July 1989 US$3.25 £1.25

Spaceflight

The International Magazine of Space and Astronautics

Special Issue

THE FUTURE OF SPACE

Apollo 11 20th Anniversary

Vol.31 No.7

Editor:
G. V. Groves

Assistant Editor:
S. Young

Managing Editor:
L. J. Carter

Spaceflight Sales:
Shirley A. Jones

Advertising:
Suszann Parry

Spaceflight Office:
27/29 South Lambeth Road,
London, SW8 1SZ, England.

Tel: 01-735 3160.
Fax: 01-820 1504.

DISTRIBUTION DETAILS

Spaceflight may be received worldwide by mail through membership of the British Interplanetary Society. Details from the above address. Library subscription details are also available on request.

* * *

Spaceflight is distributed in the UK and overseas through newsagents by AGB Impress, Cloister Court, 22-26 Farringdon Lane, London, EC1R 3AU. Tel: 01-253 3135.

* * *

Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society.

* * *

Back issues of *Spaceflight* are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

* * *

Published monthly by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L., Ltd., Aylesbury, Buckinghamshire, England.

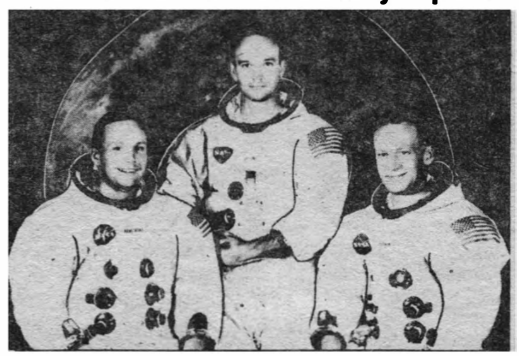
* * *

Spaceflight
The International Magazine of Space and Astronautics

Vol. 31 No.7 July 1989

THE FUTURE OF SPACE

Apollo 11 Twentieth Anniversary Special Issue



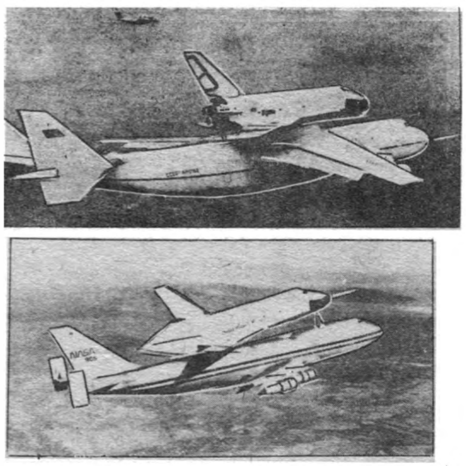
The Apollo 11 crew (left to right) Neil Armstrong, Michael Collins and Edwin 'Buzz' Aldrin *NASA*

Buran Flies West

Soviet Shuttle at Paris Air Show

The Soviet Space Shuttle Buran made its first appearance in the West at the Paris Air Show, June 8-18. The spacecraft was ferried to the show atop the massive Antonov An-225 cargo plane.

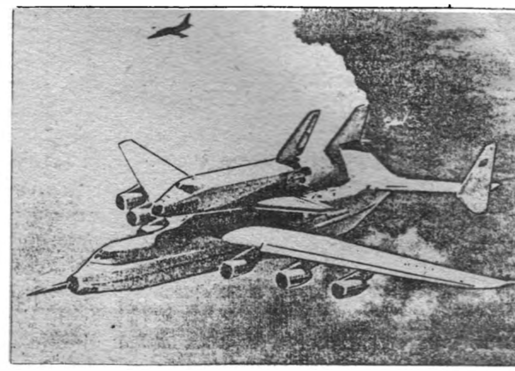
The An-225, named Mriya (meaning dream), arrived at the Baikonur Cosmodrome in mid-May to pick up Buran. The shuttle was attached to three struts on the Antonov's fuselage. The combined vehicle carried out a number of test flights and on June 6 the An-225 and Buran took off on a non-stop flight to Paris.



The sheer size of the An-225 is clear when photographs of the US Shuttle and its Boeing 747 carrier (bottom) and Buran on the An-225 are compared (top).

Unlike its American counterpart the Soviet shuttle does not use a tail cone during ferry flights. US Shuttles have their main engines shrouded within a tail cone to prevent damage to the engines and to avoid turbulence. Buran has no need for a tail cone: its has no main engines and turbulence is avoided because the An-225 has two twin vertical stabilizers mounted on each end of a vertical stabiliser.

Glavkosmos chief, Aleksandr Dunayev told reporters in May: "Buran has been completely restored and is ready for more flights." However, Soviet State Television reported not all of Buran's scorched surfaces had been cleaned and some of the tiles lost during her maiden flight have have not yet been replaced. Dunayev added the next mission would be conducted when there a was a payload that could, at least partially, make up for the costs involved. In a reply to a reader's letter in Komosomolskaya Pravda, Dunayev said: "There are no faults [with Buran]. We have simply started counting our costs and relating them to economic and technical expedency."



The Antonov Mriya and Buran during a test flight.

● During the 11 day Paris Air Show NASA exhibited a full scale model of the Hubble Space Telescope, now scheduled for launch in early 1990. Other exhibits included a 75 foot mock-up of the US National Aerospace Plane (NASP) and full scale mock-ups of the Hermes mini-shuttle, ESA's ERS-1 remote sensing satellite, the European Columbus attached and free-flyer laboratories for Freedom Space Station.

Soviets Give SL-16 Details

The Soviet Union has revealed details of the SL-16 Medium Lift Launch Vehicle. The two stage booster, named Zenit, is capable of lifting 13.7 tonnes into Low Earth Orbit. The vehicle is expected to launch a large cargo craft for space station resupply missions. Because the vehicle can be readied for launch very quickly (in about 80 hours), the booster could also launch manned craft for an emergency space station rescue mission.

Columbia Engine Leak

Engineers at the Kennedy Space Center have discovered a leak in a fuel pump in the No.1 main engine of Columbia. The pump is to be replaced. Launch Director Bob Sieck was unable to tell what effect the problem would have on the launch date, which is currently scheduled for no earlier than August 1.

Proton Stage Comes to Earth

A Proton rocket's third stage failed to burn up in the atmosphere as planned after its launch on May 31. Parts of the stage fell along the US-Canadian border. The Soviets have launched an investigation into the incident, which was reported by American officials. The Proton had orbited three satellites: Cosmos 2022, 2023 and 2024.

Galileo at the Cape

The Galileo Jupiter penetrator probe arrived at the Kennedy Space Center on April 17. The Galileo orbiter arrived a month later on May 16. They are undergoing checkout in the Spacecraft Encapsulation and Assembly Building No.2.

Shatalov Speaks Out

In a recent interview, Lt-Gen. Vladimir Shatalov head of the Gagarin Training Centre at Star Town castigated central planners for not providing the cosmonaut team with a plan for the future.

The decision to stand down the two teams training for the Soyuz TM-8 flight (prime crew Viktorenko/Balandin, reserves A. Solovyo Serebrov) was taken late in the training cycle Shatalov said.

He said that the crews would need to be trained for working with the new modules which were to be launched in August/September 1989 and later.

He also said that because of the delays in launching the modules some 50% of Mir's scientific equipment was not functioning and the interior of the complex was cramped due to the amount of equipment that had been delivered.

Shatalov called for the formation of a Space Agency of the Soviet Union to coordinate all aspects of the programme. It would be similar to NASA of the United States.

He cited the current system as an example of failure in long term planning. In the past this was the province of an interdepartmental scientific and technical council led by Academician M.V. Keldysh, President of the USSR Academy of Sciences. The council is now headed by Academician G.I. Marchuk. But, Shatalov said, "We are still waiting for results from its work."

Today, he said, the Soviet Union has "no programmes... I have no idea what we will have to do tomorrow or the day after. And even the current tasks are changing all the time. We still have no programme for specific training for, say, next year, never mind the more distant future."

Neville Kidger

NASA Names Crews for 1990 Military Missions

NASA has named Shuttle crews for two Department of Defense Shuttle missions scheduled for Mid-1990.

Air Force Colonel Richard O. Covey will command STS-38, a classified DoD mission aboard the Space Shuttle Atlantis, in May of 1990. Covey's pilot will be Navy Commander Frank L. Culbertson. Assigned as Mission Specialists are Marine Colonel Robert C. Springer, Air Force Major Carl J. Meade and Army Captain Charles D. "Sam" Gemar.

Named as Mission Specialists for STS-39, another DoD mission scheduled for July 1990, are Air Force Colonel Guion S. Bluford Jr., Richard J. Hieb and Charles Lacy Veach. The remainder of the seven member crew will be assigned later. The early assignment of Mission Specialists will allow payload training to begin.

Phobos Loss - Spacecraft Designers Blamed

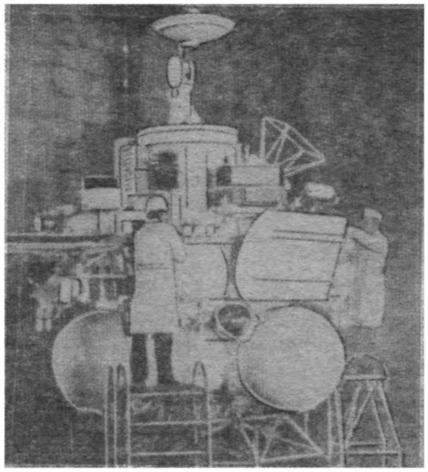
The loss of the two Phobos probes has caused much controversy in the USSR. The designers of the Phobos probes are being criticized by the scientists. ***Mikhail Chernyshov*****, speaks to leading Soviet space officials and asks what lessons have been learnt.**

Several months have passed since the completion of Project Phobos, but passions are still running high in the scientific community. So what happened to the two automatic probes which successfully started out on their journey to the planet Mars but never completed their mission. The special commission which is looking into the matter has so far failed to arrive at any definite conclusion. Conversely, the situation seems to be growing more complicated, and the decision now is to enlarge the commission by inviting foreign scientists in order to preclude any bias in the investigation. For the time being, let us look at the data provided by the Phobos probes.

The International Scientific Council on Project Phobos met in Moscow to sum up the first results of research relating to Phobos, Mars and the Sun - the three bodies which the joint programme was mostly concerned with. As for the study of solar activity, scientists consider it a great success that the Terek telescope, mounted on the first probe, had sent back to Earth a number of extremely interesting pictures of the Sun before its loss, including a picture of plasma shooting out at a distance roughly equal to the Sun's radius. The onboard photometer of the probe recorded more than a hundred outbursts of hard gamma-radiation.

In January-March of this year, when the second craft reached the vicinity of Mars, it transmitted data relating to Mars and Phobos. Altogether several dozen detailed television pictures of these bodies had been obtained. Ballistic and other measurements will enable a more accurate assessment of the Phobos orbital movement and its mass and the mapping of its surface. It turned out that Phobos minerals contain less water than was expected. Daytime temperatures on Phobos reached 27 degrees Centigrade.

The new data about Mars concerned, in particular, the Martian atmosphere and the plasma and wave processes taking place in the magnetosphere of the planet. The probes failed in what was their principal mission: they were to approach Phobos at a maximum distance of 50 metres and to do a high resolution photographic survey. Several major experiments had not



One of the two Phobos probes during final preparations. *Novosti*

been carried out either. So what are the factors behind the failure?

"The breakdown of the second craft is being attributed to extraneous causes, notably, a possible collision with a meteorite," says Professor Vasiliy Moroz. "Indeed, there may be a rarefied meteorite belt around Mars, but the likelihood of collision with a spacecraft is very low. I think it was just that the systems were not good enough. They might have overheated because of the strenuous work schedule."

Says Academician Roald Sagdeyev: "Of course, the participants in the project, who come from 13 countries and who carried out experiments using tax payers' money ought to have given an explanation in their countries as to what exactly had happened to the two craft. But, within the first few weeks of the failure of the mission, there were only hints that the craft might have come into collision with something. At the meeting of the International Council, we, at long last, heard statements by the developers of the crafts' main systems. That was the first time that the general and chief designers spoke before a scientific audience. And we agreed on the need to set up an international working group that would sum up the results and analyze what had happened. In any future missions, an international group concerned with spacecraft survivability will be in place from the outset, right after the outline of an international project has been defined. I see it as a further step in promoting greater openness.

"On Project Phobos, we were at odds with General Designer Vyacheslav Kovtunenko, who blames the breakdown on extraneous factors, whereas we are taking a different view. I think a joint inquiry would shed light on the matter. The first and second craft were both lost in a very similar way. In the case of the former, an operator's error on Earth caused the craft to go off course. In the latter case, some malfunction in the onboard systems led to the same result. However, a really foolproof design must return the craft to the original position in a contingency. Something like that happened on the Vega-2. Thirty minutes before its rendezvous with the nucleus of Halley's comet, its computer guidance system broke down. But a similar backup system was switched on, and the rendezvous was successfully accomplished. Regrettably, such options were not available in the case of the Phobos probes. I hope that, in the future, space technology producers will have their absolute freedom restricted so that the world scientific community, as the end user of this technology, can have a say in decision-making on spacecraft design.

"At present space programmes are having a difficult time. Deputy Boris Yeltsin, for one, has proposed shelving them for 5 to 7 years. This is a serious matter. In addition to nuclear-phobia, there has emerged a space-phobia. It is not just a question of economic difficulties. The fact is that there is no openness as far as spending on particular projects is concerned. In my election platform, I urge the re-establishment of the popular belief in space science and exploration through truthful information. I will press for the publication of the space budget and spending on particular projects and activities. Nothing short of open debates will convince the public of the need for such work. I am positive that we must not throw overboard what we have already created. But a number of projects may seem to be before their time. For instance, there appears to be nothing at this point to justify the outlays for the reusable spacecraft Buran."

"Space technology designers," says Roald Kremnev, one of the men behind the Phobos craft, "have to comply with a set of restrictions relating to funds and the weight and size of spacecraft, etc. Of course, Project Phobos has taught us a lesson, and we are determined to rectify the defects we have identified, notably, those relating to power supply, operational errors, and the possibility of probes functioning in an automatic mode. Actually, I think such craft are capable of efficient performance." ***APN***

Progress 41 Reentry: Another Soviet Space Mishap

The unique re-entry of Progress 41 - four days of autonomous flight - was noted in last month's ***Spaceflight.*** **Analyst Phillip S. Clark has provided an explanation in the absence of official Soviet clarification - the craft ran out of propellant!**

Working from data supplied by the Goddard Space Center, Clark has derived the following:

Between April 9 and 17 two manoeuvres were performed by the Progress 41 spacecraft to place the Mir complex into a higher orbit. The complex was being stored in the higher orbit due to the enforced need to fly the station in an autonomous mode for a period of about three months following delays to the launchings of the add-on modules for the station (see *Spaceflight* June 1989, p.191-194).

Progress left the complex in an orbit of 373 x 416 km after the April 16/17 manoeuvre. (The Soyuz TM-7 engine was later used to raise the perigee to 388 km).

Progress 41 undocked at 0146 GMT on April 21. Firings of the engines after this time gave this history of the decay:

April 21.38 orbit was 213 x 417 km
April 21.50 orbit was 191 x 410 km
April 21.63 orbit was 124 x 390 km

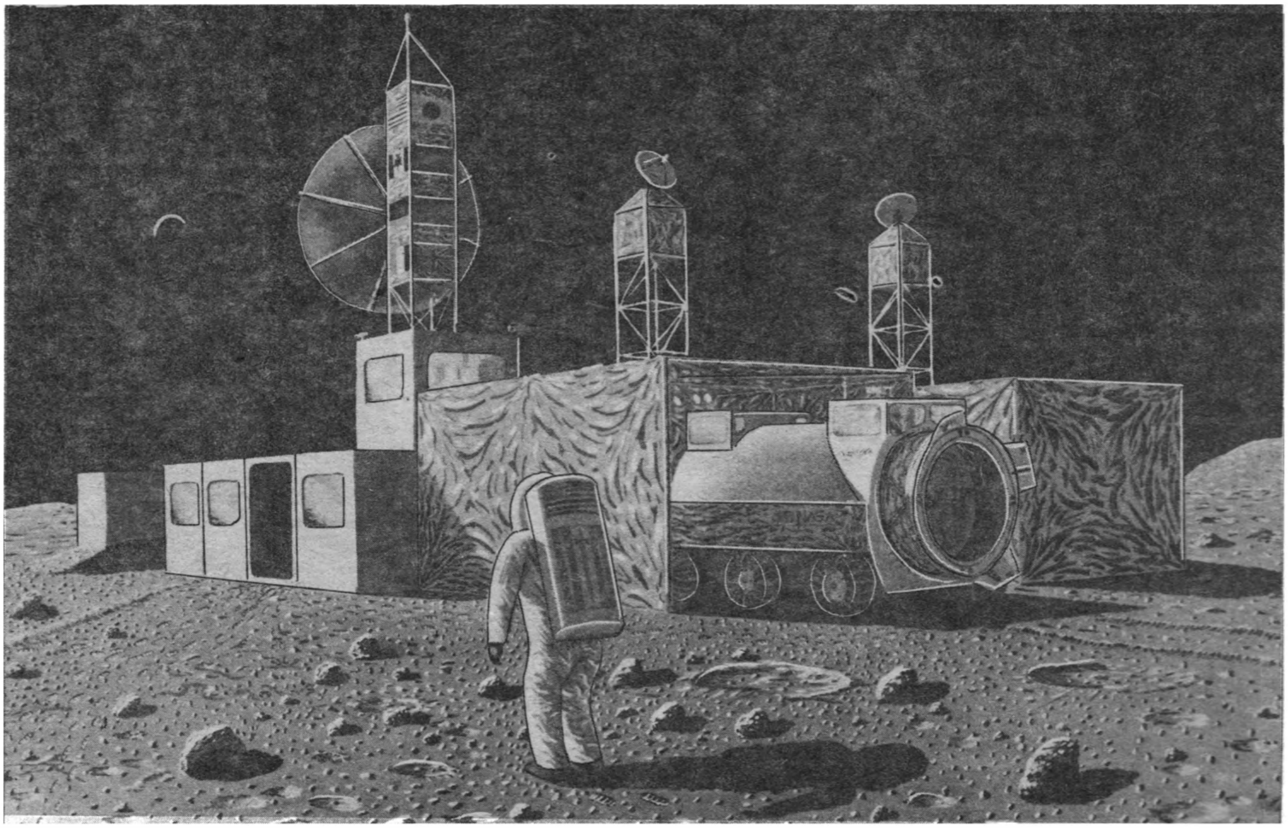
After the failed attempts at re-entry the orbit decayed naturally, and sharply, until, at April 25.33 the orbit was 105 x 203 km. Clark's analysis of the Goddard data shows that at April 25.51 (i.e. midday GMT) Progress 41 was in an orbit of 92 x 150 km.

