MOAB
Gehon
THYMIAMATA
OXIA PALUS
Oxus
CERBERUS
Eunostos
AETHIOPIS
NEPENTHES
ISIDIS REGIO
TRIVIUM CHARONTIS
ELYSIUM
PHLEGRA
THOTH
NEITH R.
MEROE
Deuteronilus
AETHERIA
CASIUS
NILOSYRTIS
Protonilus
ISMENIUS LACUS
CYDONIA
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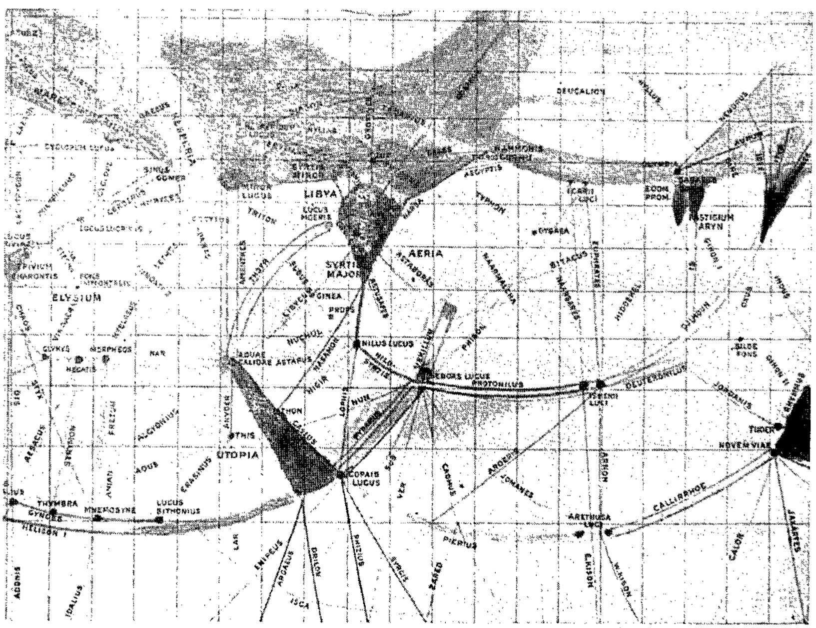
DEUCALION
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EDOM PROM.
FASTIGIUM ARYN
PROTONILUS
DEUTERONILUS
TUDER
NOVEM VIAE
MNEMOSYNE
LUCUS SITHONIUS
THYMBRA
GYNDES
ARETHUSA LUCUS
CALLIRRHOE
JORDANIS

2

It is interesting to compare Lowell's faith in his telescopic observations with that of Galileo. Both men were interpreting what they saw in line with what they believed. All scientific experiments are like this.

The last decades of the nineteenth century saw the first of a new crop of science fiction novels, many of them were concerned with extraterrestrial life. The earliest was Jules Verne's *Moon Voyage* where the explorers were launched from Earth by being fired out of a cannon.

H. G. Wells's famous story *War of the Worlds* used authentic scientific data, but the end product was far more exciting. In 1894 a report of some faint flashes observed on the surface of Mars was printed in the scientific periodical *Nature*. The author had allowed himself to speculate that the lights might be due to intelligent life on Mars. This was enough to fire Wells's imagination. In his book, published four years later, the mysterious flashes became evidence for the launching of a Martian invasion fleet. As a radio play its broadcast of invasion and victory by the conquering Martian forces was so realistic that it produced panic in some of the 1940s' listeners.

Wells's second novel of space-flight, *The First Men on the Moon*, did more than describe an alien race of half plant and half insect life living within a hollow moon, it made social comment on the violence and greed of his own civilisation. His *Time Machine*, strictly Earthbound but set in the future, used imagined deviant races to make serious criticism of the class structure of his society. This was to become an important and valuable feature of some of the best science fiction.

From the outset it has been a matter of pride to the authors of SF that their scientific detail should be convincing. Jules Verne himself attacked H. G. Wells for using anti-gravity material in the launch of his space ship: 'He goes to Mars in an airship he constructs of a metal that does away with the law of gravitation. That's all very fine, but show me this metal. Let him produce it!'

Many scientists have written SF, among them A. Clarke, B. F. Skinner, I. Asimov and F. Hoyle. In a recent anthology from Russia every SF author was a practising scientist.

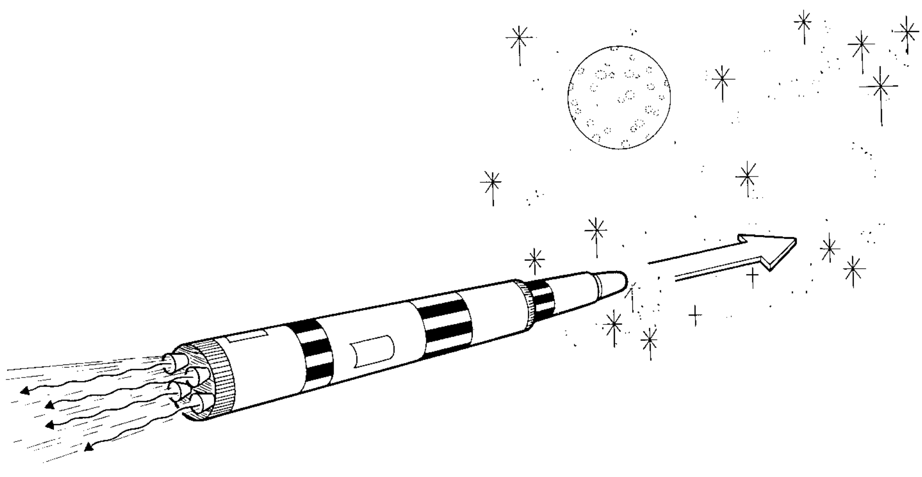
Do you find that there is a close connection between science and imagination?

Think of SF you have read and point out its scientific features and the social comment the author was trying to make.

3 First Journeys into Space

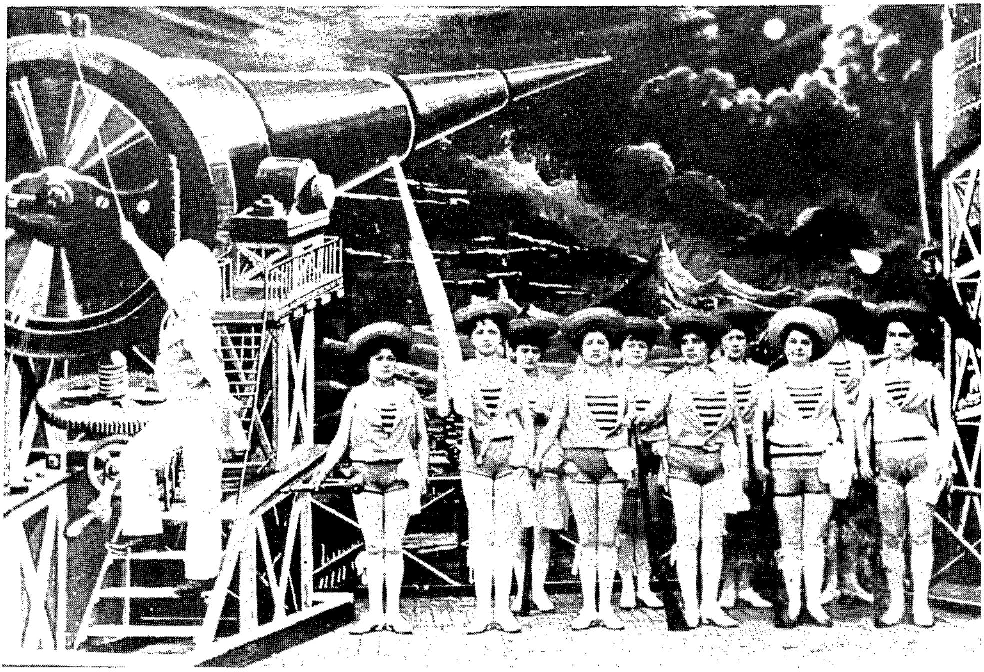
THE ROCKETS GO UP

Before the twentieth century the rocket was either a firework or a clumsy kind of weapon. The first of the new rocket pioneers was Konstatin Tsiolkovskii, a Russian schoolteacher who was partially deaf and self-educated. He constructed the theory of the *reaction engine* which is rather like the working of a toy water rocket. It does not depend upon pushing on the air, like a propeller, nor on an intake of air as in the jet; instead it contains within itself some material and the means of ejecting it out backwards. This pushes the rocket forwards. The greater the *mass* of material and the *faster* it is ejected, the greater will be the *thrust* on the rocket.



Tsiolkovskii calculated that it would be best to use liquid fuel for the explosion which throws out the material (spent gases) and that it would be possible to reach out into space 'to set up moving stations, living rings around the Earth, the moon and the sun, and even to land on the surface of Mars'. This was in 1912.

Tsiolkovskii's work was not recognised until the 1920s when two other inventors reached the same conclusions independently. One was



Science fiction films began by looking like music hall shows (A Trip to the Moon, 1902).

Robert Goddard, an American army rocket expert, who published his designs for a liquid-fuelled engine with the comment that it could 'reach the moon'. It made slow progress. His first successful launch took place in 1926, and by 1930 his prototype still could not rise more than 2,000 feet. The other rocket pioneer was the German, Hermann Oberth, whose treatise on rocket design, published in 1922, was entitled *The Rocket in Interplanetary Space*. Oberth's engineering talents were not recognised for many years but his scientific knowledge and enthusiasm for space travel found a different outlet. He was engaged by the film producer Fritz Lang to design the spaceship for his film *Girl in the Moon* which was released in 1929. Under Oberth's influence it showed the first countdown to launching, the effects of crushing g-force during acceleration and the weightlessness of space. The public was eager to imagine the possibilities of space flight, and popular interplanetary societies were being founded in America, Germany and England. When the German rocketeers of the 1930s began to build their powerful liquid oxygen-ethanol-fuelled engines it was to Oberth that they owed their theory and inspiration.

Less than thirty years later they were predicting phenomena such as weightlessness (The Girl in the Moon, 1929).

At the same time there was a flood of new space adventure stories. Many described weird kinds of bug-eyed monsters (known affectionately as BEMs) who inhabited other planets – Mars was the most popular – and had a knack of carrying off beautiful human girls in their claws, to judge by their covers. The most prolific writer was Edgar Rice Burroughs, the creator of Tarzan as well as countless BEMs. Quarterly or monthly issues came out as *Amazing Stories* and *Astounding Science Fiction*. The best can still be read in modern collections such as *SF, the Great Years* edited by C. and F. Pohl. There was a tremendous range of quality but addicts read the lot.