TASS later announced that Progress 41 has entered the Earth's atmosphere at 1202 GMT April 25.

If the delayed, and hence uncontrolled, re-entry of Progress was due to running out of propellant it illustrates the degree to which the rapid decision to terminate the permanent manning of the Mir complex affected mission planning.

Neville Kidger

Cities on the Moon - A Lost Vision?



A concept for an early, permanent, ten man international lunar base from prefabricated sections ferried from Earth. BAe

By Dr. R. C. Parkinson

Twelve years after Columbus discovered America, Breton fishermen were trawling the cod banks off the coast of Newfoundland. Thirty years later, Cortez was engaged in the conquest of Mexico. The human race first landed on the Moon in 1969. Apollo 17 left in 1972. Since that time there has been no return. Nor, at least in the Western world, are there plans to return in the remaining years of this century. Yet if we look at the parallel with Columbus, we should have returned to the Moon by 1981. We should now be planning for the start of permanent Lunar colonies by the end of the century.

The prophets of astronautics in the 1950s saw a natural succession of developments. First we would build a reusable, regular Shuttle launcher to take men and equipment into low Earth orbit. (They didn't call it a Shuttle, and by regular they meant perhaps once a week, not six or eight times a year, but they had the scale right). Once established in orbit, we would build a permanent space station to act as an observation point and a construction site for ships to take us further. We would build true space ships in orbit, unfettered by the need to lift structures through the Earth's atmosphere and to carry wings and protection for re-entry. From the staging point of the space station we would move onward to the Moon. Initially the exploration of the Moon would make temporary encampments, providing stays of six weeks or so. But we would quickly convert from a temporary to a permanent base with a stockpile of resources, and from there we would move outward. Soon we would learn to use the resources of the Moon and found permanent colonies. One day there would be Cities on the Moon, with inhabitants who were born, lived, worked and died there.

What went Wrong?

This isn't simply an article about what went wrong with the vision of the Founding Fathers of astronautics. The Moon remains the most important natural resource in our sky. If we are to exploit space, if we are eventually going to leave our planet behind, we will need to learn to use what the Moon offers. The findings of the Apollo missions have not altered that. There is oxygen on the Moon, extractable as rocket propellant, and capable of being transported into Earth orbit for a fraction of the expenditure of energy required to lift material from the Earth's surface. There are construction materials - basalt fibre as tough as glass fibre, and chemical engineers will give you schemes for the recovery of titanium and aluminium from surface rocks. Even nickel must lie below the asteroid impact craters scattered across the lunar surface as it does on Earth. If we are eventually to build large structures in space, it will be easier to do it with Lunar industry than launching from Earth. Orbital industry on a large scale will have to draw on the Moon for its stocks. And as an energy resource, if clean fusion power eventually comes, it may need a ready supply of helium-3-atoms which have been gently deposited over millennia in the surface dust of the Moon by the Solar Wind.

Yet the world seems to have few plans to return to the Moon, let alone build permanent bases, colonies and industries on its surface. Why?

I believe that the answer to that question reveals rather more than why the richest nation of the world won

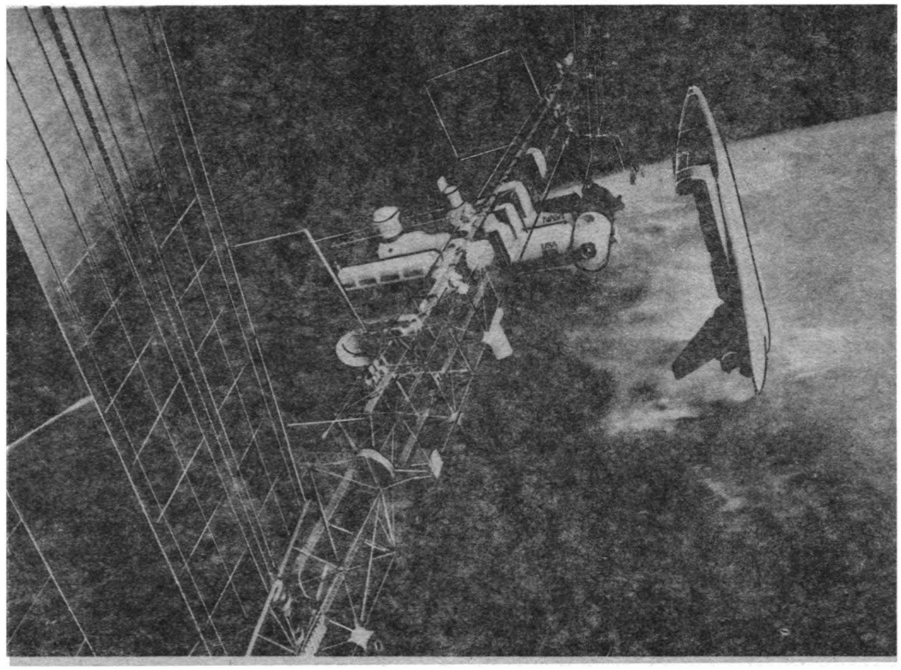
the race to the Moon and then spurned the prize. I believe that the same problems continue to bedevil "European Space", and have relevance to the attitude taken by a "poor country" (in space terms) like the UK.

One reason for the demise of Apollo was the cost. Each Saturn V launch, in modern-day terms, cost in excess of one billion dollars. Even the USA could not afford to keep such an expenditure going for long without very positive returns. Yet, in less than a decade, the USA had found $40 billion to invest in Apollo. Had it spent a similar amount over the next two decades in reducing transport and operating costs, the price for a ticket to the Moon today (or say by 1992, for the 500th anniversary of Columbus' landing in the New World) need have been no greater than that for a current Shuttle flight into low Earth orbit. It would probably have been less.

That much was in NASA's plans in 1970. The Space Shuttle was aimed at bringing costs of transport into low Earth orbit down to $300/kg. With hindsight, that may always have been unrealistic. Even with our studies on HOTOL we believe that a realistic target lies in the range of $500-$1000/kg. But the basis on which we calculate costs today are far sterner (post-Challenger) than those used by NASA in 1970. And achievable launch costs are still well below the actual $5000-$10,000/kg for a Shuttle launch.

Coupled with the Space Shuttle in the 1970 plans was a reusable, cryogenic, European Space Tug intended to extend low cost access to space as far as Lunar orbit. The cost of cargo on the Moon need have been no more than four or five times that in low Earth orbit. Furthermore, NASA had plans for a modular Space Station which, if not to the scale of the current $20 billion Freedom International Space Station, would certainly have matched the Russian Mir as a staging point in low Earth orbit, and for a quite moderate cost.

It is hardly necessary to review what went wrong. With restricted development budgets, successive decisions made in the Space Shuttle design abandoned the target of low operational costs. Without the Space Station (which in 1972 need have been no more than a second Skylab) the Space Shuttle had to turn into a miniature Space Station of its own on each flight. European participation was diverted from the Space Tug to Spacelab, to provide an extended laboratory capability for the Shuttle which, with a Skylab station in orbit, would not have been needed. Transport beyond low Earth orbit was restricted to inefficient and expensive solid stages, and a reusable cryogenic Tug (now that Shuttle-Centaur has gone) still lies a decade or more in the future. The path to low cost Space Transportation was certainly more difficult than envisaged by George Muller in his historic speech to the British Interplanetary Society in 1969, but decisions and events made in the meantime have meant that it is no longer even possible to evolve towards such an objective. The Shuttle operations are cast in concrete and steel, and while it is a brilliant technical achievement, future low cost launchers will not build on it so much as bypass it.



Space Station Freedom will set the standard for future spacecraft for years to come. *NASA*

It is the glory of things which have never been done before that command funding.

Cost was one factor in the abandonment of Apollo, but not the essential factor. The planned scientific programme was incomplete. Indeed, the first trained scientist on the Moon - Harrison Schmidt - did not fly until the final Apollo mission. At least three more Apollo missions were planned - the objectives defined, the hardware paid for - Saturn V vehicles were abandoned in mid-construction. Even more telling - there are other, cheaper ways of returning scientific information from the Moon, post Apollo, but none have been taken up. A lunar polar orbiter would give detailed geological information about the Moon - essential information for future colonists - for the price of a modest unmanned space-probe. It has been proposed several times since 1972, but remains unfunded.

Despite the fact that it revealed a more interesting world than we had imagined, Apollo did not encourage further exploration. It actually inhibited it.

Not only lunar exploration suffers this way. Mars has not been visited since Viking. Mercury lies untouched since Mariner 10. It is not that there is no work to be done, it is the spectacle of achievement that is missing. While politicians and administrators listen patiently and with polite interest to carefully thought out and cost-effective programmes presented by the scientists, the words mainly serve to assure then that their money is not being mis-spent. They have little interest in progressive plans for space exploration. It is the glory of things which have never been done before that command funding.

Unfortunately, for space programmes which are done for glory and not for simple commercial gain, this attitude seems likely to stay. And it brings with it two problems which continue to bedevil us.

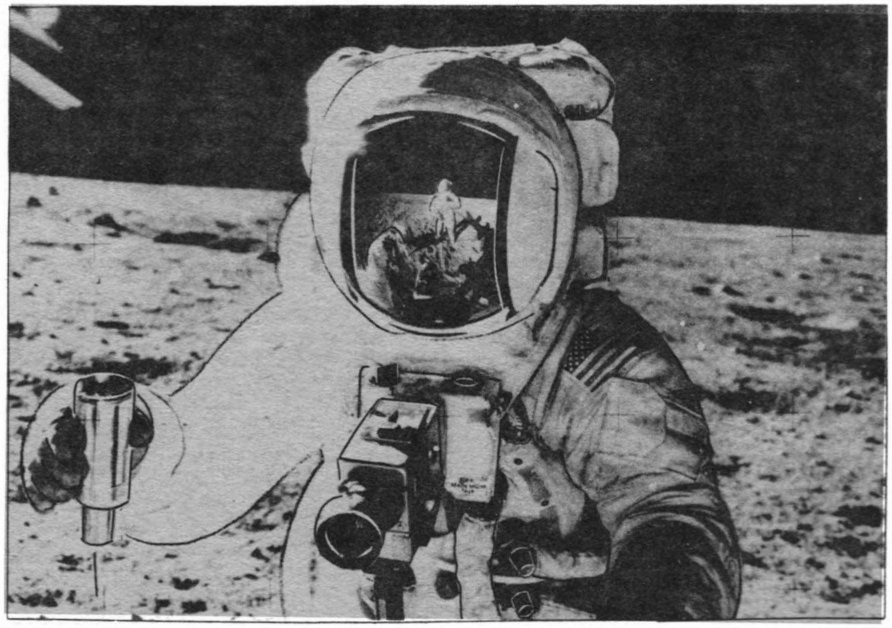
The first problem is that if each new thing we do in space is done because it has never been done before, because it is difficult and shows off our cleverness, then the impetus to reuse systems and hardware, to design spacecraft and launch vehicles for the long term is reduced. The Apollo programme was a prime example. NASA built hardware dedicated to a very specific mission. It performed that mission admirably, and then turned to something else. Skylab succeeded

because it ingeniously used left over hardware to score another first, but like Apollo it was not allowed to lead on anywhere. The Space programme is littered with one-way examples. The engineers and planners are only too aware that such economics are senseless. Multi-purpose spacecraft which can be used for mission after mission, with relatively low costs after the initial development, are proposed regularly. But programmes are funded on a one-at-a-time basis. That front-end funding is important, and commitment to doing the same thing twice is quite missing.

Looking to its future programme, and as a background to the "Pathfinder" technology development programme, NASA has made studies of potential ways of putting a Man on Mars as a "long term goal". Ivan Bekey described some of these studies at Space 88. It is apparent that these studies continue to follow this philosophy. The possibility of exploiting lunar resources has been looked at - but only as a cheaper way of getting one manned mission to Mars, not as a long term investment to our whole future in space. Not surprisingly, given the terms of reference of the study, the initial conclusion was that exploitation of lunar resources was probably not cost effective. But the objective was to repeat Apollo, this time on Mars.

The second problem follows. If difficulty and spectacle are drivers for governments to put money into space, then it does not matter very much that space is expensive despite lip service given to the idea. Those governments which want glory from space will want to demonstrate that they command the resource and the will to do such things. (Furthermore, since it is a hugely glamorous thing to do, there are thousands of scientists and engineers who will flock to such enterprises and help demonstrate - for a price - the scope of their ingenuity and expertise). Those governments which see no profit in glory, on the other hand, will suspect that the large investments needed to make space activities cheap and affordable are excuses for spending vast sums on space in another guise.

I detect this sort of process in the current European activity on Hermes and Columbus. French engineers are quite clear that the more modest cost of a Gemini-style ballistic capsule to carry men into space and service the Columbus Man-Tended Free Flier would not command the funding which Hermes has acquired. The United Kingdom, briefed to take a moderate and cautious line, instead simply abandoned European space to its fate. There is now a danger that, if the German Columbus MTFF and the French Hermes cannot be reconciled, or become unaffordable, the consequence will be not a return to realistic proposals, but a catastrophic collapse in European interest in space.



An Apollo 12 astronaut holds a container of lunar soil. The Apollo programme proved Man could work on the Moon. *NASA*

The traditional assumption has been that space exploration will naturally be followed by space exploitation. Exploration represents the desire to do difficult and expensive things first, and can be funded as national goals. Exploitation makes a profit and is naturally funded from commercial sources. But this expectation misses a stage. Exploitation only follows the establishment of an infrastructure. And to date, the explorative motive has been notably unsuccessful in establishing a commercially viable infrastructure.

The one spectacularly commercial return from space has been in telecommunications. The returns were so obvious and so large (putting the satellite in geosynchronous orbit costs only about 2% of the revenue it generates), that President Kennedy founded intelsat to stop commercial warfare between the industrial communications giants. Nevertheless, even with the multinational resources it had at its disposal, Intelsat has not even partially funded the development of one launch vehicle or even an upper stage.

The reasons why commercial ventures are unwilling to found infrastructures is twofold. One is that all the possibilities for exploitation are not apparent until the transport and handling infrastructure is in place. The second is that there is a political dimension - infrastructure defines the channels of power in the new territory. Develop an infrastructure for commercial ends and your profits are at the mercy of those who wish to use the infrastructure for other, political ends.

Actually, exploitation of the possibilities provided by an infrastructure demands not only the existence of that infrastructure, but confidence in its future. Prior to the Challenger accident, such confidence was beginning to develop with the Space Shuttle. As a consequence a variety of commercially funded space exploitation ventures were beginning to emerge. The Challenger accident threw the Space Transportation System firmly back into the political arena, and the commercial ventures based on it are now dead. Such confidence will be more difficult to establish the second time around, even if the Shuttle becomes available for such enterprises.

It appears that Space Exploration has ceased to provide the requisite long-term infrastructure needed for Space Exploitation. Those things that can be done with expensive, throw-away launchers, will be. That includes telecommunications (although some telecommunications applications are undoubtedly inhibited by costs still), Earth Observation (if the question of getting people to pay for things they expect to get "free" can be solved), and possible some very exotic micro-gravity products. The things which cannot be done for the price are obviously not worth doing. And so space will remain a playground for the very rich.

Recognising that settlement of space is a goal might help to change that. If we could design new systems just a little bit beyond the local Spectacular towards a belief in a long term future Space Development might build towards a consistent long-term

infrastructure.

Let me mention a couple of little things. The US Freedom Space Station project will set some standards for a long time to come. The docking hatch is one. Things that visit the Space Station will have to have a compatible docking interface. Things that they dock with will also. Whatever replaces the Space Station will still need to provide compatible docking arrangements. The Space Station hatch could well set the dimensions of the hatch of the Starship Enterprise. The hatch will eventually provide interfaces for vehicles operating on the Moon - operating under gravity conditions. Yet such long term objectives were not considered in the detailed debates within NASA, and certainly would not have been considered prime reasons for decision making. As a consequence, long after the world has gone metric there will be a funny-sized hatch on every spaceship. Rather as railway gauges were set by Stephenson's coal trucks, remaining a problem for every carriage designer for the next 150 years.

The railways are a good example. For over a century they provided the central transport infrastructure for the developed world, and it was possible to evolve a steady series of developments which improved efficiency, speed and pulling power without ever having to abandon what had gone before. We need to learn how to do the same exercise in space.

How do we build systems which will last? Logically the hard-won experience of Spacelab should have progressed directly into the Space Station module. In practice the sub-systems of Spacelab were old before it made its first flight, and even on the European Columbus Module the inheritance from Spacelab will be marginal. Electronic systems are particularly vulnerable in this way. But we cannot afford to redevelop launch vehicles, orbital modules and upper stages every fifteen years or so when it takes that long to get the financial decisions and carry out developments.

Let us agree then what the pioneers of astronautics knew full well. After the Space Station we need a Lunar Base. We need to start the Lunar Base programme soon enough to exploit the technologies and components won for the Space Station. There is not a need for a long preparatory programme - we could set the location for a permanent Lunar Base site today as a centre for exploration and exploitation if we cared to. But we need to reflect the Lunar programme potentials already in the Space Station programme. Then, when we begin the Lunar programme, we need to build a permanent facility with an emphasis on long-term industrial benefits, and we need to ensure that its architecture reflects the following step - Mars.

The opinion makers have tended to talk about goals in space, missions and objectives. We have become coy about the real reason we want to go. We have lost our Cities on the Moon because we feel that they may not be credible to the outside world. But that is the long term goal, and if we become serious about it then some of the shorter term goals might become easier. And one of the messages that we must get over to the decision makers is that space is not an arena for large and expensive projects, but needs more and more efforts into making access cheaper. Only then will our children be able to afford to build and live up there in the sky, and use the resources of space to solve Earth-bound problems.

Space Industrialisatio

Even the earliest pioneering thinkers assumed that industrial applications would eventually become mankind's most important activity in space. In the event space technology found early commercial applications with communications satellites and, more recently, Earth observation systems. The next step will undoubtedly be small-scale manufacturing of space processed products. Indeed, one of the main reasons for orbiting laboratories such as Mir and Shuttle/Spacelab is to explore the potential of microgravity processing, thus leading to the first "made in space" products.