> Froud grinned. 'The camera never lies . . . It'll be amusing,' he went on, 'to see which of the story-tellers was nearer the truth. Wells, with his jelly-like creatures, Weinbaum, with his queer birds, Burroughs with his menagerie of curiosities, or Stapleton, with his intelligent clouds'.
>
> From *Stowaway to Mars* T. Beynon (Wyndham, 1936)

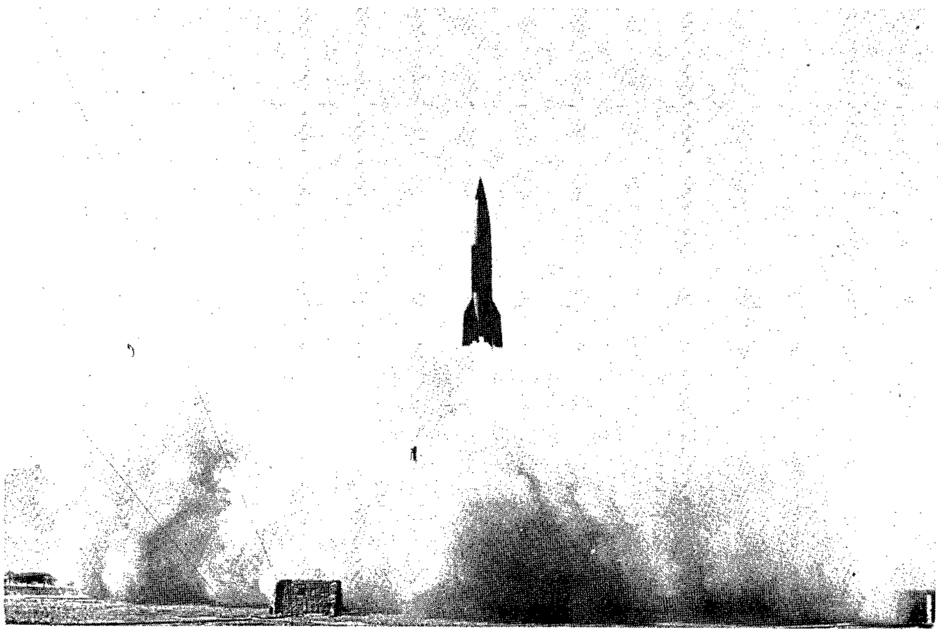
That extract does little justice to the works of Olaf Stapleton who, with Aldous Huxley and others, was pursuing the other aim of science fiction – prediction and social comment. *Brave New World* by Huxley is not space fiction but he uses the evolutionary theories of Darwin and the possibility of the genetic engineering of test-tube babies to criticise the aims of the Eugenics movement. (see *Evolution* in this series.)

ROCKETS AT WAR

By the time the Second World War broke out German engineers had constructed gyroscopically controlled rockets which could rise vertically to heights of a mile or more. The leader of this team was Werner von Braun, who was willing to convert his interplanetary rocket into a weapon of war for the Nazis in return for financial support. However, it was not until the tide of war had turned against Hitler that he ordered an all-out rocket effort. Von Braun had designs for a rocket which was huge by the standards of the times, it could rise five miles into the atmosphere and reach speeds of more than 3,000 mph. This was soon developed into the supersonic V-2. More than 3,500 rockets landed in Britain during the last year of the war and she was defenceless against them. The German team dreamed about their next project, a two-stage rocket into space.

> With our big rocket motors and step rockets we could build spaceships, which would circle the Earth like moons at a height of 300 miles and at a speed of 18,000 mph. Space stations and glass spheres containing the embalmed bodies of pioneers of rocket development and space travel could be put in permanent orbits around the Earth.
>
> *General W. Dornberger (commanding rocket project during war)*

It is hard to tell engineer and soldier from science fiction writer.



First American launch of the V-2 rocket in the New Mexican desert.

It was too late for the V-2 to win Hitler's war; rocket scientists became prizes to be seized by the victorious Allied armies. Von Braun's team and about one hundred V-2 rockets were taken to the USA and a team of rocket engineers, complete with their production plant, went to the USSR.

Both countries lost no time in trying out their new possessions. In 1946 the Americans launched their first V-2 in the New Mexican desert; it hit the ground, after a faultless flight, only thirty miles from the glassy radioactive scar where the first nuclear bomb had been exploded a few months before. The Russian V-2 was launched in the following year.

During the next ten years Russia and America were locked in the cold war. Rockets were transformed into intercontinental ballistic missiles with nuclear warheads. In America there was little money or incentive for developing new interplanetary rockets. The situation was different in Russia where the nuclear bombs were heavier, so more powerful rockets were needed to propel them. In both countries the captured German inventors were confined to military programmes and the dreams of those like von Braun, who saw the rocket as a launcher of spaceships, had to wait.

There were no limitations on imagination. Science fiction stories in magazines and anthologies doubled in popularity and full-length books caught the reading public's interest as never before. SF films with BEMs on unlikely planets seemed to be lagging behind the times. The better SF writers had abandoned the weird shapes of extraterrestial life, in order to focus more sharply on human problems.

The 1940s and 1950s were haunted by the destruction of Hiroshima and the possibility of nuclear warfare. While the Committe for Nuclear Disarmament organised protest marches, SF writers spun tales of the maimed remnants of some global disaster struggling to regain civilisation, to survive or failing to survive. Some of the better novels of the period, in ascending order of fantasy, were *On the Beach* (N. Shute), *The Chrysalids* (J. Wyndham), *The Overman Culture* (F. Cooper), *Childhood's End* (A. Clarke).

Another feature of scientific advance which found its way into SF was the robot or computer. Electronics at this time still relied on the valve rather than the transistor or microprocessor but the breakthrough was foreshadowed in the stories. Robots, it seemed, were just around the corner and the interaction between human and artificial intelligence formed the basis of many of Isaac Asimov's stories.