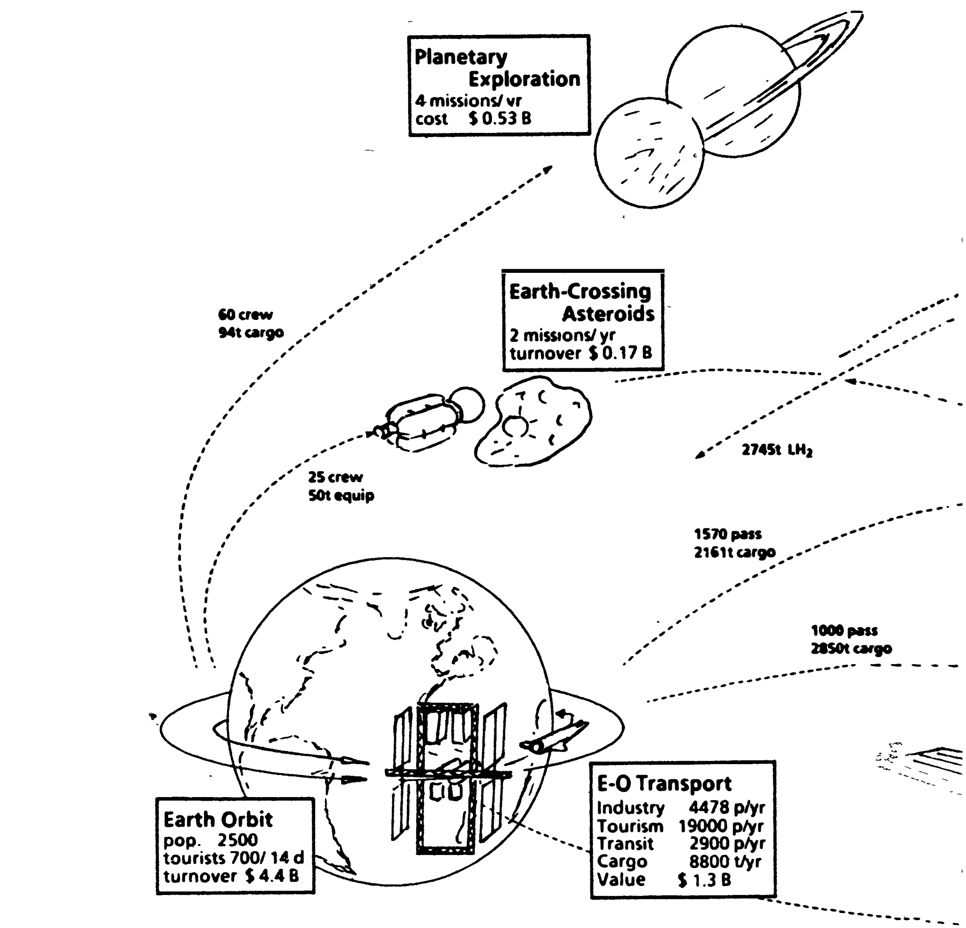


Figure1

By Mark Hempsell

These first commercial products will involve very small production runs of high-value items such as drugs, large pure protein and semiconductor crystals and advanced structural materials. One example which has already proved viable is the production of very small but perfect spheres used for calibration purposes. These first products represent valuable business and will, no doubt, profit those countries that show the foresight to invest in the necessary technology.

How important is space industry? Much of past discussion regards it as just another business opportunity, a desirable but optional extra for a developed economy. However, recent studies which have examined the long-term development of this embryonic technology suggests that the industrialisation of space is far more than just another shrewd investment; it is crucial for the continued survival of our technological civilisation.

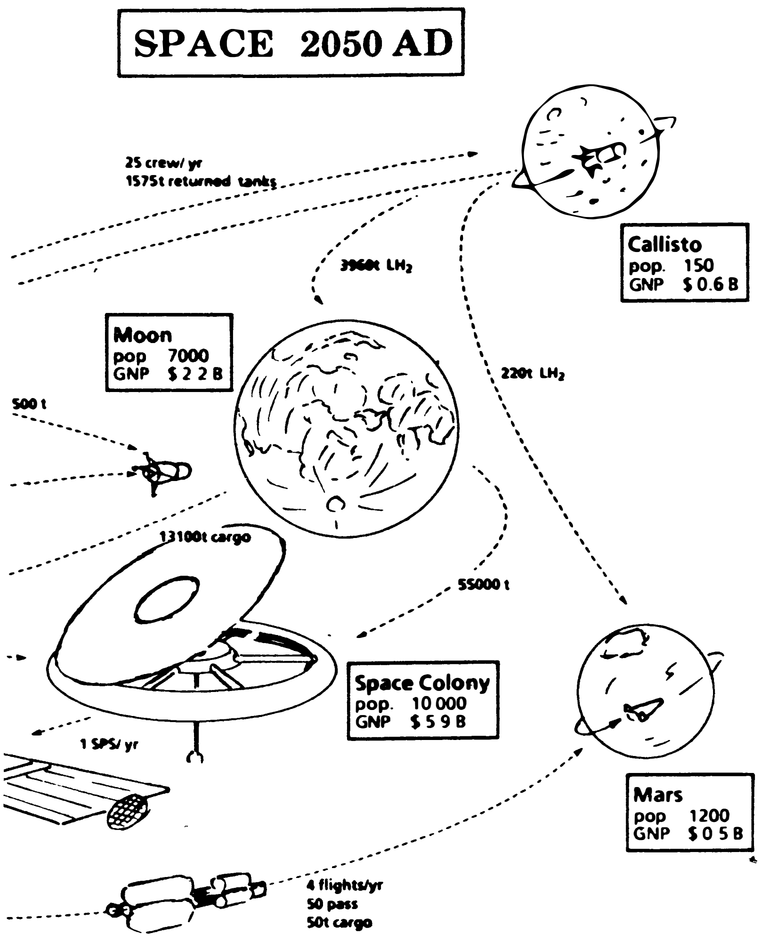
The chain of work which led to these conclusions did not begin with the intent of considering the future of spaceflight at all. A number of studies were performed in the late 60's and early 70's using computer simulations of the total world system [1]. These showed that the depletion of vital resources and the accumulation of pollution effects are linked to increases in population and standard of living. The models predicted growth continuing until early in the next century but after that the effect of pollution and resource depletion constrain growth and cause a rapid decline to medieval levels or lower. The solution proposed by the early researchers was to undertake a retreat into a "Post-Industrial" society, which would lead eventually to the same low economic levels but more gradually and in a more controlled manner.

Not unexpectedly, these conclusions were unattractive so it is not surprising that those looking for alternatives explored the impact of the continuing advancement of technology on the computer models. The most famous of these responses was the work by Kahn at the Hudson Institute [2] which showed that technology could significantly alter the predictions made by the models. However, these "technological fixes" are generally vague as to which technologies will really achieve the two effects of increasing resources and reducing pollution. From this viewpoint, the most satisfactory of the new investigations (i.e. those providing the most detail and the most sustained growth) are those which consider the impact of a major space economy, able to provide a new source of raw materials and a sink for pollution and yet not affect the Earth's biosphere.

The earliest specific use of space in these models is attributed to Peter Vajk. He was largely sceptical of the computer modelling technique and was using the space inputs to economic models as a "parody" of the Club of Rome work "to show that such models can be used to 'prove' any conclusion you like" [3].

At the British Interplanetary Society's Space 1984 Conference, Dr. Tony Martin provided a talk which outlined the conclusions of his work on the effect of such space industry [4]. He took the modelling more seriously and showed that it pointed to only two alternatives for mankind, either a space age or a stone age. He demonstrated the urgency of establishing space economy by the second half of

A New Perspective



the next century, otherwise it will come too late to save civilisation. The volume of space activity needed is not clearly defined in Martin's work but it was clearly substantial. More recent work by F.W. Schultz [5] shows the need for almost a third of all industrial investment to be in space-based business ventures.

Figure 2 (p.226) shows two projections into the future. The first is by Forrester of MIT which is, essentially, an indication of what happens if we do nothing. For the immediate future population will continue to increase, as will the average standard of living, but these lead to an increase in the consumption of material resources and the level of pollution. By around 2020 the impact of these last two factors start to constrain the first two, so population and the average standard of living start their irreversible decline.

The second projection is by Martin. This analyses the impact on the original projection of a space industry addition to the model which increases the material resource base and acts as a sink for pollution, both features being introduced during the second half of the next century. The effect is again dramatic. Population, after a slight dip, once again continues to grow and the material standard of living also steadily increases.

The global system modelling technique is clearly too simplistic to provide an accurate prediction tool. However, the overall picture shown must be taken seriously. Different models have been created by other researchers which are more complex than the original Forrester model shown in fig. 2, but all have produced similar results. In any event some of the predicted effects can be seen at first hand in the real world. In the 20 years since the Forrester models were first produced, the population has grown a little faster than predicted. Some of the dramatic effects of pollution are apparent in recent events such as the depletion of the ozone layer, acid rain destruction of the northern temperate woodlands and the greenhouse warming of the atmosphere. One can even see the beginnings of a major decline in resources such as oil.

The broad conclusion of these studies is that, in the second half of the next century, there will need to be a massive movement of industry into space, if we are to maintain our current civilisation. The question then arises of how will this happen? It is unreasonable to assume any major change in Society's economic structure over the next century, so each new space factory would need to be constructed on a commercial basis, driven there by a carrot and stick effect. The carrot will be the freely available energy and resources which will become increasingly rare on Earth. The stick will be the Draconian legislation which will be required to keep industrial activity compatible with the Earth's ecology.

If major companies are to make such decisions, the space option must be viable. When setting up a factory on Earth, viability is assessed on such factors as transportation links, power utilities and workforce availability. These factors are generically referred to as "the infrastructure". The same will be true in evaluating the economic viability of a space factory; it will be assessed on the extent and efficiency of the space infrastructure in place.

The next stage in the argument is thus to establish what infrastructure has to be in place around the middle of the next century so that expansion into space is both a viable and economically attractive commercial option. It must be attractive not just for specialist processes that can only be done in space but also for products where it is merely more desirable that they be processed in space.

Dr. R.C. Parkinson has been modelling a possible space economy around the year 2050 [6]. The work uses a technique called input/output modelling and was not originally intended as a follow-on to the global modelling work. Parkinson was interested using this relatively new economy modelling technique to get an insight into the way an economy could develop within the space infrastructure. However, its results forward our understanding of the implications of the global models. What needs to be in place is an infrastructure that makes it economic for moving industry into space. The Parkinson model shows the transport cost, wages, and other important factors. It is useful as it provides a link between pure economics and the technical features such as the size of facilities, the prod-

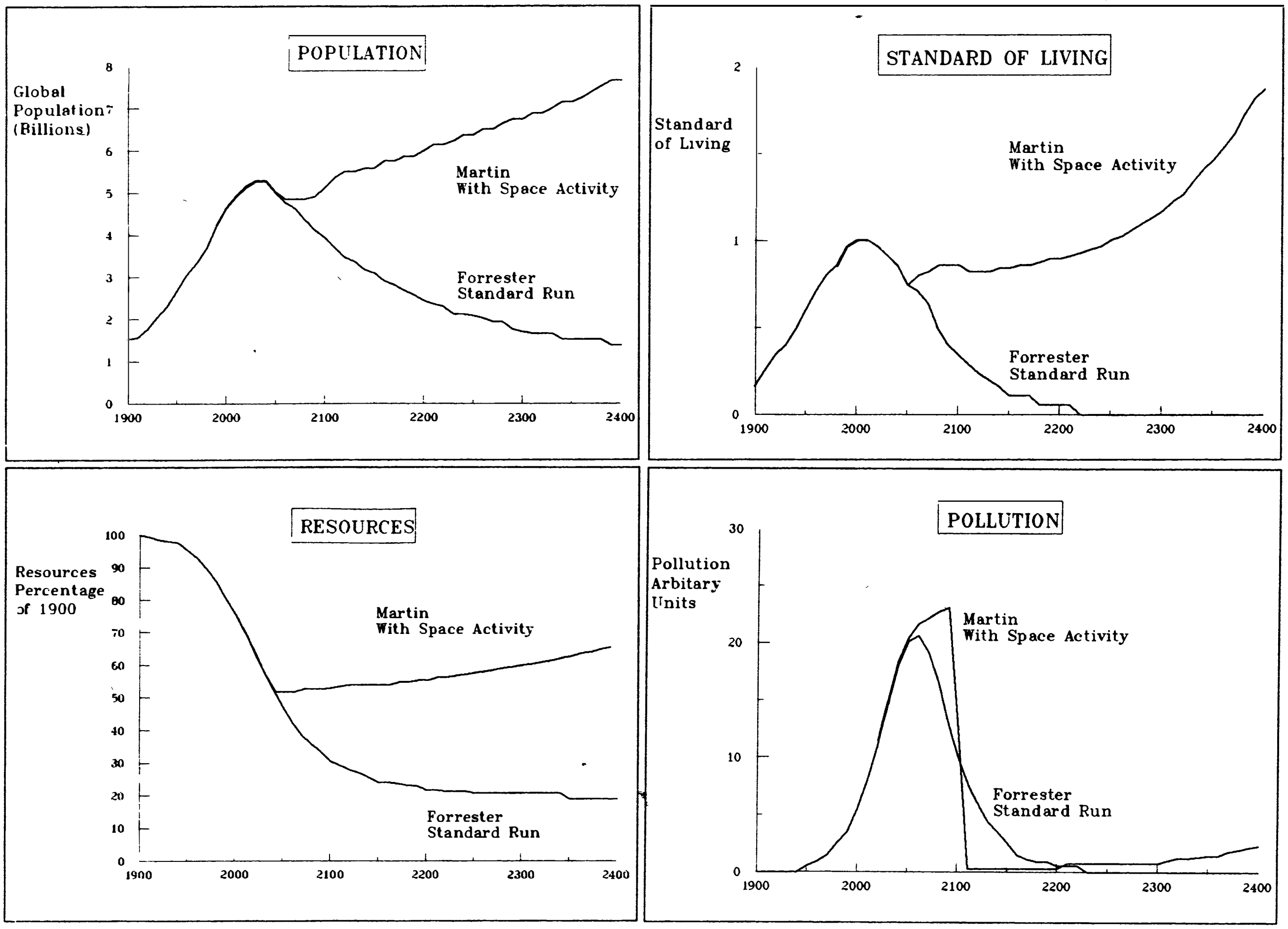


Figure 2 :Comparison of Global System Models With and Without a Space Economy.

ucts and the technologies used.

The Parkinson model (fig. 1) has all the main types of activity required. However, it is nowhere near the scale of activity required. From the Parkinson model in 2050 with a Gross Space Product of around $15 billion to a Gross Space Product a thousand times greater in the year 2100 would suggest that the growth in the space economy in the second half of the next century would average 20% per annum. When this is compared to current national economic growth rates, typically 2% to 3% p.a., the scale of the problem can be appreciated.

The Parkinson model can be viewed as the absolute minimum that needs to be in place by the middle of the next century if mankind is to have the option of a space future.

Currently, new space infrastructure elements are introduced in the West every 15 to 20 years. There are only 60 years until 2050 and it is clear that much more than 3 or 4 programmes of the Space Shuttle or Space Station type are going to be required. The pace of the Western space effort will need to be substantially accelerated if we are to get anywhere near this target.

Some of this effort may be commercial, though it is difficult to predict at present which steps could be commercial and which would need to be directly funded by governments. As a general rule, the less the government invests in the early stages, the less opportunities for commercial activity arise and the more government will need to invest in the later stages. Conversely, the more the government invests in the early stages, the more business opportunities arise and the commercial sector becomes more confident and willing to invest capital.

This can be seen by looking back to a long-term programme put forward in the United States 20 years ago. In 1969 NASA proposed the Post-Apollo programme which covered 20 years from 1970. By 1990 there would have been Space stations, Lunar and Mars bases, all large facilities with 50 to 100 people. The growth that would then have been required to reach the 2050 target from this start would have been about 8% per annum. At this level the majority of the growth activity would probably have been commercial. NASA estimated annual budgets for the Post-Apollo programme at the same sort of level as during the peak of the Apollo programme. This would have been about twice the actual funding level over the period.

However, the Post-Apollo programme never happened and new long term programmes are now being proposed. The National Commission on Space report [7] and the Ride report [8] both like the Post-Apollo before them, offer a vision of Lunar bases and manned flight to Mars. The pace of the two proposals is different and the scale of the activity a little vague in both, but they could lead to bases and stations of several hundred people in the various locations by 2020. If this took place, then growth over 15% per annum would reach the 2050 target. In this case it is unlikely that so much of the growth activity could be commercially sponsored, as would have been in the case of the Post-Apollo.

Cost estimates on these programmes show annual budgets four times the current levels or twice the annual budgets needed for the Post-Apollo programme. When the longer timescale is taken into account the total programme cost is four times as great and, even then, the overall result is not as effective in terms of

reaching the 2050 target.

If we do not undertake such programmes and leave space alone with only modest initiatives (e.g., only undertake the Space Station programme) for another 10 or 20 years, the task of reaching the 2050 target becomes massive. There is so little time that, effectively, all the growth would need to be government-funded and the total programme would cost maybe 15 times that of the Post-Apollo programme. This will mean annual Western world civilian space budgets 10 times current levels. That is in the order of $200 billion a year in late 1980's dollars, with money needed to be found at the time when the decline of the global economic and social infrastructure has already started.

Not only are such levels of expenditure unlikely, there would also be a technical problem with moving at such a fast pace. Each infrastructure element needs to be introduced before the other systems it relies upon are properly verified and operational. Thus the budgets, the pace, methods of technical progress, and the probable cost in human lives, will make the exercise seem more like a war than building an infrastructure.

It is imperative to act now. There are many good short-term reasons why investment in space is important and these alone could be used to justify the development of a space infrastructure. However, we should not lose sight of the long-term goal of expanding our civilisation into the Solar System, as this will be the only viable way, eventually, of maintaining that civilisation. We face a choice of the type future that we leave to posterity; a stone age or a space age. If it is to be a space age there is a need to act now with much greater vigour than is currently being shown.

References

1. The best known of these is: "The Limits to Growth" by Meadows et al. Pan 1974 ISBN 0 330 24169 9.
2. "The Resourceful Earth; A Response to Global 2000" by Julian Simon and Herman Kahn, Blackwells 1984 ISBN 0631 13467 0.
3. J. Peter Vajk's comments are quoted on page 97 of "Space Colonies" Edited by Steward Brand Penguin 1977 ISBN 0 14 00.4805 7.
4. This talk was published in: "Space Resources And The Limits To Growth" by A.R. Martin JBIS Vol. 36, No. 6, June 1985.
5. "The Effects of Investment in Extraterrestrial Resources and Manufacturing on The Limits To Growth" by F.W. Schultz JBIS Vol. 41, No. 11, November 1988.
6. A description of this model can be found in: "Citizens of the Sky" by Robert C. Parkinson 2100 Ltd, ISBN 0 9512989 0 9.
7. Published as: "Pioneering The Space Frontier" by the National Commission On Space, Bantam Books 1986 ISBN 0 553 34314-9.
8. The report was called: "Leadership and America's Future in Space" by Dr. Sally K. Ride.

Near-Earth Asteroids Observed

International cooperation plays a vital role in the observation of near-Earth asteroids and the determination of their orbits. When an orbit becomes established, it may be possible to relate old sightings to the same asteroid body. The feasibility of spacecraft rendezvous missions to asteroids is currently being assessed on the basis of available orbital data.

In 1988, 390 new asteroids were discovered during the Planet-Crossing Asteroid Survey's (PCAS) monthly observing runs at Palomar Observatory. Of particular interest are three near-Earth asteroids, Apollo 1988 EG and two Amors, 1987 QB and 1988 PA. To date, 1988 EG and 1988 PA are the only near-Earth asteroids found worldwide although the search activity for those rare objects has increased substantially. In conjunction with the International Near-Earth Asteroid Search (INAS) program - coordinated from JPL - the Bulgarian wing of the project discovered Apollo asteroid 1987 SB. Nearly concurrent, confirming observations were provided from Palomar. In addition, about 40 high-inclination objects were found: Mars-cross asteroids and inner-belt-region objects, the Hungarians and Phocaeas. Since 1982, the known number of those intriguing objects, which seem to be precursors to the near-Earth asteroids and probably number among them a few degassed comets, has more than doubled.

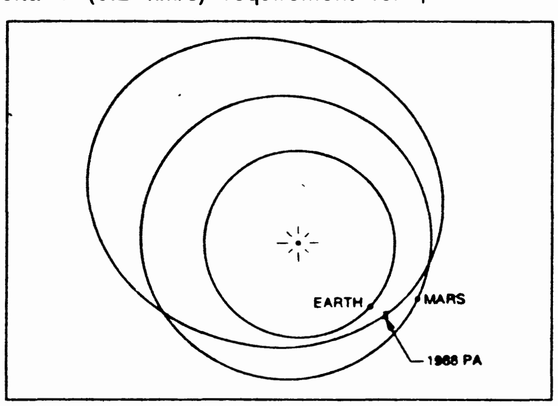
Of special note is the number of recoveries of PCAS-discovered asteroids. Amor asteroid 1982 XB was recovered in November 1987. Refined observations led to the recovery of tiny, 350-m asteroid by radar from Arecibo. These radar results will help ensure the future acquisition of 1982 XB over the next 25 years. Amor 1982 XB has been identified as a prime mission candidate because of its low delta v (5.2 km/s) requirement for rendezvous. Thirteen opportunities between 1990 and 2010 have been found.

The most favourable are in 1992, 1995, 1997, and 2007. It has now been officially numbered 3757. Tow other very faint near-Earth asteroids, 1986 LA and 1986 PA, have been recovered. They are two of the smallest objects of the some 110 known near-Earth asteroids. Amor, 1985 D02, was recovered in August 1988. It brightens to magnitude 13 in September so that it offers an excellent opportunity for extensive physical observations. Unique Mars-crosser (3800) 1984 AB, and strong Mars-crosser (3737) 1983 PA were also recovered and numbered this year.

Earth-crossing Apollo 1988 EG was discovered March 12, 1988, after it had already made its closest approach to Earth on February 26 at 0.040 AU (6 million km). It was then already moving away from Earth. Apollo 1988 EG travels in an orbit that takes it inside the orbit of Venus (perihelion distance of 0.64 AU) to beyond the orbit of Mars (aphelion distance of 1.90 AU). The asteroid has an inclination of 3.5 deg to the ecliptic and an orbital period of 1.4 years. The circumstances of discovery were fortuitous, since the small body makes an approach to Earth is favourable for observation only once in 10 years. 1988 EG has been observed over a 2-month period, which ensures the asteroid's recovery with the use of large telescopes in mid-1990 and the spring of 1991.

Preliminary assessment suggests that, with its small orbit, modest eccentricity, and a low inclination, they recently discovered Amor asteroid 1988 PA may rank among the first dozen or so further spacecraft mission candidates with minimum delta V requirements.

From a NASA/JPL 1988 report on the Asteroid Search Program.



Orbital plot of Amor asteriod 1988 PA at discovery on August 9, 1988. A possible candidate for spacecraft rendezvous.

Space Travel: Fiction and Reality

In his Pulitzer Prize winning *book ...the Heavens and the Earth,* Walter McDougall suggested that all science fiction "was a form of cultural anticipation." [1]. He begins *...the Heavens and the Earth:* "The great pioneers of modern rocketry-Tsiolkovsky, Goddard, Oberth, and their successors Korolev, von Braun, and others, were not inspired primarily by academic or professional interest, financial ambitions, or even patriotic duty, but by the dream of space flight. To a man they read the fantasies of Jules Verne, H.G. Wells, and their imitators. The rocket, for them, was only a means to an end" [2].

By Dr. L. Suid

Tsiolkovsky saw science fiction as giving direction to his work: "For a long time, I thought of the rocket as everybody else did - just as a means of diversion and of petty everyday uses. I do not remember exactly what prompted me to make calculations of its motions. Probably the first seeds of the idea were sown by that great fantastic author Jules Verne. He directed my thoughts along certain channels, then came a desire, and after that, the work of the mind" [3].

For his part, Robert Goddard believed that he had probably inherited his "innate interest" in mechanical things from "a number of ancestors who were machinists." Nevertheless, the future rocket scientist attributed the motivation for exploiting his aptitude to reading science fiction stories, particularly H.G. Wells's "War of the Worlds." According to Goddard, the stories "gripped my imagination tremendously. Wells's wonderful true psychology made the things very vivid, and possible ways and means of accomplishing the physical marvels set forth kept me busy thinking" [4].

In writing to Wells in 1932, Goddard described how the images in War of the Worlds interacted with his thought processes: "I was sixteen years old and the new viewpoints of scientific applications, as well as the compelling realism of the thing, made a deep impression. The spell was complete about a year afterward and I decided that what might conservatively be called 'high-altitude research' was the most fascinating problem in existence." This inspiration had led Goddard to the study of physics and of space flight. He told Wells that he did not know how long he would be able to work on the problem, but he hoped, "... as long as I live. There can be no thought of finishing, for 'aiming at the stars,' both literally and figuratively is a problem to occupy generations, so that no matter how much progress one makes, there is always the thrill of just beginning" [5].

In contrast to Tsiolkovsky and Goddard, Hermann Oberth contributed not only to the development of space science but also experienced the thrill of seeing man land on the Moon. Oberth's broad interest in mechanical things that moved quickly received an early focus from science fiction: "At the age of eleven, I received from my mother as a gift the famous books, From the Earth to the Moon and Travel to the Moon by Jules Verne, which I read at least five or six times and, finally, knew by heart" [6].

While the stories of man's first journey to the Moon stirred his imagination, Oberth recognised "that shooting a missile out of a giant gun with the travellers inside, as Verne imagined for space flight, would not work. Even if it would have been technically feasible to produce such a gun, the travellers inside the missile would have been crushed without pity by the enormous acceleration." Although he had not yet acquired a significant knowledge of mathematics, Oberth was able to calculate that Verne had come close in his writings to the actual escape velocity which a missile would need to leave Earth's gravitational field. Since a gun would not serve as a missile launcher, Oberth began to think of other solutions of giving a vehicle the necessary speed [7].

His early musings did not provide answers to the problem. Nevertheless, he continued to draw on Verne's imaginative writings: "From the very beginning in these childhood projects, I always had in mind the rockets designed by Jules Verne for braking the gravitation pull toward the Moon and for changing direction of travel in space. I gradually realized that reaction propulsion actually offered the only means of achieving space travel and that giant rockets would be used as spaceships of the future, even if they lost in appearance any resemblance to our fireworks, as in the case with the electric spaceship designed by myself" [8].

Ultimately in 1923, Oberth published The Rocket into the Interplanetary Space, in which he set out all he had to say about transporting human beings into space using liquid rockets. The book established his eminence in the field and his reputation grew during the 1920's as he continued to write and teach. As a result of his reputation, the German film director Fritz Lang asked him to serve as the technical adviser during the production of his 1929 film A Girl in the Moon. Although Oberth's efforts to promote the film by launching a liquid fuelled rocket failed, the film inspired many young Germans, including Werhner von Braun whose early interest in rockets had also come from Jules Verne.

Like them, Oberth worked on the German wartime rocket programmes and joined von Braun in Huntsville later during the development of the rockets that were to put the first men on the Moon. In Oberth, then, the transformation of the dream of manned space flight into reality came full circle. Inspired by Verne, Oberth provided the scientific basis that turned imagination into hardware and, unlike most of the early visionaries, he was at Cape Kennedy to watch Apollo 11 take off for the Moon.

On his part, however, Walter McDougall argues that scientists and rocket engineers made no contribution to the policy decisions that led to the Apollo programme:

"Of all those who contributed to the Moon decision, the ones farthest in the background were the engineers of Langley, Goddard and Marshall, many of whom devoted their lives to space flight, designing dreams. Their reports and studies were necessary buttresses to the political arguments: they had to persuade that the thing could be done. Otherwise, they were absent. Some of their visionary talk about exploration and destiny found place in political speeches but their efforts to stretch the minds and hearts of their fellows, to sow wonder for its own sake, got lost in their very adoption by the technocratic state. [9].

President John Kennedy did not go before Congress on May 25, 1961 to request money for research and

development of rockets so that the US could someday have a space programme. In fact, he came to Capitol Hill to propose specifically that the US turn man's dream of going to the Moon into reality. He could propose this only because the space scientists and rocket engineers, the Tsiokovskys, Goddards, Oberths, and von Brauns, inspired by Verne, Wells, Lang and their cultural successors, had already developed and were prepared to build the vehicles that could go to the Moon "in this decade."

Simply put, the imagination of manned space flight, at least since Jules Verne, had convinced the vast majority of the American people that a trip to the Moon would occur sooner or later. Without this belief, people would undoubtedly have laughed President Kennedy off the podium for proposing such an absurd idea of going to the Moon.

What relationship did the ideas about man's first trip to another heavenly body have to the reality of the Apollo Moon programme?

H.G. Wells may have made a deep impression on Robert Goddard but, nonetheless, his images of space travel remain little more than fantasy, ie., Martians coming to Earth in firey missiles and man going to the Moon propelled by an anti-gravity element attached to the outside of the space capsule.

In contrast, Jules Verne drew upon the best available scientific information, thus gaining credibility from scientists and the general public. To be sure, some implausibilities exist in his stories, e.g., the method he used to launch his space vehicle. Consequently, despite the occasional flaws, Verne's work introduced science to the masses in a form they could understand.

Hermann Oberth

In From Earth to the Moon and Around the Moon Verne's travellers reach Moonspace and continue their voyage back to Earth, ultimately landing in the Pacific where an American warship rescues the astronauts. Verne did not have his crew actually land on the Moon, probably because he could conceive of no way to duplicate his launching cannon there.

Verne's ideas had a profound influence on readers, in addition to the early pioneers of space flight. Dr. Melvin Calvin, the 1961 Nobel Prize winner for chemistry and a leading planner and experimenter in the search for extraterrestrial life recalled that as a boy, he read Wells and Verne from cover to cover: "I used to live those stories. I can remember actually departing from this world for the course of the hours or days that it took to read one of the books. I was not a part of this world - I was a part of what I was reading" [11].

Even Neil Armstrong, who has claimed that he could not "provide any information regarding science fiction films that would be of any value, as I have no expertise in that field," once cited Verne. In a televised news conference on his way back from the Moon, the first man to walk on the Moon told the world, "A hundred years ago, Jules Verne wrote a book about a voyage to the Moon. His spaceship Columbia [sic], took off from Florida and landed in the Pacific Ocean, after completing a trip to the Moon. It seems appropriate to us to share with you some of the reflections of the crew as the modern day Columbia completes its rendezvous with the planet Earth and the same Pacific tomorrow" [11].

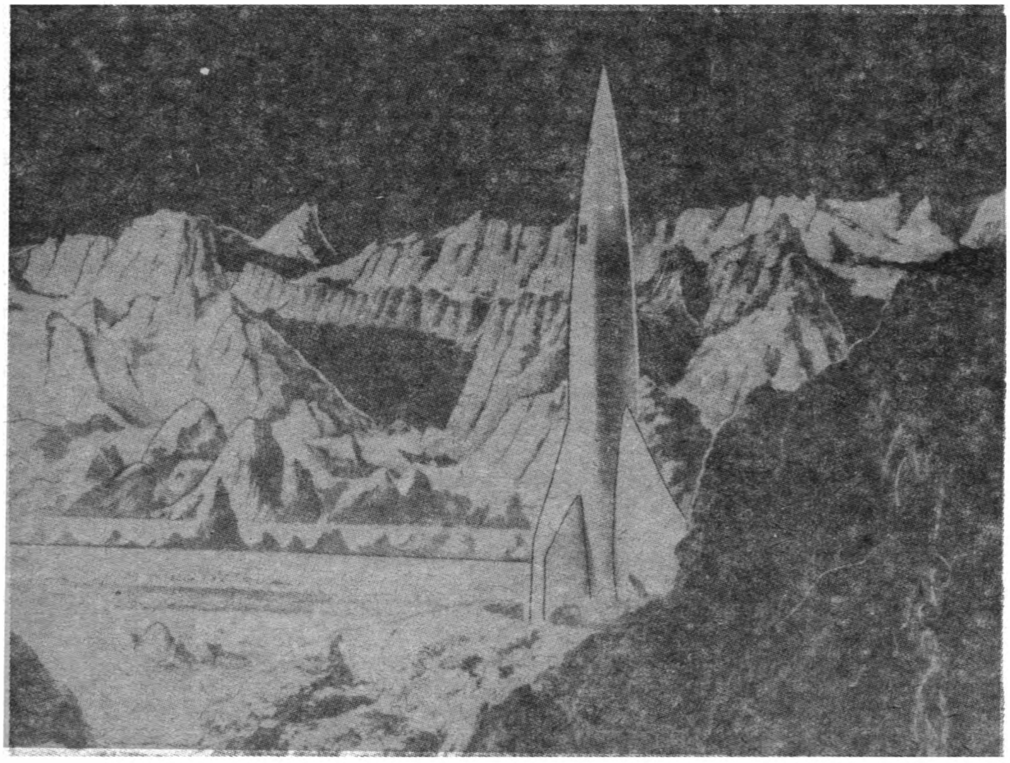
Turning to the first cinematic representation of manned space flight in the 1903 French movie A Voyage to the Moon, the filmmaker, George Meleis drew his inspiration from Verne's two books. While also committed to scientific accuracy, Meleis changed the literary images. Unlike Verne, who had postulated a barren and lifeless Moon, Meleis, populated it with strange, fairy tale-like creatures.

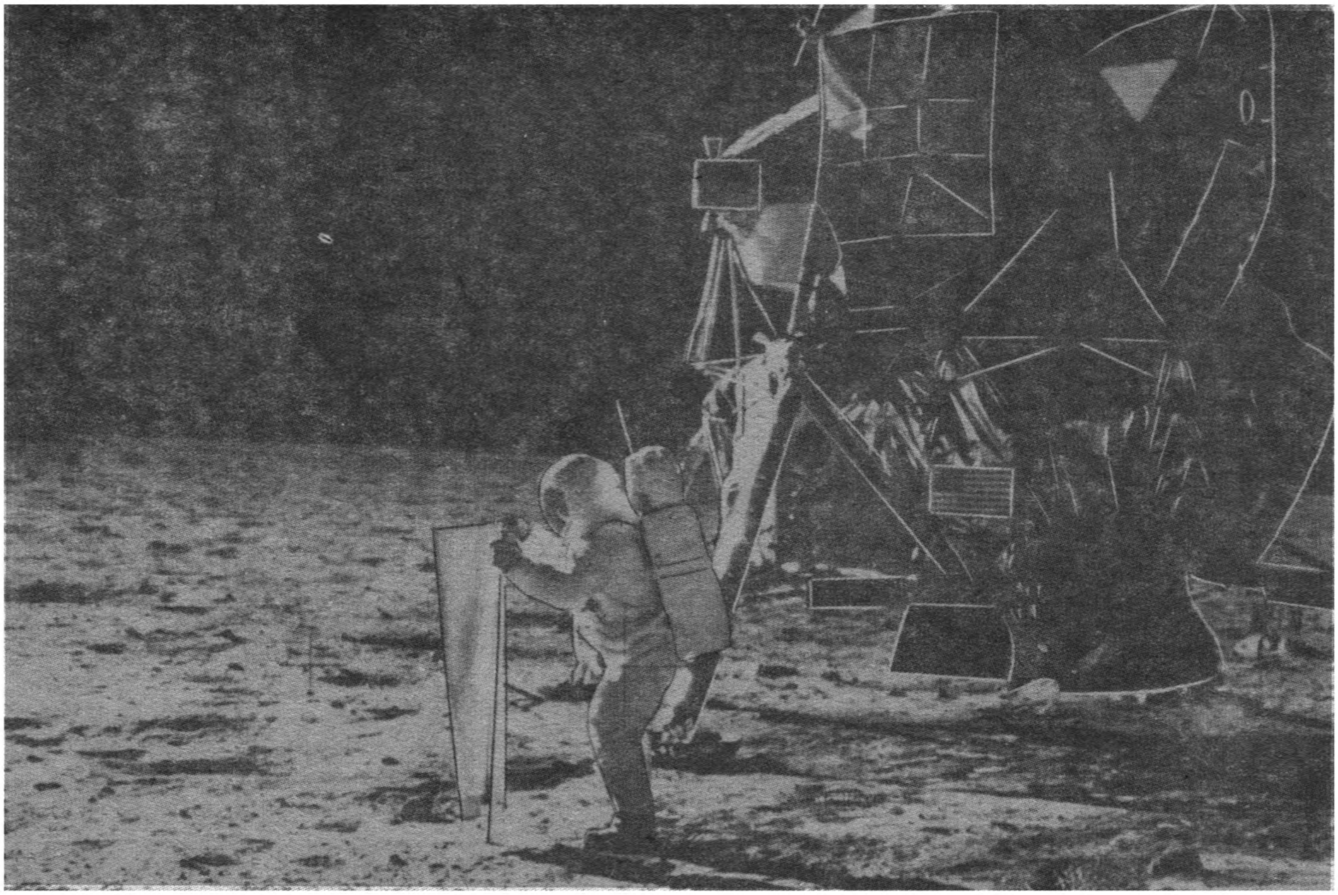
This allowed the director to include a major battle between the Earthmen and the residents of the Moon. More important, having landed his men on the lunar surface, scoring a direct hit in the eye of the man in the Moon in the process, Meleis did solve the problem of getting the space travellers back to Earth.