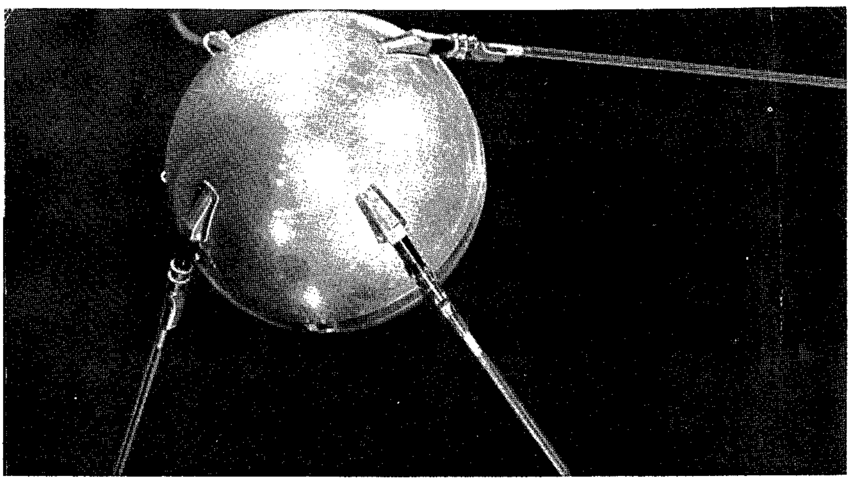
The postwar population explosion was another powerful stimulus to writers. If this planet became unbearably overcrowded would it not force man out into space to seek new worlds to colonise? Two excellent books on this theme are *The Space Merchants* by Pohl and Kornbluth, and *The Mote in God's Eye* by Larry Niven.

Even in the simplest space sagas echoes of terrestial politics could be heard. Two galactic superpowers often fought each other for empires among the stars while whole civilisations watched in terror of destruction. *Foundation and Empire* is part of a trilogy on this theme, and William Tenn's short story *The Liberation of the Earth* treated it satirically. Humility and doubt about man replaced the optimism of earlier years.

IN ORBIT

By 1955 the Korean War was over, Stalin was dead, and the conflict between east and west began to shift from the expectation of confrontation and war towards a struggle for prestige in the eyes of the other nations. Russian scientists began to participate unexpectedly in peace moves, but realisation had already dawned that the greatest prestige would arise from superiority in space technology.

As the International Geophysical Year of 1957–58 approached, USA and USSR announced preparations for launching a satellite to mark the occasion. On October 4th 1957 the news was broken that the Russian *Sputnik 1*, a metal sphere hardly bigger than a beachball, had been sent into orbit above the atmosphere and was sending radio bleeps back to earth.



The Russian Sputnik 1.

The Americans had lost the first lap of the space-race. Some senators appeared to believe that the whole episode was a Russian hoax; others blamed it on American school science teaching and set about organising educational reforms.

The US Navy's reaction was to push ahead with their own satellite launching in December 1957. They had to use the largely untried Vanguard rocket since Atlas, the ICBM, was not powerful enough. They planned a public launch in front of the television cameras of the world. It was a failure; the rocket exploded on the ground and the little satellite rolled on to the tarmac emitting its radio bleeps. An engineer was heard to remark, 'Why doesn't someone kick it and put it out of its misery?'

At last von Braun, who had been planning for space flight since the 1930s, was given his chance. The nation which had treated his research with so little respect that they had insisted that he use a sand-filled dummy for the third stage of his experimental rocket, now needed his help. The first American satellite, *Explorer*, was launched by von Braun's rocket *Jupiter* the following month. Although smaller than the Russian *Sputnik* it reached a higher orbit and discovered the van Allen radiation belts around the Earth.

The race went on. In 1958 America founded NASA (National Aeronautics and Space Administration) and almost immediately USA and USSR made attempts to reach the moon. The Russians crash-landed *Lunik 2* on the surface in 1959, to be followed a month later by *Lunik 3*, which went round the back of the moon sending photographs of the side which is always turned away from Earth. The year after, both countries made their first attempts at interplanetary travel. Unmanned probes from America failed to reach orbit round Venus and those from Russia failed to reach Mars. Nevertheless the space age, long heralded by science fiction, had begun.

THE MOON ADVENTURE

The Russian cosmonaut Uri Gagarin made the first manned orbit of the Earth in 1961. This event, combined with the USA's defeated attempt to invade Cuba at the Bay of Pigs, so deflated national pride that President Kennedy decided to go all-out for a dramatic space achievement – the landing of a man on the moon. This enterprise was to be more than a trial of technological strength, it was deliberately chosen as an excursion into the realms of imagination. 'No enterprise', said Kennedy, 'could be more impressive to mankind'. Von Braun thought that it would 'stimulate the imagination of the nation.' It did more; it became an adventure for the world to watch.