Their capsule conveniently falls off the Moon and plummets into the Pacific Ocean and is rescued by a warship. Meleis created one enduring image that proved prophetic: his crew received a tumultuous welcome, very similar to what both the cosmonauts and astronauts were to endure.

A Voyage to the Moon had a great impact. The landing itself, actually portrayed twice from different perspectives, has become something of an icon of science fiction and remains almost as familiar as Neil Armstrong's first step on the Moon. According to

A scene from: Destination Moon.





In July 1969 the fiction became a reality when Neil Armstrong and Buzz Aldrin became the first men on the Moon. Buzz Aldrin is pictured here assembling an experiment. *NASA*

the film director's granddaughter and great granddaughter, the film became the most popular of all the director's 500 plus movies. Some audiences even came to believe the film portrayed an actual trip to the Moon and became very worried, not unlike what happened with Orson Welles "War of the World" only 50 years ago [12].

Fritz Lang's 1929 A Girl in the Moon did not provide any single image that has endured as long as Meleis's lunar landing. While the film has its own moments of implausibility, the visualisation of the rocket hardware does not look all that outdated even today, undoubtedly due to the technical advice of Herman Oberth.

To be sure, Oberth could not dissuade Lang from having his Moon contain a breathable atmosphere. The director argued that he would not film his actors in "diving" suits even though Oberth pointed out that the Moon had no oxygen. He even cited an authority to justify his portrayal - H.G. Wells, who provided his Moon with breathable air.

Giving some lipservice to plausibility, however, Lang did have the first man on the Moon disembark from the lunar lander in a space suit and test for an atmosphere, by lighting a match. When it burns, the scientist joyously throws off his protective outfit and Lang has his freedom to film the actors cavorting in normal clothing.

On the other hand, the director did use Oberth's concept of a multi-stage rocket as the vehicle of choice. Unlike fictional trips before and after A Girl in the Moon, Lang created an ambience of scientific exploration by including a reference to an unmanned surveyor satellite which sends back photographs of the Moon to prepare for the manned trip.

Like Verne and Meleis, Lang included the standard debate between groups of scientists over the possibility of manned space flight to the Moon. In his case, the scientist who proposed the trip in order to mine gold is discredited and the actual flight occurs many years later - with the now-old scientist aboard.

Lang, with Oberth's help, created a Moon journey not too different from the ultimate trip. Unique to science fiction, the movie anticipates the future by portraying the vehicle as a multi-stage rocket assembled in a building not unlike the Vehicle Assembly Building at the Kennedy Space Center. The completed rocket is then towed out to the launch pad which proves to be under water. According to the title, this technique is necessary because the rocket is too light to support itself during its launch.

Ironically, NASA seriously considered using a barge as the launch pad for Apollo because of the very weight of the Saturn rocket.

The actual launch, which takes place at night, probably to save money on special effects, anticipates the huge gathering of spectators and media types, If nothing else, the scene suggests that science-fiction writers and filmmakers appreciated the significance of the first trip to the Moon.

During the flight, Lang portrayed weightlessness aboard the rocket, albeit for dramatic effect when convenient. The crew moves around, sometimes normally, sometimes by floating, and sometimes by hooking their feet through stirrups attached to the walls of their ship. But Lang does not concern himself with maintaining the effect on a consistent basis since the movie remains nothing more than a romance and melodrama set on the Moon.

Overall, the hardware is surprisingly believable. The portrayal of the rocket stage separations is not all that different from the simulation which the TV networks used during the Apollo missions and the rocket lands

on its tail.

What A Girl in the Moon and most similar stories from Meilis onward lacked was any portrayal of a series of flights, each building on the experiences of the previous effort in preparation for the final assault on the lunar surface.

When asked about the significance of the lunar landing, Wernher von Braun observed: "Oh, I would say about with the events of aquatic life crawling on the land for the first time." After the successful touch down of the lunar lander, the rocket engineer went even further: "I think the ability of man to walk and actually live on other worlds has virtually assured mankind immortality" [12].

Put another way, the landing of the Eagle on the lunar surface represented the culmination of man's cultural dreams of manned space flight and of his scientific and technological creativity.

The success of his book, Rocketship Galileo, and the images of manned space flight which he created provided Robert Heinlein with an entree to Hollywood and, working with George Pal, he wrote the screenplay for Destination Moon, the first postwar and first colour movie about a lunar expedition.

Unlike his book, the movie portrays a highly plausible expedition. The "standard" debate focuses not so much on whether man can or should go to the Moon, but whether the government or private industry should undertake the project. Given Heinlein's political philosophy, private industry wins out. We are told that the government does nothing except in crisis so industry must act to protect the nation's interests.

Besides failing to predict that a lunar landing would require the entire resources of the nation, filmmakers did not foresee the explosive growth of television and how the medium would be able to capture virtually every moment of the lunar flight. Nor did they recognize that computers would become indispensable for the journey.

Moreover, Pal and Heinlein did choose to return to the pre-Girl in the Moon, single stage, direct ascent rocket, now atomic powered, rather than accept Oberth's multi-stage rocket. Like a good action, adventure movie, the crew is composed of a cross-section of Americans and, in the tradition of previous science fiction movie, the men do not undertake any special training for their flight.

Nevertheless, the filmmakers did have a strong commitment to making Destination Moon as scientifically accurate as possible within the knowledge then available. Consequently, for the most part, the film has the aura of a documentary, which, even today, does not seem too dated.

During the flight, the crew functions in a weightless environment at all times. The rocket lands on its tail and, while on the Moon, the astronauts perform their tasks as if they were actually under the influence of one-sixth Earth gravity. More important, they seem genuinely awed by their accomplishment and their comments are not too different from those of the men who walked on the Moon less than twenty years later. While the film's

The hardware of the Mercury, Gemini, and Apollo programmes started to influence what filmmakers began to create.

climax resembles a melodrama, the viewer has the impression that the ship will return to Earth safely.

Whatever dramatic and scientific shortcomings Destination Moon had, it did launch the Golden Age of Science Fiction that existed during the 1950's. Ironically, the movie lost the race to the nation's theatre screens for Rocketship X-M made in ten days, appeared a few weeks before Pal's movie.

Originally intended to portray man's first voyage to the Moon, the producers changed the destination to Mars to avoid a possible lawsuit from Pal. While lacking some of the scientific accuracy and production values of Destination Moon, Rocketship X-M contains many of the same images as its more expensive companion, and it offered the same message - man would shortly break his Earth bonds, fly to other heavenly bodies, and face new challenges.

As is often the case with literature or film, most of the stories which followed the initial groundbreaking stories remained little more than pale imitations of the originals. One of the worst of these, and perhaps one of the worst movies ever Cat Women on the Moon, uses a generic, single stage, direct ascent rocket to take its crew to the Moon.

Budget considerations or, more likely, a disinterest in hardware or plausibility take over. The spaceship's cabin looks as if shot in some office furnished with a "government-issue" desk and standard, commercial radio microphone for communication with Earth. The producers did not bother to simulate weightlessness, even occasionally, as Fritz Lang had done. Though they did follow his approach to the environment of the lunar surface by providing it with a breathable atmosphere. Of course, the film was not aimed at a knowledgeable audience but to young males who might find the "catwomen" appealing.

Whether bad or good, however, the science fiction literature and movies up to Sputnik and the beginning of manned space flight may well have influenced at least one element of the population, the rocket engineers. Except for Hermann Oberth, the men most directly involved in finding ways to transform the dream of manned spaceflight into reality seemed committed to the direct ascent approach of putting man on the Moon.

In discussing his efforts to sell to NASA engineers and scientists the "rendezvous in orbit" approach, John Houbolt recalled that he simply could not interest anyone in the method. When asked if this resulted from images in books and movies having influenced people into thinking only in terms of a direct ascent approach to a lunar landing, Houbolt replied that it seemed as good an explanation as any [13].

In any case, once President Kennedy issued his call to the US to place a man on the Moon before the end of the 1960's, the fiction and reality of manned spaceflight began to merge. The hardware of the Mercury, Gemini, and Apollo programmes started to influence what filmmakers began to create. However, NASA never really came to terms with how to use these images to further its programmes. It tried to spread its message through the news media and in educational programmes but, in the end, did not trust the reality of its space missions to generate sufficient excitement to produce on-going support within the US Congress and among the American people.

As a result, the NASA Public Affairs Office cooperated with Hollywood in the making of feature films purportedly to show the American space programme in operation. Unfortunately, the major releases did not contain stories that in any way would engender support for its projects.

Countdown portrayed NASA's internal operations filled with policy disagreements, backbiting among officials and astronauts, and a decision to launch a suicide mission to the Moon in the hopes of beating the Soviet Union to a lunar landing. As the title suggests, Marooned told the story of a failed American orbital mission, the death of one astronaut while the crew waits for an American rescue rocket and their ultimate rescue by a Russian cosmonaut. Finally, Capricorn One details how the head of NASA stages a fake landing on Mars.

The success of the Apollo programme itself made all previous sto-

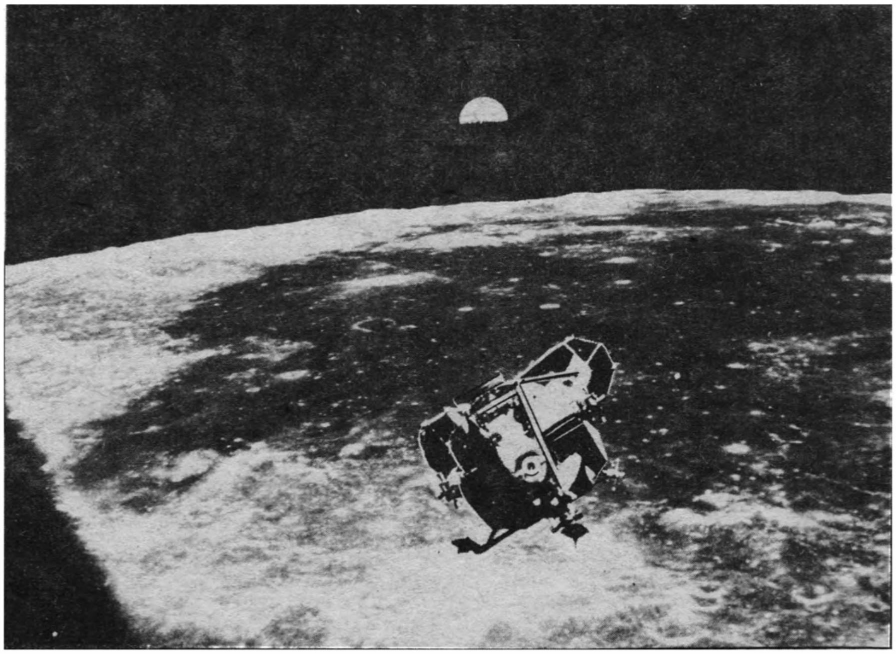
ries about the first men on the Moon obsolete. 2001 stands as a link between the science fiction past, the contemporary reality of the Moon becoming known to man and the model for the subsequent space epics that appeared during the 1970's. In making the movie, Arthur Clarke and Stanley Kubrick faced the possibility of having the discoveries of the Apollo programme render their portrayal of the Moon out-of-date. The fact that the movie's images of the Moon still seem real speaks to the success of the filmmakers.

Except for the fleeting scenes on the Moon in 2001, no significant portrayals of life on the Moon existed for NASA to use in helping sell Congress or the American people on the need to establish permanent lunar colonies. So, with the Vietnam War having drained funding from NASA and created antipathy to future, large scale government programmes like the Apollo Project, America's space programme entered into limbo during the 1970's.

To science fiction writers and filmmakers, the Moon no longer became the focus of attention. The shuttle became the vehicle of choice for travel in near space. However, for the most part, images of manned space flight from Star Trek to Star Wars and the continuation of Isaac Asimov's Foundation series, became those of exploration into the outer reaches of the Universe, "where no man has gone before."

Whether these images will ultimately have an impact on America's space programme remains to be seen. Jesco von Puttkamer, NASA's Programme Manager for Long-Range Planning and a technical advisor to Star Trek: the Movie, believed film provided NASA with "a legitimate way of beating our drum" and "by showing deeds rather than words, demonstrate what we are standing for." The film, he said, gave NASA " a chance of being depicted in a positive way where we can show, hey, we made it 200 years from now. And that the name NASA survives and is being used as a plug" [14].

Beyond that possibility, what impact has science fiction had on America's space programme? In his chapter on the decision to go to the Moon, McDougall says, "When the Soviets weighed in by orbiting Gagarin, and the Shepherd flight confirmed NASA's contention that the mission was feasible, all barriers came down. All, that is, except cost, and that, too, was less important in the new White House. We will probably never know precisely what was in Kennedy's mind when he decided that Americans should go to the Moon. What may have tipped the balance for him and for many was the spinal chill attending the thought of leaving the Moon to the Soviets. Perhaps Apollo could not be justified, but, by God, we could not **not** do it" [16].



The Apollo 11 Lunar Module, Eagle, returns to the Command Module after completing work on the surface.
NASA

John F. Kennedy did not apparently read science fiction and so did not see his decision to embark on a lunar landing as fulfilment of a childhood dream. He saw space as a new arena to explore in much the same way as Columbus saw the oceans of Earth as avenues to the unknown. In some measure then, by launching the Apollo Programme, Kennedy saw himself in relation to NASA as Isabella to Columbus, with a successful landing on the Moon ensuring his place in history.

Clearly, the President could not go before Congress and request $25 billion to become immortal. Instead, he used other arguments the need to beat the Soviets and so demonstrate the continued American technological superiority over the USSR; the gains for science and technology regardless of the outside competition; and the "focus argument", which used the Apollo programme to push the entire US space effort [16].

Likewise, while citing the space race and the need to demonstrate leadership to the World, Bobby Kennedy recalled that the President compared the importance of space to the exploration of the US by Lewis and Clarke, concluding, "I think that made a profound impression on him" [17].

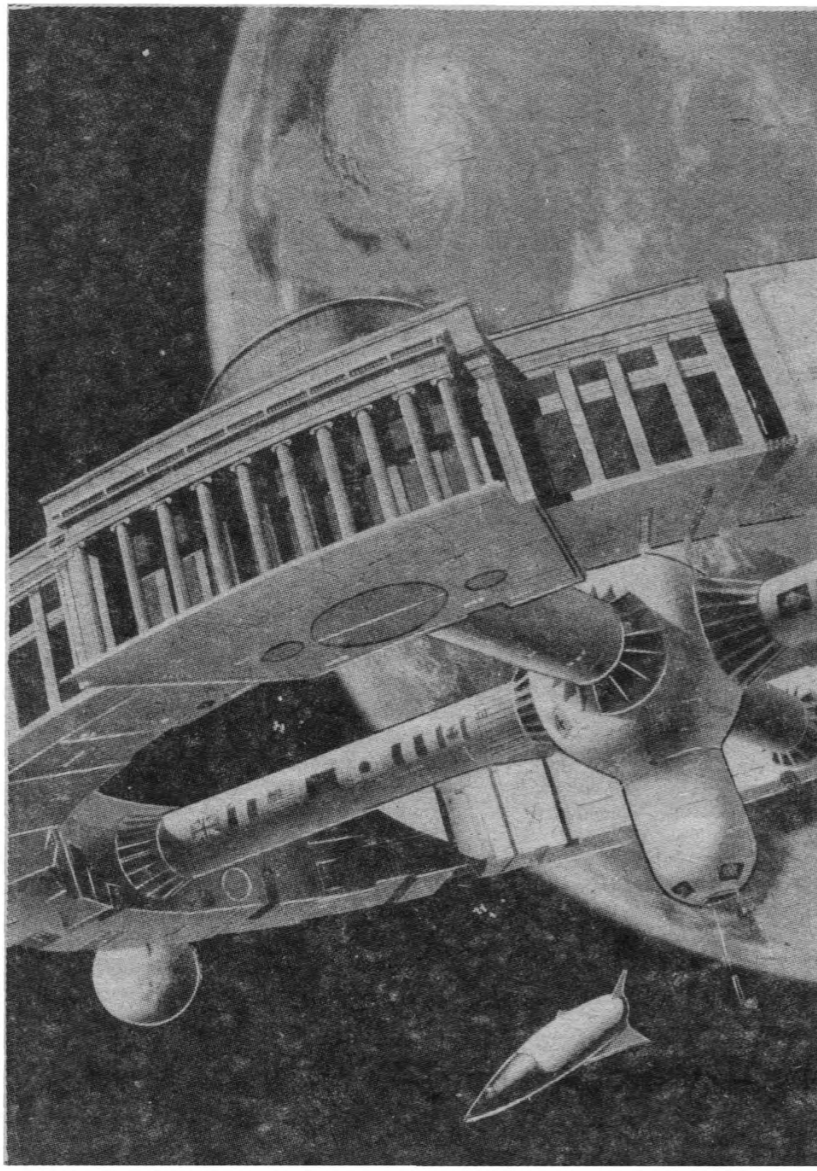
As with most significant events in history, the decision to go to the Moon can only be understood as the result of the merging of many ideas and influences. While not the only one, popular cultural expressions of science fiction clearly had an impact on the American space programme, in the politics of space and, through scientists and engineers, on the development of the technology of space flight.

If nothing else, science fiction created an interest in space among the majority of the American people and convinced them that going to the Moon would occur one day. In turn, President Kennedy, consciously or subconsciously, drew on the cultural images of adventure and exploration within science fiction to sell the Moon programme to the nation.

References

1. WalterMcDougall,...the Heavens and the Earth. p.100.
2. Ibid., p.20; Author's conversation with McDougall, January, 1986.
3. Wernher von Braun and Frederick Ordway III, History of Rocketry and Space Travel, p.41.
4. Robert Goddard, "Autobiography," in Arthur Clarke, ed., The Coming of the Space Age, p.107, cited hereafter as Clarke.
5. Robert Goddard to H.G. Wells, April 20, 1932, Correspondence, pp.821, 3.
6. Hermann Oberth, "Autobiography," in Clarke, p.114.
7. Ibid., p.115.
8. Ibid., pp.115-6.
9. McDougall, p.324.
10. Shirley Thomas, "Melvin Calvin," in Men in Space, V. 6, 59.
11. Neil Armstrong letter to author, August 22, 1988.
12. NASA press conferences on July 14 and 22, 1969.
13. Interview with John Houbolt, April 6, 1956.
14. Interview with Jesco von Puttkamer, October 26, 1986.
15. McDougall, p.324.
16. Interview with Theodore Sorensen, December 2, 1987.
17. Robert Kennedy in His Own Words, p.340.