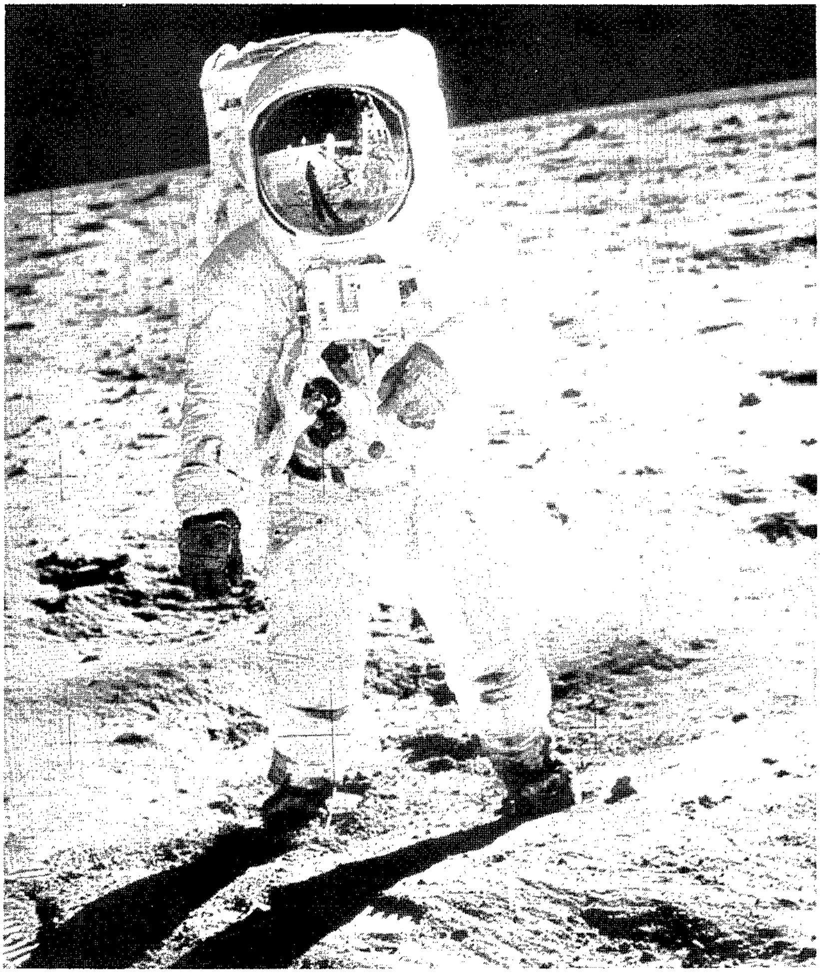
One result was a fall in the sales of science fiction (although they recovered later) as reality took over from fantasy. Every cosmonaut or astronaut launched into space looked back at Earth and commented on its beauty, a detail that fiction had not foreseen.

These human adventures were not without the danger and tragedy appropriate to fiction. Spacecraft went out of control, emergency splashdowns were made and the heat menace of re-entry was faced.

1967 was a year of tragedy when three American astronauts were burned alive during a trial run as the oxygen in their cabin exploded, and a Russian cosmonaut was killed on landing when his parachutes failed to open. The *Apollo 13* spacecraft burst one of its oxygen tanks on a trip to the moon and had to hobble the quarter of a million miles home with almost no fuel to a tense re-entry watched on millions of television screens. It landed safely.

The culminating spectacle was the landing of Neil Armstrong and Buzz Aldrin on the moon on July 21st 1969. Three astronauts took off from Cape Kennedy at 2.30 p.m. on June 16th; they made two and a half orbits of the Earth before they pointed the *Apollo 11* at the moon and coasted there at 24,000 mph for three days. Armstrong and Aldrin entered the lunar module, separated, and descended towards the surface, while half the world watched on television. Suddenly it became clear that the computer guiding-system had let them down; they were approaching a huge crater, miles from the prearranged site. The directors at Mission Control could only listen and watch helplessly while the flight was taken over by Neil Armstrong to be flown and landed by human touch on a new world.

A worldwide television audience waited for disembarkation. Many stayed up all night. At 4 a.m. British time Armstrong placed his foot on the moon's surface and made a 'giant leap for mankind'. The astronauts moved slowly about, arranging scientific apparatus, placing a plaque which reads 'We came in peace' and planting a flag bearing the stars and stripes. Reduced gravity enabled the men to hop and leap in a way which would have been impossible on Earth.



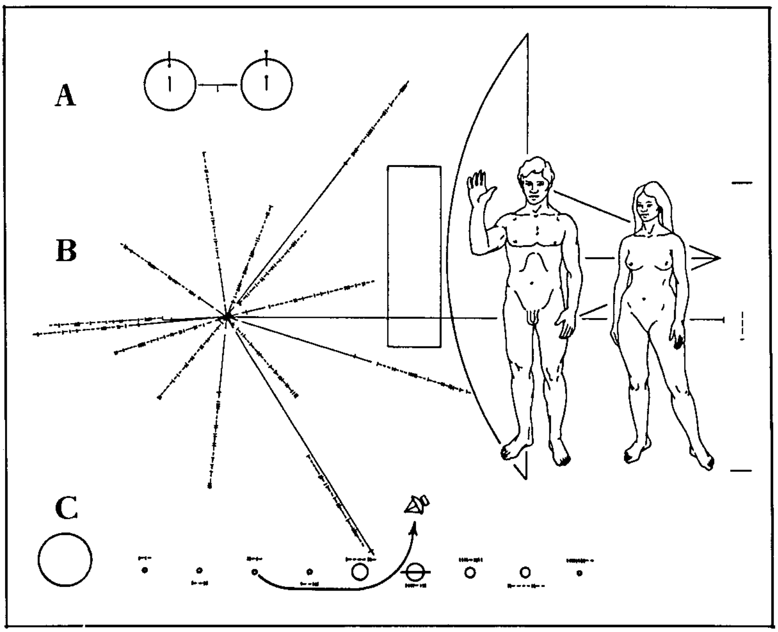
The astronaut Buzz Aldrin on the moon. The suit, oxygen and cooling water on his back weigh 183 lbs on Earth; on the moon they weigh 28 lbs.

IS THERE LIFE OUT THERE?

Sales of science fiction slumped again, but not for long. The central point of space imagination – contact with other forms of life – was still strong. The moon may have proved empty of life but belief in the existence of creatures in outer space continued. Some people believed that alien astronauts had already landed here, leaving carvings and earthworks which were cited as 'proof'.

Sightings of Unidentified Flying Objects continued to be reported as did rarer accounts of their occupants. In the USA and the USSR giant radio telescopes have been used systematically by respected astronomers to listen for communications from outer space.

Since the *Apollo* moon landings, unmanned spacecraft have journeyed further afield. In 1972 *Pioneer 10* and *11* took advantage of the positions of the major planets to pass close to Jupiter and Saturn before being catapulted into extra-solar space. They sent back photographs and carried humanity's first message to intelligent life in other stellar systems. It was a 6 × 9 inch gold-coated aluminium plate.



The plaque aboard Pioneer 10 spacecraft.

If one of the spacecraft should fall into the hands of intelligent scientists, however alien, they could read the plaque as follows:

A Scale factor measured from the wavelength of hydrogen radio waves.

B Bearings for our region of space (and time) using fourteen pulsars.

C The planet of origin and identification of the sun.

Could they understand that we are life-forms? What message do you think we should have sent?

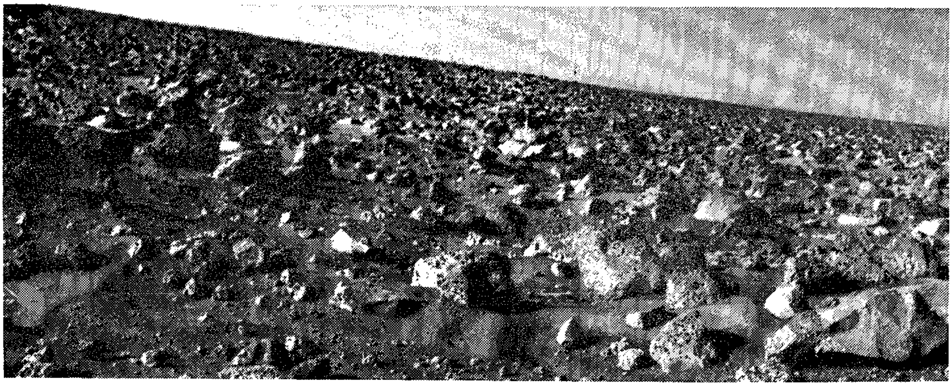
4 How We Use Space

EXPLORING THE SOLAR SYSTEM

In late 1971 the orbiting spacecraft Mariner 9 sent back a detailed photographic survey of the area that Lowell had mapped (page 25), but none of his canals, not even the massive 'Protonilus', were to be seen. This photograph is a Mariner 9 shot of the gigantic Coprates canyon, 45 miles wide and 20,000 feet deep. Its path almost coincides with a faint canal that Lowell drew. Could this be coincidence?

The first planet to be explored by rocket was the nearest. In 1973 the first soft landing on Venus proved that it resembled a traditional hell, with high temperatures, perpetual gales and a rainfall of hot acid.

During 1976 two *Viking* spacecraft examined Mars with hopes of discovering some form of life. The surface was dry and barren, but there were channels which looked as though they had been carved out by rushing water. The *Viking* lander scooped up earth samples, moving boulders to reach soil beneath. Each sample was treated with water and



This photograph was taken by the lander of Viking 2 in 1976 which came down in Utopia (page 25). There were no canals but could there be a dried up stream bed on the bottom left?

nutrients to awaken dormant bacterial life, but the only reaction was a chemical out-gassing. Mars, the cradle of space fiction, seemed to be without life.

At the time of writing, news of the planets in our solar system is coming in from two other space missions. In 1977 the two *Voyager* spacecraft were launched. *Voyager I* took a shorter and faster trajectory passing Jupiter about four months earlier than *Voyager II*; both sent back pictures of Jupiter's moons including erupting volcanoes on Io and a ring of dust around the planet itself, which was unexpected and like the rings of Saturn and Uranus. *Voyager I* made its closest approach to Saturn in 1980 and, ten months later, *Voyager II* came even closer to photograph its rings in detail. Between them they discovered about twenty new moons. Now, as *Voyager I* heads into empty space, *Voyager II* continues towards Uranus which it should pass in 1986. Neptune should be reached in 1989.

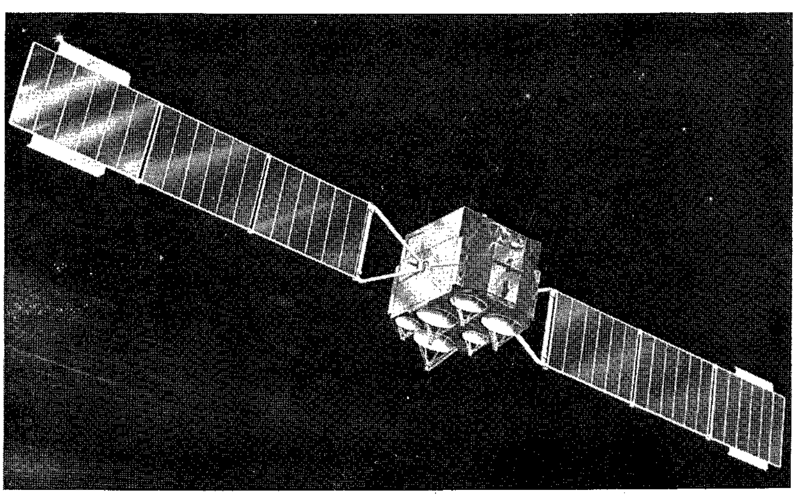
Though the dream of scientists and fiction-writers does not appear to be coming true, and there may be no other forms of life within the solar system, our curiosity about space does not stop. Space programmes are not cheap and there has been criticism about the amount of money spent on such research while millions of people starve and suffer from preventable illness. Even more money is spent on military research, but it is hard to answer those who ask what use is space research.

Is scientific curiosity good, bad or unnecessary?
Can it be stifled?
Have we got our priorities wrong?

SATELLITES FOR RESEARCH

A quarter of a century has passed since the first man-made object went into Earth orbit. There are now probably more than 5,000 pieces of hardware circling the Earth, although the majority are debris and burned-out third stages of rockets. From our activities in this near region of space we can begin to build a picture of society's interests and fears.