INTERNATIONAL SPACE UNIVERSITY® HEADING TOWARD ORBIT



The International Space University (ISU) was founded in April 1987 at a conference held at the Massachusetts Institute of Technology (MIT). The ISU co-founders—Peter H. Diamandis, Todd B Hawley and Robert D. Richards—forwarded a concept in space education which has captured the imagination and support of the world's space community. With the involvement of academia, governments and industry from numerous nations, ISU will expand into a full-year academic program and permanent campus locations following 1992, the International Space Year. "Clearly the ISU plans are quite ambitious, but the concept has won over many of its early doubters," notes Mr. Ian W. Pryke, head of the European Space Agency's Washington Office. "The momentum and success the ISU has built is why I am proud to serve as its Chairman of the Board "

continued on next page

The Birth of a 21st Century Institution

It is my pleasure to write a few words on behalf of an organisation I helped to start and which is close to my heart: the International Space University. ISU is an outstanding new institution dedicated to identifying, unifying and educating the world's best young professionals and outstanding graduate students involved in space-related studies from architecture and engineering to life sciences and business. Through its academic programmes, ISU is cultivating a new generation of leaders dedicated to the peaceful use of outer space.

After the phenomenal success of its inaugural summer session at MIT, ISU is setting its sights on the establishment of a permanent central campus during International Space Year (1992). In the next few years, ISU will expand to include multiple campuses at centres of excellence around the world—linked together via satellite, sharing an electronic library and data bases, offering live lecture transmissions and implementing modern technologies—to enhance cooperative research and development of space. One day soon, perhaps by 2001, ISU will have a campus where it is destined to be: *in orbit!*

ISU is doing more to promote and guarantee the peaceful and permanent development of space than any other institution I know. I have been a sponsor of ISU since its founding, and I hope that you will be able to join with me in supporting this unique educational endeavour.

Sincerely,

Arthur C Clarke

Arthur C. Clarke is the author of* 2001: A Space Odyssey. *He serves on the ISU Board of Advisors and is the Chancellor of the University of Moratuwa, Sri Lanka.

ISU Gains Momentum

continued from first page

The inaugural summer session of ISU was held at MIT in 1988, and brought together 104 graduate-level students and young professionals from 21 nations. ISU's first academic program provided an innovative package: a nine-week summer session involving a broad curriculum, state-of-the-art equipment and labs, design projects, and an international faculty and student body. During the program, all students participated in a total of 240 hours of lectures encompassing eight disciplines. The ISU academic program was led by a core faculty of 30, enhanced by more than 70 visiting lecturers representing today's leaders in the international space community.

ISU operates from its Executive Office in Boston, Massachusetts, USA, which is headed by Peter H. Diamandis and Todd B. Hawley

The 1989 summer session will take place at Université Louis Pasteur in Strasbourg, France from 30 June to 31 August. The structure of ISU'89 evolved from the ISU program offered at MIT in 1988: a nine-week session of interdisciplinary lectures and design project activities, and eight academic disciplines: Space Architecture, Space Business and Management, Space Engineering, Space Life Sciences, Space Policy and Law, Space Resources and Manufacturing, Satellite Applications, and Space Physical Sciences.

In conjunction with summer sessions, ISU is pursuing the goal of establishing a permanent campus during International Space Year (1992). Following the 1992 International Space Year, the ISU plan is to open first its Central Campus, later adding Satellite Campuses for advanced research and study in ISU disciplines in existing centers of excellence located around the world. At the permanent campus, worldwide satellite broadcasting of lectures will be routine; computer conferencing and networking, electronic library and database access will be used to link together the varied elements of ISU.

An ISU Founders Association has been launched to help establish ISU's permanent campus and to assure the continuation of this global experience for future generations. Founders Association members will help finance the planning, analyses, needs assessments, design and construction of permanent ISU facilities. Members of the Founders Association are determined to prepare a complete development plan for International Space University, and secure a sound financial base for its implementation.

The process by which humanity develops and explores space has changed in many critical ways over the last 30 years. Space is no longer the realm of the economic superpowers, nor is it a domain limited exclusively to scientists and engineers. Today space development takes place in an international, interdisciplinary arena. ISU seeks to provide a general understanding of technical and non-technical areas important to space development, and to gather together the leaders of tomorrow, allowing them to discuss common goals, motivations and ideas. The International Space University invites visionary men and women of all nations to join and support this critical mission.

ISU Captures the

The International Space University mission is to offer educational programs which are of relevance to today's space industry. From its inception in 1987, ISU has fostered increasing levels of support from a diverse international roster of corporations and agencies whose leaders recognize the value and impact of the programs offered at ISU.

"In this era of expanding civil space programs, there is an ever-growing interest and need in our industry to identify and train young people who can operate successfully in an international commercial environment," notes John McLucas, Chairman of QuesTech, Inc. "The ISU seeks to satisfy the emerging training needs of the aerospace industry"

ISU has pioneered a unique education niche which has proved as relevant to aerospace firms in North America, Japan

The Power of ISU

One hundred and four rare individuals now have friends and professional colleagues in 21 different countries of the world. These are the students of the first graduating class of International Space University. The ISU alumni form a cadre of dedicated space professionals who will provide the leadership to launch humankind into space.

To illustrate the effect the "ISU Experience" has already had, a sampling of alumni perspectives is presented here:

- "This has been the most important educational experience of my life," said Mark Matossian, the first alumnus to obtain graduate course credit for his work at ISU'88, and now a staff scientist at SAIC. "Never have I been asked to push myself as far and as fast as I did at ISU this summer."

- "During ISU I made contact with individuals from many space-related corporations—many of them I have remained in frequent contact with, this will help to create new opportunities for all of us,"

Interest of Space Industry Leaders

Space industry leaders from over 20 nations have endorsed ISU.

Yasuhiro Kuroda
SHIMIZU

Claude Goumy
MATRA SPACE

Dean Burch
INTELSAT

and Europe as it has to telecommunications corporations in Africa and Australia. Proof of this relevance may be noted in Japan's increased participation in ISU in 1989, which will include at least 17 students—an increase from five participants in the 1988 program at MIT

"We wish to promote the ISU program among Japanese corporations because we believe that space development will require professionals who have an international perspective and who will succeed in the increasingly cooperative world space industry," explains Dr. Yasuhiro Kuroda, Senior Advisor of Shimizu's Space Project Office, Japan's ISU Liaison since 1987

"In Europe, the multi-national nature of many space activities makes the International Space University program particularly valuable," remarks Claude Goumy, General Manager of MATRA SPACE, which is sponsoring students and curriculum development for the ISU'89 program in Strasbourg, France. "I believe that the international educational experience of the ISU will have very great long-term benefits in our firm, our nation and the world."

At the INTELSAT Organization, 115 nations own and operate an expanding international satellite communications system which is often referred to as one of the best examples of successful multi-national space cooperation. "It has been our pleasure to support [the ISU] enterprise," notes Dean Burch, the INTELSAT Director General and a member of ISU's Board of Advisors. "It is extremely pleasing to see how successful the ISU program has become in such a short period of time."

Networking

says Akiyoshi Kabe of Mitsubishi Electric Corporation. "I know I am only a fax or a phone call away from hundreds of people—space experts, astronauts and CEOs—who are not only my colleagues but also my friends"

- ISU Alumna Marina Aguiar of Brazil adds "ISU gave me an excellent understanding of how my work in materials science can be used in the development of space, and the multicultural environment helped to broaden my view of the world."

- Vadim Vlasov, a Soviet alumnus very active in US-USSR relations, noted: "I was impressed with the expertise, diversity and enthusiasm of the ISU faculty. It was extremely interesting for me to hear the perspectives of faculty from 14 nations."

- "Immediately following ISU, I was offered a job by the Canadian Astronaut Program. As one of my first assignments I was sent to the Soviet Union to discuss experimental procedures and logistics for two Canadian experiments to fly on Biocosmos 1989," says Canadian Alumna Kristiina Valter. "My friendship and experience with my 12 Soviet ISU colleagues was invaluable in this trip to the USSR."

ISU'88 graduates Mark Matossian (USA), Akiyoshi Kabe (Japan) and Kristiina Valter (Canada)

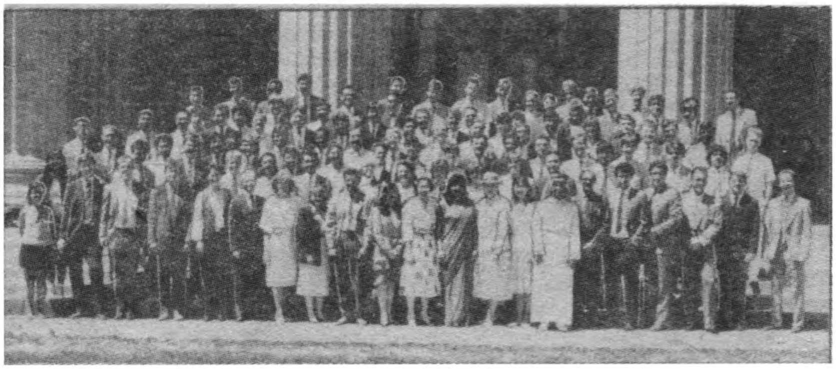
The shaded regions on this world map represent those nations which sent their top students to ISU'88

- Russel Hannigan is the youngest member of the British Aerospace Hotol research and development group. He notes, "My experience at ISU and the design project activities allowed me to work with a culturally diverse group of people, and also gave me the opportunity to gain knowledge which is valuable to my work at British Aerospace."

- "When I returned from ISU I received a very important job proposal from Aeritalía, and now I am in Torino (Italy) working on the Human Factors Aspects of the Columbus Space Station," says alumnus Francesco Brunelli. "I really do have to express my warmest gratitude to ISU. I owe it all to ISU."

Between 20 June and 20 August 1988 a group of outstanding students and young professionals came together as strangers and left as friends and colleagues. Coming from 21 different nations, but sharing a common dream and the qualities of perseverance, leadership and brilliance—these students have set out to change the world...together.

Investors in Space Leadership



The 104-member ISU Class of 1988 at MIT

Over 70 corporations and government agencies in more than 20 nations joined to support the ISU program when it began in the summer of 1988. Over US$1 million was raised to finance ISU Executive operations and the innovative ISU'88 program held at the Massachusetts Institute of Technology. In 1989 and beyond, ISU seeks to expand its network of supporters to include individuals and institutions to provide scholarships, curriculum and permanent campus development. Space Biospheres Ventures has already commited a five year scholarship and Life Sciences curriculum support to ISU. "We are delighted with the ISU program, level of excellence and international scope, and are proud to be sponsoring ISU's first textbook this year in the field of Space Life Sciences," says Margret Augustine, CEO and Project Director, Space Biospheres Ventures.

European Space Agency Director General Reimar Lüst has noted that, "[ESA] supports not only the 'principle' of the ISU, but also its day to day activities To date this has included free advertising in Agency publications, ISU brochure sponsorships and, in conjunction with the 1988 summer session, ESA sponsored scholarships and ESA staff as visiting lecturers." Lockheed Corporation has contributed a senior executive to serve full-time on the ISU summer session faculty for two months each in 1988 and 1989. "ISU is an important force for international space education and awareness. Few programs offer a more inventive and forward thinking approach to this vital frontier," says Lockheed Chairman and CEO Daniel Tellep. "We applaud ISU's efforts and are proud of our company's role in its continuing success."

ISU supporters, Margret Augustine of Space Biospheres Ventures, Reimar Lüst of the European Space Agency and Daniel Tellep of Lockheed Corporation.

ANNOUNCEMENT

An ISU Founders Association has been established to provide a vehicle for visionary men and women to become involved with and to support ISU's transition to a permanent campus in 1992. For more information on the Founders Association, contact:

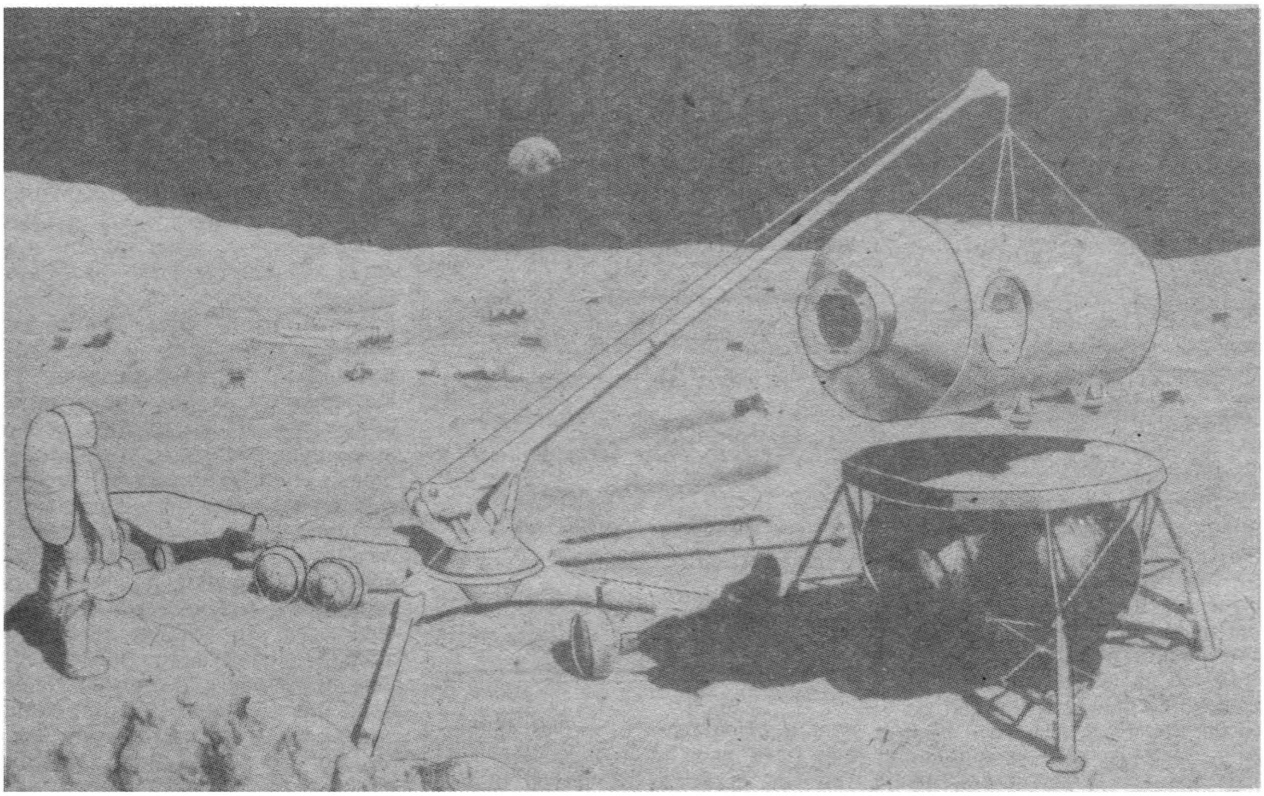
INTERNATIONAL SPACE UNIVERSITY

ISU

International Space University
636 Beacon Street
Boston, MA 02215 USA
FAX: (617) 247-1832

ISU extends its thanks to the following for their support of this supplement:

Deciding to Colonize the Moon



An artist's impression of a lunar mining complex.

The decision to establish a base on the eastern coast of Australia two hundred years ago has many points of comparison with the case for establishing a Lunar Outpost within a Space Industrial Infrastructure. The author argues that the growing global environmental problems will compel industrial nations to make such a major decision.

By J. Syed *

Australia

In 1988 Australia celebrated the bicentenary of the beginning of European settlement. The colonisation of Australia may serve as an analogue in the forum concerned with our future expansion into space and global survival.

Starting in 1616, dutch convoys followed the route from the Cape of Good Hope eastwards for 3000 miles and then northwards to Java, a course dictated by wind dynamics which would drive unlucky ships on to the barren western Australian coast. The motivation for such far-flung voyages was the feasibility of returning with goods both rare and valuable in the markets of Amsterdam, Madrid or London. Australia itself offered no such products of commercial value to the trading companies.

A century and a half later in April 1770, the "hidden" east coast of Australia was sighted. Captain James Cook's missions were a manifestation of the rise of international commerce, the growth of science and the industrial revolution.

Cook's discoveries about Australia were not attractive for commerce minded colonists seeking to re-create a European way of life using a high value local product as a means of trade to obtain resources not locally available.

It appears that the arguments for using the east Australian coast as a port on an alternative route to China and as a site for a new colony were familiar to the British government. Sir Joseph Banks advocated in 1779 that a "thief colony" be established [1]. In 1784 James Matra, who had also sailed with Cook, promoted the idea of an Australian settlement [2]. The Pitt government, which was preoccupied by more pressing problems, was prodded, according to historian Manning Clark [1], by concern about a general revolt of diseased convicts.

* The author works in the Flight Operations Department of MBB/ERNO, Bremen.

However, historian Geoffrey Blainey [3] suggested that the strategic reasoning was that Norfolk Island had two resources vital for maintenance of England's naval power i.e. mast and spar timber plus flax of the best quality. The Australian mainland, 1600 km away would provide the infrastructure and greater potential for flax farming and production of sailcloth.

Both the Norfolk flax and Pine failed to live up to expectations. The flax posed problems of technology for canvas production due to its unrivalled length of fibrous material. The timber was found to be flawed and unsafe for masts. In both cases the usual sources of these materials were never denied to the British during periods of war.

In the nineteenth century Sydney was not only a port of call, on the way from Europe to Asia, it became a base for traders of goods obtained from the Pacific Islands. With their profits the business people developed the wool industry which was the first exportable product after 1830 [4].

The cost of maintaining the convict settlement was unexpectedly high. Instead of rapidly achieving self-sufficiency, Australia cost Britain the huge sum of one million pounds in the first twelve years. At the end of that

period its population was only 5000. However, Australia's place on new trade routes was decisive. It prompted the rise of a free group of Australian traders who did not depend heavily on the favours of colony's governors, who were alert for new ways of making money and who eventually hastened Australia's transition from convict to free colonies by 1840.

The initial expenditure by the British government of one million pounds two hundred years ago is approximately equivalent to half a billion dollars today based on a simple weekly cost of living comparison [5]. Objectors, such as the East India Company, were concerned about loss of business monopolies [5] or other schemes for use of convict labour.

The decision to colonise a very distant land promptly was forced by the perceived problems of resources (convict accommodation and strategic materials). Perhaps there was a period of panic when the British government felt compelled to make provision for an alternative supply of strategic materials. After the decision had been made political considerations, as well as long communication delays, ensured that there would be no reversal. The costs may have been difficult to ascertain by critics. Eventually, a commercial momentum developed and the colony was able to supply marketable services.

Environmental Issues

The Earth's environment is now an issue of growing political importance as more adverse effects of the alterations caused by a century of industrial activity become apparent, even to non-technically minded people.

The consequences of interacting factors such as increased carbon dioxide in the atmosphere, destruction of the ozone layer, deforestation, thermal and chemical pollution and nuclear contamination are being recognised as the key points in ongoing research. A fleet of spacecraft will be put into operation in the 1990's to measure such global environmental parameters.

Extrapolative analyses that use some of the environmental characteristic parameters for dynamic models of global change have been attempted [6] but "world dynamics" modelling is open to question because the parameter measurements are incomplete and trends and interactions remain unclear. Most governments prefer to believe that technology will solve the problem in a "business as usual" manner. However, there are no models predicting a happy future without drastic intervention during the next century. Such scenarios do not contain much prospect of sustaining improved living standards for the inhabitants of Earth [7].

The 1988 drought in the USA prompted many climatologists to declare that the "greenhouse" effect may be building up faster than anticipated. The rate of CO_2 production from combustion of fossil fuels has already doubled the percentage in the atmosphere. Another ominous phenomenon appears to be hurricanes of increasing intensity resulting from the heat input in the Atlantic ocean during the northern summer. Models of solar heat trapping used in earlier studies may have been far too conservative. The well publicized destruction of the ozone layer by chlorofluorocarbons (CFC) is also contributing to the greenhouse effect [8].

Environmental crises will force governments to consider major corrective projects that will effect their short term political horizons. The space industrialisation option will be compelling. Transportation systems adequate for the task will be the priority.

Assuming that a catastrophe of hotter climate and rising ocean levels is much nearer than the next 50 to 100 years, the consequences and options for reaction need to be explored without delay. Conferences of specialists in fields related to or affected by the climate change have been sources of press reports acknowledging the impact of a warming climate.

An example of the perceived "business-as-usual" reaction option to warming and drying of agricultural regions is to develop hardier varieties of plants such as winter wheat. This technological fix will do nothing to reduce the climatic warm-up. Similar expert reaction may be observed in other specialist fields where some technological options for adaption may exist. The adaption to a degrading environment can go only so far before a major unpleasant change becomes unavoidable.

The source of more CO_2 in the atmosphere is well known i.e. fossil fuel burning power stations, transportation fuelled by combustion of fossil fuels and the destruction of vast regions of forest. It is clear that the reduction of these CO_2 sources would reduce the CO_2 problem by halting the increase. Natural CO_2 absorption through the long term carbonic acid cycle may eventually reduce the amount in the atmosphere. Nuclear power advocates push their technology as an alternative but the total replacement of fossil fuel burning power plants with fission reaction poses grave environmental problems from accidental leakage of toxic material. The long-awaited fusion reaction plants may be safer but this has to be demonstrated. Predictions of commercial fusion power production by 2050 are not encouraging.

Conventional solar power advocates characterised by the "Green" political movement believe that wind, tide and "direct" conversion of solar thermal radiation can ultimately replace fossil fuel power sources. So far the opportunities are limited to predominantly windy locations or even less numerous appropriate coastal areas. There are technical problems with wind power. The acquisition and maintenance cost of thousands of wind powered generators seems to be always greater than a large conventional power plant located close to the customers. The present market for solar energy systems for buildings demonstrates this by remaining modest. Energy savings are demonstrable but the incentives are reliant on legislation [9]. Replacement of fossil fuel burning power plants by terrestrial solar energy driven systems is not credible. Sites in deserts may be optimal today but a change to a more stormy climate may negate the marginal advantages.

Return to The Moon

Dr. Peter Glaser proposed, in the early 70's to build very large solar power satellites (SPS) located in geosynchronous Clarke orbit to beam microwave power to simple clean microwave antenna arrays on the Earth and then feed the recovered electrical current into existing power grids. This led to studies of large industrial infrastructures employing thousands of people in near-Earth space. Government funded studies were made in the late 70's following the OPEC led oil price increases. The reference scenario for these studies was the use of heavy lift reusable launch vehicles to lift all materials from the Earth's surface and Space Shuttle flights for personnel rotation. Why such a limitation was imposed is not clear. Perhaps consideration of the Moon or other Solar System resources was regarded by the study patrons as not politically fashionable. The conclusion was that the cost was not competitive with the then prevailing oil prices. As efficiency improvements subsequently forced down the demand and thus the price of oil, the urgency for development of an alter-

native to conventional power sources receded.

Some work continued in the Space Industry by people who were not compelled by Earth-only scenarios. The late Krafft Ehricke was a strong advocate of the use of Lunar Resources [10]. Those who had been inspired by Gerard K. O'Neil concepts considered asteroids as a supplementary source of materials not available on the Moon. A return to the Moon became an acceptable topic for several NASA supported symposia, after a hiatus in the early 70s.

The general view is that oxygen can be recovered from Lunar surface soil and used as rocket propellant. There are significant savings in launches from Earth when a LUNOX plant and associated space port are installed on the Lunar surface. A minimum amount of space traffic is necessary to break-even and then achieve true savings. Traffic models have been conservative by assuming no massive effort to construct SPS's until the technology has been demonstrated over some 20 years of Lunar Base operations. If hydrogen could be found on the Moon in sub-surface ice deposits in the polar regions or near suspected volcanic vents, the economics would be dramatically improved.

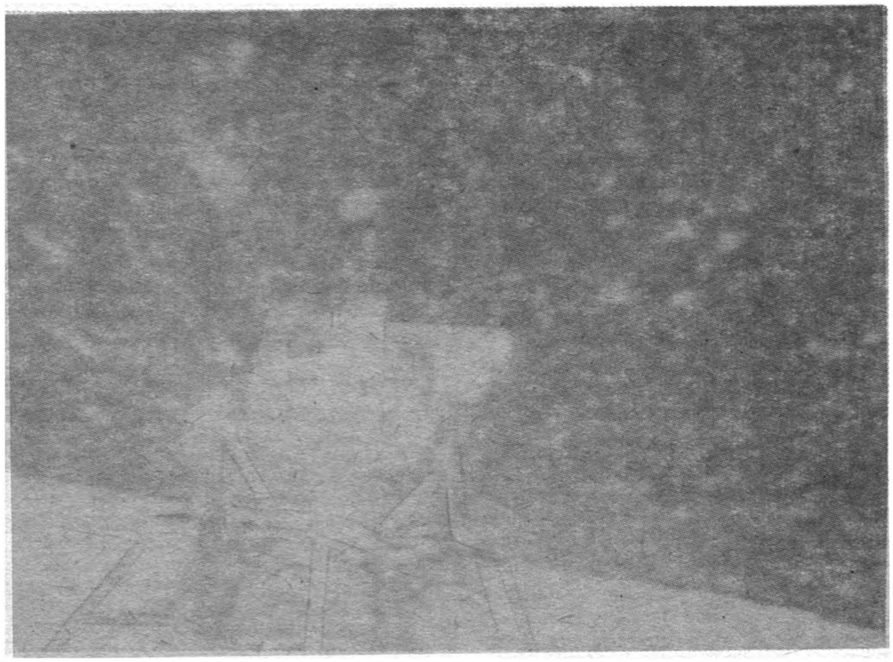
Aluminium and other metals can be recovered from Lunar rocks with processing plants that are transportable from Earth. Many volatile elements are available in abundance in the lunar regolith due to the solar wind which has delivered atoms for billions of years. These should be readily recoverable by processing the top 10 cm of scraped Lunar soil. The Helium 3 isotope has been identified as a high value exportable material. The customer would be the nuclear fusion power industry [11].

The Decision Forcer

Returning to the Australian analogy, one may now see parallels in the circumstances of major decision making. The Earth faces multiple environmental crises. The continuation of conventional practices does not inspire confidence. Politically unacceptable "Draconian measures" may be necessary to limit growth. The urgency today is debatable because there are still many people to educate about the relevant options.

The return to the Moon in order to establish a permanent human presence there is not regarded as a high priority by governments or commercial interests. The perceived cost of developing a transportation infrastructure does not appear acceptable without a convincing market plan.

The space domain today presents an established commercial sector for



The Apollo 16 Lunar Module blasts off from the lunar surface. NASA

communications and several sectors providing services to governments in the areas of military data gathering and Earth monitoring. Further commercial growth is constrained by the perceived risks of building new infrastructures, including new cheaper to fly launch vehicles, to support new markets for high value goods manufactured or processed in space.

Governments of the major space-faring nations are aware of a global resource problem as a limit to growth although this is not a current political issue. However, it seems that merchant-minded investors have realised the commercial attraction of a rapidly growing Space Industrialisation option to help overcome inevitable world problems. Environmental crises will force governments to consider major corrective projects that will effect their short term political horizons. The space industrialisation option will be compelling. Transportation systems adequate for the task will be the priority. The financing of spaceplanes, such as HOTOL, will be somewhat analogous to the Indian merchants who ventured to Sydney on speculation despite disincentives such as hostile naval activity and high insurance costs.

Soviet advances should not be overlooked and indicate the capability to undertake a major space industrial project. A manned presence on the Moon is far more credible than recently publicized manned Mars missions.

The political climate today is not tuned to supporting cures to environmental problems; only reactions to the symptoms. Natural climatic pressure will soon change this attitude. Alert governments will commit themselves to space endeavours that, at first, seem rash to the political critics. Spaceplane technology studies are increasing in the first world nations. The rationale may be disguised to avoid alerting the competitors: a scientific Lunar Base rather than an industrial Base.

There is however, a problem as waiting for environmental crisis to become politically obvious may be too late to avoid major disasters and disruptions. Complex engineering systems take time to reach operational status. HOTOL will possibly only fly after the year 2000 without the support of a crash programme.

The initial objective of producing Lunar derived construction material for orbital Power Stations may be found to be faulty but the prospect of no return on investment is not credible. Environmental crisis may be delayed by other terrestrial options such as global resource management (aided by satellite observations) and the Lunar infrastructure may demand more Earthly support than originally budgeted to sustain the growing infant. Ultimately, there will be unforeseen returns just as Australia produced unforeseen wealth.

The prospect of clean nuclear fusion power appears too distant to help, if the current "fusion in a test tube" controversy is discounted. The next most significant and much less radioactively hazardous, fusion reaction after Deuterium and Tritium is D + Helium 3. The required plasma containment and heat transfer technology is less demanding. Since Helium 3 isotope fuel is virtually non-existent on Earth the Lunar mining industry

would have a guaranteed initial customer and the nuclear power industry should consider space development as complementary to its interests rather than as a competitor for government funding [12]. This is analogous to Australian supplies of "yellow cake" Uranium Oxide to the established fission power industry.

Conclusions

Elaborations of these arguments must be prepared by specialists in the world-wide Space Industry. Criticism that the Space Industry is just a vested interest must be aggressively refuted. Critics must be forced to offer credible long term solution options or accept the Space Cause. Advertisements which advocate solutions to environmental problems using adequate Earthbound technologies should be refuted. The Space Industry needs to allocate funds to a low key but effectively sustained campaign to awaken the average citizen's interest in space based solutions to Earthly problems. Political acceptance of the merit of significant space budget increases for industrial and environmental goals must be encouraged.

Effort should also be redirected to the hard and dirty work of Lunar mining. A joint one-off venture by two superpowers would be just about as useful as another Apollo project. A more multinational endeavour, such as Lunar Industrial development, has far more human emotional (political) attraction if the prospects are sold effectively by public advocates [13].

An Intelsat style of international corporation must be established to focus the competitive energies of the major industrial players. This would call for tenders to fulfil space industrialisation operations concepts that are technically rather than politically determined [14,15]. Operational goals that help cure the global environmental problems as well as generating new economic domains will be drivers rather than political prestige projects.

As with any historical analogy, there are points of weakness. In this case the resources offered by the Moon and the rest of the Solar System are ultimately essential to avoid a drastic limitation to the growth of mankind. Australia has never offered that sort of benefit.

References

1. Manning Clark, A Short History of Australia, The New American Library, Inc. 1969.
2. E.M. Jones and B.R. Finney, Historical Perspectives on the Moon Base, Cook and Australia, pp. 765-770, Lunar Bases and Space Activities of the 21st Century, W.W. Mendell (Ed), Lunar and Planetary Institute, Houston, 1985, ISBN 0-942862-02-3.
3. G. Blainey, The Tyranny of Distance: How Distance Shaped Australia's History, Sun Books 1966, ISBM 0725100192.
4. E.M. Jones, Economic Foundations of Permanent Pioneer Communities, p.128 of Abstracts from the Symposium on Lunar Bases and Space Activities of the 21st Century, Texas 1988.
5. C.M.H. Clark, Selected Documents in Australian History 1788 -1850, Angus & Robertson 1950, ISBN 0207941432.
6. A.R. Martin, Space Resources and the Limits of Growth, JBIS, 38, (243) 1985.
7. W.K. Hartmann, R. Miller and P. Lee, Out of the Cradle: Exploring the Frontiers Beyond Earth, Workman Publishing, New York, 1984, ISBN 0-89480-770-6.
8. W.F.J. Evans, A measurement of the altitude variation of greenhouse radiation from CFC-12, Nature 333, June 23, 1988.
9. A.H. Rosenfeld and D. Fafemeister, Energy-efficient Buildings, Scientific American, May 1988.
10. Krafft A. Ehricke, Lunar Industrialisation and Settlement - Birth of Polyglobal Civilisation, pp.827-855, Lunar Bases and Space Activities of the 21st Century Proceedings of 1984 Symposium.
11. Abstracts from the Symposium on Lunar Bases and Space Activities of the 21st Century, Texas 1988.
12. Various papers dealing with Helium 3 on the Moon, Lunar Bases 1988.
13. S.L. Adamson, Blueprint for Action: Establishing Political Support for Lunar Bases, p.1 of Abstracts from the Symposium on Lunar Bases and Space Activities of the 21st Century, Texas 1988.
14. C.C. Joyner and H.H. Schmitt, Extraterrestrial Law and Lunar Bases: General Legal Principles and a Particular Regime Proposal (Interlune), Lunar Bases 1984.
15. H.H. Koelle, Towards an International Lunar Base, IAA-87-673 presented at the IAF Congress, 1987.

CORRESPONDENCE

Justification for Space

Sir, Easter Island is a barren Pacific island that is famous for its great Stone Heads. But recent archaeological work indicates that originally this island, far from being barren, had the ecological balance of other Pacific islands with a plentiful supply of palm trees. The island was colonised by Polynesians probably about the 12th Century and it is suggested that over the succeeding centuries the palms were cut down in order to clear land for crop cultivation, to construct canoes and to assist in the erection of the giant Stone Heads. The population eventually increased beyond the capacity of the island to renew its resource of palm trees. Without the trees to replace worn or damaged canoes, the inhabitants were imprisoned on the island and the inevitable decline began.

It could be said that the Earth is an island in the vastness of space, that we are busily duplicating the Easter Island experiment on a global scale. Here then is my justification for going into space and for going now, within the next few decades.

When the global civilisation reaches the state in which the Earth is now, there are many conflicting requests for the money of any government, regardless of its political colour. There is a point of balance between the money which is available to sustain an industrially-based society, and that which is available for scientific endeavour. Briefly, any industrial nation uses more material than it can itself produce and inevitably produce more waste than it can handle this last problem can only be ignored in the short term by parking the problem on somebody else's doorstep. Eventually, however, options become limited and extremely expensive steps have to be taken, firstly to find and extract the minerals required by industry and secondly to clean up waste products. In the end, there is not enough money left for certain scientific activities perceived as non-vital - namely going into space. Civilisation then has no choice but to devote all its financial resources to the vital steps necessary to attempt to maintain itself this is only a short-term solution and doomed to failure. Civilisation will then have evoked the Easter Island factor - metaphorically speaking it will have condemned itself to a life on a island where all the trees have been cut down - where there are no resources left to build the canoes necessary to obtain materials from other islands to re-stock the barren land.

We are not quite yet at this point, but within a few decades we will be. Unless we go into space now, take what is perceived to be a selfish move in the face of so many competing calls for money, the we will go beyond the point where we can access the unlimited resources beyond the Earth.

Finally, it may now be necessary to add an additional factor to the Drake equation (the equation which can be used to determine whether intelligent life may exist elsewhere in the Universe). The present final factor is whether a technologically-advanced civilisation would explosively self-destruct.We must now add the Easter Island factor, ie., can a global civilisation make a move into space before it uses up its available resources, both mineral and financial.

SALLY LORD
Cranfield, Bedford, UK

THE INTERNATIONAL MAGAZINE OF SPACE AND ASTRONAUTICS

Spaceflight **has been published continuously for over 30 years and distributed world-wide.**

Spaceflight **provides expanded news coverage of international events for which it has been renowned since the dawn of the Space Age.**

lence • Europe in Space • Hermes • Hotol • Latest Space
• Space Stations • US Space Shuttles • Utilising Space
• Hotol • Latest Space News • Man in Space • Planetary
ttles • Utilising Space • Ariane • Asia in Space • Books
an in Space • Planetary Missions • Soviet Launchings
• Spaceplanes • Space Stations • US Space Shuttles • Utilising Space • Ariane • Asia in Space • Books • Correspondence • Europe in Space • Hermes • Hotol • Latest Space News • Man in Space • Planetary Missions • Soviet Launchings • Spaceplanes • Space Stations • US Space Shuttles • Utilising Space • Ariane • Asia in Space • Books • Correspondence • Europe in Space • Hermes • Hotol • Latest Space News • Man in Space • Planetary Missions • Soviet Launchings • Spaceplanes • Space Stations • US Space Shuttles • Utilising

APPLICATION FOR MEMBERSHIP OF THE BRITISH INTERPLANETARY SOCIETY

Send to: THE BRITISH INTERPLANETARY SOCIETY, 27/29 SOUTH LAMBETH ROAD, LONDON, SW8 1SZ, ENGLAND.

I apply for Membership which will include receipt of monthly issues of ***Spaceflight*** & one of the following as my FREE gift as follows:

Six large reproduction Star Maps reproduced from J. Bayer's classic *Uranometria,* published in 1603, valued at £15 ☐

or "High Road to the Moon" by Dr. R.C. Parkinson, 120pp, valued at £12 ☐

I enclose (please indicate as required):

(a) £25 (US$45) for a twelve month subscription from January-December 1989. ☐

(b) £36(US$65) for an eighteen month subscription from July 1989 to December 1990. ☐

NB Reduced rates are payable by those under 22 or over 65 years. For (a) the amount is £18 (US$33) and for (b) the amount is £27 (US$49).

Full Name (please PRINT surname first)	**Date of Birth**
Postal Address	
Organisational Affiliation & Address (if applicable)	**Job Title or Position**
Signature **Date:**	***Application constitutes acceptance of the Society's Constitutional Rules.***

Apollo Spirit Lives On

This month **Spaceflight** takes up the theme of 'The Future of Space' in recognition of the 20th Anniversary of the first manned lunar landing by Apollo 11 on July 21, 1969.