Many satellites are built to take scientific instruments and telescopes of various kinds high above the Earth's atmosphere. Some have detected X-ray stars and radio galaxies; others have observed the activity of the sun, its eruptions and sunspots. Other instruments have measured the cosmic wind of invisible particles hitting the Earth, and the formation of the Northern Lights. It is possible to use satellite photographs to explore the land and prospect for oil and minerals in remote regions on Earth. It is even possible to locate aeroplane wreckage after a crash.



The European Communications Satellite (ECS).

In this kind of work there is a large measure of international co-operation, just as there was in nuclear research before the Second World War.

SPACE GOES COMMERCIAL

Satellites can be used to relay television programmes and telephone conversations, either worldwide or on a national basis.

In order to be useful for communications, a satellite needs to be continuously in the right position. This means that it must be 36,000 km high, its orbit synchronised with that of Earth, taking exactly twenty four hours to complete one revolution around the Earth's equator. Because this is the same as the length of one day the satellite will always appear to be 'hanging' in the sky in exactly the same position when seen from the Earth.

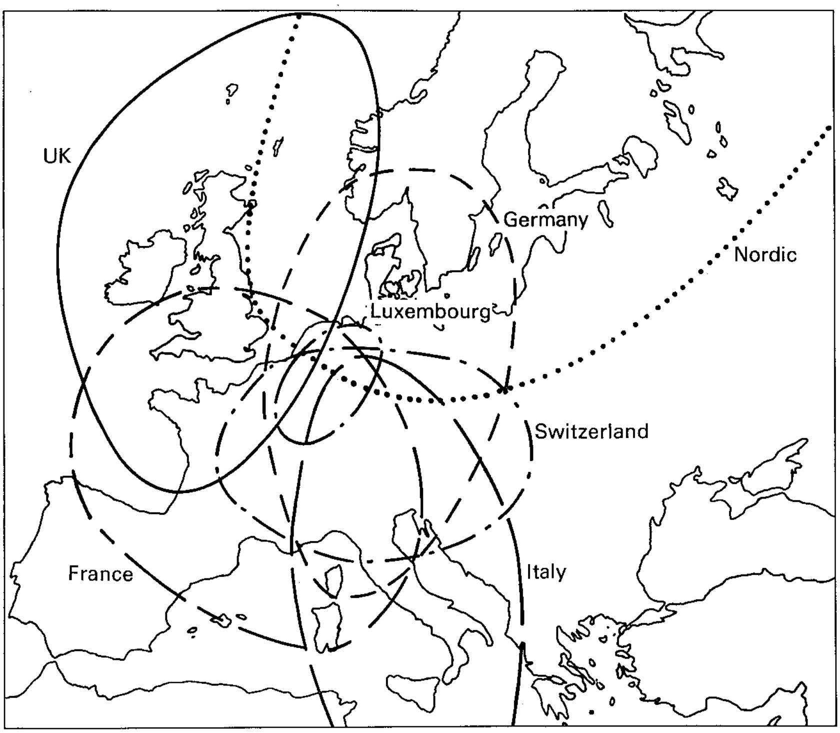
The first communications satellite was *Early Bird*, launched into orbit over the Atlantic ocean in April 1965. It was powered by solar cells and was able to receive, boost and retransmit a small number of television programmes or telephone conversations. This satellite was owned jointly and financed by a consortium of sixty nations. Gradually, however, these kinds of projects are becoming more competitive. There are still some co-operative ventures in which European nations are involved, but most countries, including Britain, are now planning to run for themselves in the commercial space race.

The new generation of communication satellites serving Europe will broadcast from far to the south in their equatorial orbits. They will be able to transmit television programmes to single countries or groups of countries, and poor reception due to interference and hill shadows will be prevented. Improved pictures will be possible, as will better definition for stereo hi-fi. International telephone communication will be more straightforward. From the point of view of broadcasting engineers, an advantage is that no relay stations will be needed to send signals from place to place. There are about 2,000 of these stations in Britain now.

British Aerospace, one of the biggest firms involved in the design of television satellites, has estimated a need for more than fifty by the end of the century. Each householder will require a dish-shaped receiving aerial, and new fibre-optics circuits are being developed in order to keep the signals as pure on land as when they are received from the satellite.

A world conference in 1977 decided on the orbit, direction and frequency of the five channels for each country, excluding North and South America. In 1979 Canada became the first country to begin broadcasting by satellite into homes equipped with dish aerials.

Who will sell the new satellite technology? It will be a profitable project. Since only a consortium of the largest firms can be expected to have enough money and research facilities for such a venture the British government is encouraging a combination of British Telecom (telephone systems), British Aerospace (aircraft and satellites) and GEC-Marconi (microelectronics). A Franco-German team is planning to build television satellites which may be launched by the European rocket *Ariadne 3* in 1984. Those countries which produce the 'best buy' in television satellites will be able to advertise their product by its public performance over neighbouring countries.



Areas to be covered by the national television satellites.

In 1982 the spending per year on space projects was as follows:

Holland	15 (Million £s)
Sweden	20
India	60
Britain	80
W. Germany	150
Japan	230
France	240
USA	4000
USSR	4000

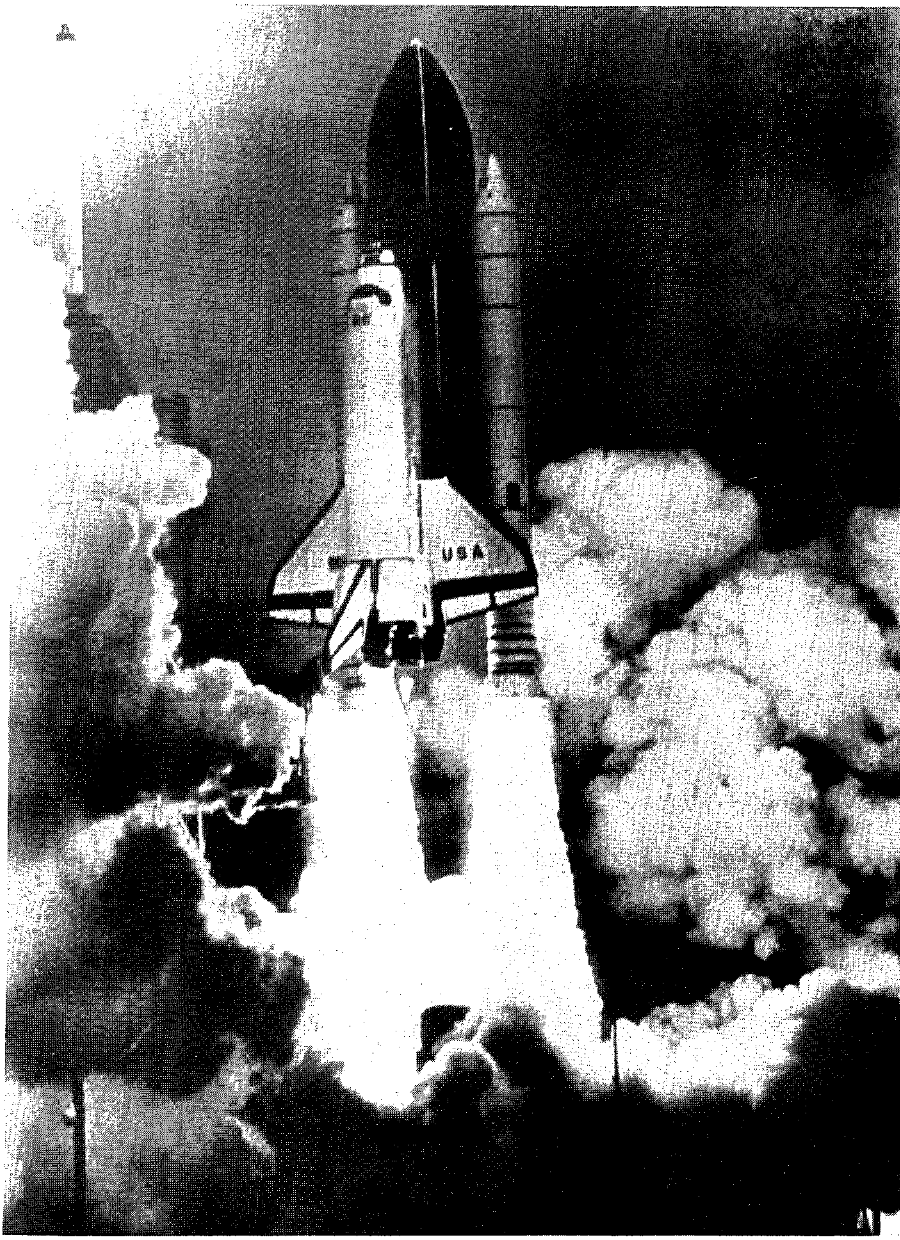
Many countries have satellites which they use for long-range weather forecasts. Pictures from them can often be seen on the television.

WAR IN SPACE?

Satellites are widely used by the USA and the USSR for military reconnaissance. This is reflected in the money they spend on space projects.

Spy satellites are launched into low orbit only about fifty miles above the Earth. From here their equipment can pick out small objects less than a foot across, photograph them and send back information. The disadvantage of a low orbit is that the thin atmosphere slows down the satellite and causes it to spiral inwards and burn up in the thicker air below, unless it is made to parachute down for recovery.

Has war now gone into space, as science fiction predicted? It is hard to answer yes or no. In 1967 both superpowers signed a treaty banning weapons of mass destruction from Earth orbit. So far as we know there are no nuclear missiles out there, but a pressure group, The High Frontier, exists in America to push the government into using orbiting missile or laser guns. We do not know what is going on in the USSR, but the politics of deterrence urges a threatened country into imitation and retaliation. The Space Shuttle, first launched in 1981, was equipped with a long retractable arm for seizing satellites from space. Could this be the first of a generation of space-war chariots?



The Space Shuttle, Columbia, is launched for the third time in 1982.

Suggested Reading

Galileo and the Scientific Revolution Fermi and Bernardini (Basic Books)

A reliable book which is pleasant to read. It should be in the school library, although for those over 16 years.

Galileo and Copernican Astronomy C. S. Morphet (Butterworth)

A SISCON book written for teachers at the tertiary level but interesting to any teacher. Many extracts from contemporary writings, with questions.

New Maps of Hell Kingsley Amis (Penguin)

About science fiction by an enthusiast. Interesting reading for teachers or the occasional 16 or 17 year old, although now a little out of date (1966).

The Invasion of the Moon P. Ryan (Penguin)

Contemporary account of the whole of the Man-on-the-Moon project. Illustrated and well written. 14 years upwards.

Satellites and probes M. Sharpe (Aldus Books)

Plentiful illustrations. Recommended for 14 years upwards.

The Cosmic Connection C. Sagan (Hodder & Stoughton)

This well-known author writes on the boundary between science and fiction. Inspiring and delightful. For 16 years upwards.

Science In a Social CONtext is a series of eight books based on the project SISCON-in-Schools. The books provide a new course in science and society for general studies at sixth-form level. The course has been specially designed to make scientific problems accessible to the non-scientist, as well as to explain the social aspects of science to the scientist.

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The Atomic Bomb
Energy: the Power to Work
Health, Food and Population
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