The events of the Apollo Program were spectacular. Man did indeed set foot on the Moon 'before the end of the decade'. The lunar surface was not a bed of quicksand. It could be traversed. Equipment worked, systems worked, the Program succeeded and then it was all over.

Much has since been written about the significance of Apollo when viewed in historical perspective. The absence of any follow-on programme has tended to down-rate it as a 'one off', or even as a 'dead end', without fairly recognizing the unique and irreplaceable role of the astronaut so consistently demonstrated.

With this special issue, we set out to show that the spirit of Apollo lives on as we take a look at space exploration's incredible past and enquire what of the future? Might some of the factors that motivate today's near-Earth manned activities, such as commercial interests or scientific progress, be relevant to more distant space?

Our contributions have some interesting ideas to put forward and in bringing these together **Spaceflight** salutes the courage and accomplishments of the first men on the Moon.

Society Honour For Apollo 11 Astronauts

In February 1970, the Society presented its gold medal to each of the three Apollo 11 astronauts. At a meeting attended by over 180 members and guests, the presentation was made to Dr. Thomas O. Paine, the Administrator of NASA, by the Society's President, Dr. W.R. Maxwell, who said:

"All the magnificent equipment associated with the flight of Apollo 11 would have been of little avail without the astronauts themselves. Neil Armstrong, Michael Collins and Edwin Aldrin proved themselves to be men of superb skill, training and courage who were able to ensure that the mission was a complete success, and the flight of Apollo 11 demonstrated very clearly the importance of men on missions of this kind."

During the following week, the astronauts received their medals from Dr. Paine and in a joint letter they expressed their warmest thanks to the Society for this generous recognition of the successful completion of the Apollo 11 mission, (**Spaceflight**, 1970, p. 191 and 354-355).

Apollo 11 Celebrations

Meetings will be held in the Society's Conference Room in June and July to commemorate the 20th Anniversary of the Apollo 11 lunar landing. They consist of a special series of four evening lectures on 21st and 28th June and 5th and 19th July and an anniversary dinner on 21st July. Speakers on the four lecture evenings will be TV space news reporters Reginald Turnill and Frank Miles, space photography specialist Douglas Arnold, Bob Parkinson, who authorised the society's book 'High Road to the Moon', and Keith Wright, who was personally involved in the Apollo Lunar Surface Experiment Package program.

These lectures are highly recommended as an opportunity for members to recapture the spirit and excitement of Apollo and the beginning of lunar exploration. All lectures start at 7.00 p.m. and last for approximately 1 hour. Admission is by ticket and members should apply to the Society by letter in good time. This is particularly important for anyone who must travel some distance to attend. Attendance is restricted to Society members but, subject to places being available, each member may also apply for a ticket for a guest. Further details including those of the Anniversary Dinner appear in Society Meetings Diary.

Rob Staehle holds the plaque commemorating his award of Asteroid (3875) Staehle by Eleanor Helin, the discoverer who stands on his left.
Ron Helin

Asteroid Recognition for Robert Staehle

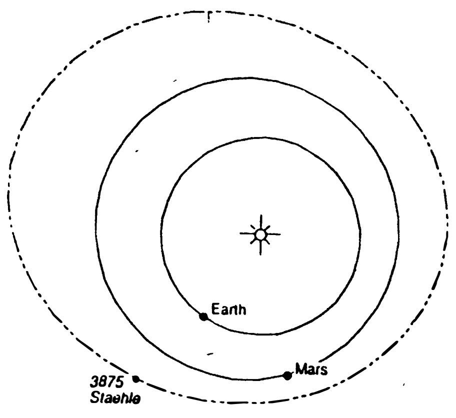
We extend our hearty congratulations to Robert L. Staehle, a long-standing Fellow of the Society, on receiving the honour of having Asteroid 3875 named 'Staehle' in recognition of his work. Rob Staehle is an astronautical engineer, a member of the technical staff of the Jet Propulsion Laboratory and president and founder of the World Space Foundation of South Pasadena, California, which promotes research into the exploration of space. The asteroid was discovered by Eleanor Helin whose work was recently featured in **Spaceflight** (January 1989, p.12). In naming the asteroid the discoverer wished to acknowledge the role of Rob Staehle and the Foundation in recognizing the importance of near-Earth asteroids and sponsoring some

of the research carried out by the Palomar Planet-Crossing Asteroid Survey (PCAS).

A report on PCAS appears on p. 247.

Rob Staehle joins a number of BIS Fellows previously honoured by the naming of asteroids. These include Asteroid 2602 (Moore), awarded to astronomer Patrick Moore by its discoverer, Edward Bowell, in 1982. South Australian astronomer W.A. Bradfield was honoured by having Asteroid 3430 named after him in 1987 and, last year, Asteroid 3817 Len Carter was awarded to the Society's Executive Secretary.

Rob Staehle maintains a close interest in the Society's activities along with his many other commitments. He was author of the article entitled 'An Expedition to Mars' that appeared in ***Spaceflight***, January 1983 and of a technical paper on the same subject published in the July 1982 'Space Technology' issue of **JBIS**.



Asteroid 3875 Staehle was observed on several earlier occasions (in 1935, 1952, 1978, 1979 and 1985) and given provisional designations before the orbit was confirmed in a one-month arc of measurements in 1988 which tied together the earlier observations of apparently different asteroids. It travels from just outside the orbit of Mars to the middle of the main-belt region. At magnitude 13.1 it probably has dimensions of 10 to 15km. Its orbital parameters are a=2.225, e=0.192, i=6.°20 and P=3.32 years.

Bequests to the Society

Valuable support comes to the Society from time to time by way of bequests which enable it to advance further its programme of development and to fulfil its role in promoting space technology and astronautics.

The attention of Members is drawn to this avenue of support and the appropriate steps to take. Suitable wording that could be incorporated in a Will is:

"I give, devise, and bequeath to the British Interplanetary Society Limited of 27/29 South Lambeth Road, London, SW8 1SZ, the sum of £ .... (followed by the amount in words) free of all duties."

If the wish is to bequeath something other than a simple sum, it may be better to have the Will prepared professionally. Copies of "Notes on Wills and Legacies", which provide general guidance, are available on request from the Executive Society.

The Society has many developments that are either in hand or planned for its future programme. These involve its library and members' facilities and services of various kinds. There is a continuing need for substantial resources to implement these plans and enable the Society to fulfil an increasingly important role.

Joint International Conferences

The following conferences are being cosponsored by the Society:

TOWARDS THE INTERNATIONAL SPACE STATION AND COLUMBUS

October 4-6, 1989

Hosted by the DGLR Hamburg, W. Germany.

40TH IAF CONGRESS

October 7-13, 1989

The 40th Congress of the International Astronautical Federation will be held at Beijing, China. The theme will be 'The Next Forty Years in Space'.

Members of the Society wishing to present papers may obtain procedural details for the submission of abstracts from: The International Astronautical Federation, 3-5 Rue Mario-Nikis, 75015 Paris, France.

Further details of the above meetings can be obtained from the Executive Secretary. Please enclose a SAE.

A NOTE FOR YOUR DIARY

Members may like to note the following forthcoming major events:

1. **SPACE '90** to be held on September 28-30, 1990 at the White Rock Theatre, Hastings. The meeting has the theme "Steps to Space" and will include a Reception and Dinner.

2. For the International Space Year (ISY), the Society plans to hold its **SPACE '92** meeting on October 2-4, 1992. The venue will again be Hastings and the theme will be "Space: Springboards to Success".

3. An extensive range of European activities for the ISY is to be expected. The European ISY Association, (EUR-ISY 1992) has been set up for this purpose. A general theme to be highlighted is 'Mission Earth' which will embrace work on surveillance and monitoring of the environment, extending the use of satellite remote sensing and improving weather forecasting.

4. In 1993, the Society's Diamond Jubilee year, a special **SPACE '93** will be held in London.

Society's 60th Anniversary

A proposal has been made to mount small displays or exhibits in the Library during the Society's 60th Anniversary year. The date of the anniversary falls in October 1993. Members interested in supporting this with suitable artifacts or in other ways are invited to send details to the Executive Secretary indicating the general nature of the artifacts concerned and the period of time for which items may be available.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. Membership cards must be produced.

Special Event

To commemorate the 20th Anniversary of the Historic Apollo 11 lunar landing the British Interplanetary Society has organised a series of lectures to celebrate Man's first steps on the Moon, concluding with a dinner at the Society's Headquarters.

Details of the meetings follow:

21 June 7.00—8.30pm

'I WAS THERE'

Reg Turnill and Frank Miles recall the atmosphere and events of twenty years ago. Reg Turnill was reporting from the US during Apollo 11, while Frank Miles was a member of ITN's 'Space Unit' covering the mission from London.

28 June 7.00-8.30pm

LEGACY OF APOLLO

A personal selection by Douglas Arnold of striking photographs - some well known, others little seen - recording Man's first steps on the Moon.

5 July 7.00-8.30pm

GOING TO THE MOON

Dr. R.C. Parkinson considers the BIS contribution to manned lunar concepts. Beginning with its design for a Moonship in 1939, the BIS continued thinking about ways of reaching the Moon throughout the 1950s. This talk illustrates some of the concepts, which culminated in the US Apollo programme.

19 July 7.00-8.30pm

INSTRUMENTATION ON THE MOON

A lecture by Keith Wright. Each of the Apollo Lunar landing missions carried an "Apollo Lunar Surface Experiment Package" (ALSEP) which would be set up by the astronauts in order to transmit data about the lunar environment after the astronauts return to Earth. The talk will provide an overview of the Package design, the experiments carried and deployed, the experimental results obtained, and will include some personal recollections of the Apollo pre-launch activities at Kennedy Space Center.

21 July 6.30 for 7.00pm

APOLLO 11 ANNIVERSARY DINNER

The Society will conclude its Apollo 11 celebrations with a four course meal on the anniversary of Man's first steps on the Moon. Guests of honour will include Patrick Moore, Keith Wright of the European Space Agency and David Wilkins of the European Space Operations Centre.

Admission to lectures is free . Apollo 11 Anniversary Dinner tickets are £28. All events will be held in the Society's Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ. Meetings are restricted to Society members. Subject to space being available members may also apply for a ticket for one guest. Please apply to the Executive Secretary, enclosing a SAE.

Lectures

4 October 1989 7.00-8.30pm

BEHIND THE SCENES WITH MAGELLAN, VOYAGER AND GALILEO

Interplanetary exploration is showing a strong resurgence in 1989 with three major events leading the way: The Magellan launch to Venus, Voyager 2's flyby of Neptune and the Galileo launch to Jupiter. Bill McLaughlin, who is involved with all three projects at the Jet Propulsion Laboratory, will outline the missions and provide insights into the actual progress and results to date of these three endeavours.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

1 November 1989 7.00-8.30pm

CETI OVERVIEW - AN UPDATE

A. T. Lawton

Recent observations have revealed that at least two nearby stars have "Brown Dwarf" mini-stars as companions. Such studies will undoubtedly lead to the discovery of Brown Dwarfs as individual single stars, so that Proxima Centauri is not our nearest extra-solar body.

The impact of these new discoveries on the more conventional ideas of CETI will be discussed.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Technical Symposia

13 September 1989 10.00am-4.30pm

SPACE STATIONS AND BEYOND

The Second BIS Space Infrastructure Symposium

Following the success of the first infrastructure symposium in November 1988, the British Interplanetary Society is organising a second with the theme of "Space Stations and Beyond".

This series of symposia is the only current forum for discussion of major infrastructure topics such as:

Launch Systems - Aerospace Planes - Space Stations - Inter Orbit Transportation - Lunar Bases - Manned Planetary Exploration

The theme has been chosen because of the studies underway both in America and Europe to plan the next major programmes to be undertaken after the Freedom/Columbus space station is established. Options under study include lunar bases, manned Mars missions and an autonomous European space station.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Exectutive Secretary.

Registration
Forms are available from the Executive Secretary. Please enclose a SAE.

27 September 1989 10.00am-4.30pm

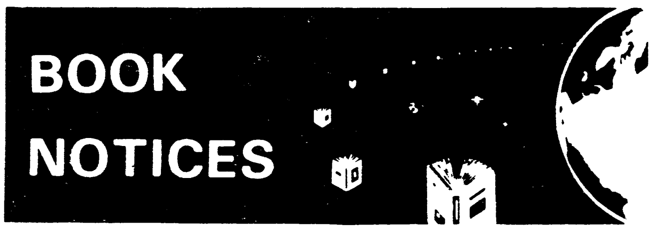
BRITISH SOLID PROPELLANT ROCKETRY

The emphasis will be on British post-war solid propellants and the development of associated rocket motor and launch vehicles.

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary. Please enclose a SAE.



Space Technology International

Ed: R. Turnill, Cornhill Publications Ltd., 4-7 Nottingham Court, Short's Gardens, London, WC2H 9AY, 1989, 284pp, £19.95.

This volume is a compendium of articles by leading contributors to major space topics such as the Space Shuttle, Space Station technology, computer technology, satellite technology, materials etc.

It is intended to be the first of annual volumes setting out the state-of-the-art in all major space areas. The presentation and illustrations are most attractive.

The 1988 expenditure on space will undoubtedly double over the next few years as the Shuttle resumes regular flights and Ariane 4 and a further generation of unmanned launchers from many countries place increasing numbers of commercial and scientific satellites in orbit. The result could be that the annual satellite launch total from the West will approach the 100 or so per year from the USSR. At the same time Europe is building up an in-orbit infrastructure for Ariane 5, Columbus and Hermes while other countries prepare their own elements for the Freedom International Space Station.

All this promises considerable challenge and offers considerable opportunities for advanced remote sensing, Earth resources and meteorological spacecraft, experimental orbiting laboratories and facilities for major materials processing activities.

This stimulation to technical development will be repeated many times before the turn of the century and confer ever-increasing benefits on those countries which undertake a major role.

Members of the Society ordering this volume direct from the Publisher may claim a 40% discount on the published price. Proof of membership must be supplied, or alternatively the order should be accompanied by a copy of this review.

The Planet Neptune

P Moore, John Wiley & Sons Ltd., Baffins Lane, Chichester, West Sussex, PO19 1UD, England, 1988. 144pp, £19.95.

Neptune will soon be in the news when Voyager 2 achieves its long-awaited fly-by of the planet in August, 1989. By way of an opener to this exciting event, this book provides an account of the discovery of this far-distant planet, its satellites and recent research into its atmosphere and "rings".

The result is a concise summary of our present knowledge of the planet and its system, supported by a detailed and extremely interesting bibliography.

Atlas of Uranus

G. Hunt & P. Moore, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1989, 96pp, £15.00.

Uranus was unknown to the ancient astronomers Its discovery had to await the development of the telescope and the observations of William Herschel in 1781. It was a distant world about which little was known until the fly-by of the Voyager 2 spacecraft in January 1986 returned astonishing new information about the planet, its rings, satellites and environment.

The book begins with an historical account of the discovery of Uranus,

including pre-discovery observations, and continues with a description of early results from Voyagers 1 and 2.

As Voyager 2 approached Uranus, the most distant planet in the solar system yet to be observed by a spacecraft, the images sent back became more and more dramatic until, eventually, at its closest approach, fabulous pictures were returned of its satellites, Oberon, Titania, Umbriel, Ariel and Miranda.

One of the very first revelations came on 30th December 1985, almost a month before the closest approach, when a new satellite was discovered, now named Puck, about 170km across. A second (Portia) was found on 3rd January and others followed until the grand total of known satellites reached 15. All the new bodies were small, with low albedoes.

The book includes the first detailed maps of the major satellites and the positions and names of their craters, while photographs depict the weather systems and cloud features of Uranus itself.

Asteroids: Their Nature and Utilization

C.T. Kowal, John Wiley & Sons Ltd., Baffins Lane, Chichester, West Sussex, PO19 1UD, England, 1988, 152 pp, £26.50.

This book presents an overview of present knowledge of the origin and composition of asteroids, their relationships to meteorites and interaction with the planets. It follows increasing interest in asteroid research which has been reflected in proposals for space missions which include the near and far scrutiny of a number of asteroids as prime objectives.

The author, who discovered Chiron in 1977 (an asteroid far beyond the main belt), discusses the significance of these interesting bodies. After a brief survey of the discovery history of main belt and asteroid families, observational techniques for ascertaining sizes, surface compositions and techniques are described as well as theories of formation and evolution.

The book includes an interesting appendix which lists the orbital parameters of numbered asteroids from 1 to 3445.

The job of cataloguing and keeping track of all these bodies was originally undertaken at the Minor Planet Centre at the University of Cincinnati, founded in 1947 by the late Dr. Paul Herget, a former Fellow of the Society. Dr. Herget pioneered the use of modern data processing systems to handle the vast numbers of observations needed to compute orbits and ephemerides. This work has, for many years since, been under the direction of Dr. Brian G. Marsden and the Centre is now in Cambridge, Massachussetts.

Some of the names given to these objects will shatter all illusions. No.3129 (Bonestell), a Fellow of the Society now deceased, jostles with 2309 (Mr. Spock) and 1537 (Transylvania). There are numerous minor gods, goddesses and nymphs, distinguished astronomers and other worthies, quite a few girl friends and at least one pet dog.

An alphabetical directory of names of asteroids containing details of discovery, discoverer and the origins of the names allotted, insofar as these can now be ascertained, would probably command a fascination and interest of its own.

Pathways to the Universe

F. Graham-Smith & B. Lovell, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, England, 1988, 239pp, £15.00.

This is an illustrated introduction to astronomy which starts at the level of common experience and develops the subject to the frontiers of modern research. In straightforward language, the authors explain how one might become an astronomer and how to find one's way around the sky, using simple binoculars and telescopes, or even the naked eye.

Each chapter leads to present levels of research with modern optical, radio, X-ray and infrared astronomy. This occurs in discussions of planets, comets, meteors, the Sun etc. The book concludes with an account of present-day thoughts on cosmology and the origins of life.

The Great Wall of China From Space

The Exploration of a Myth

Although not included as one of the seven wonders of the ancient world, the fame of the Great Wall of China is firmly established in public consciousness the world over. Its reputed, monumental *length* is the essence of its claim to public regard and for some decades writers have sought to emphasise the Wall's characteristics by making claims about its visibility from great distances - more specifically from (a) the Moon, (b) Mars and (c) "space" - the last an admittedly vague term but one which may be interpreted to mean Earth orbit.

By H.J.P. Arnold
Space Frontiers Limited

The earliest of these claims pre-date the space era. Thus the earliest reference so far found to the Wall's supposed visibility from the Moon was made in 1909 by the American traveller William Edgar Geil [1]. In 1923 Adam Warwick began an article on the Wall in The National Geographic Magazine thus: "According to astronomers, the only work of man's hands which would be visible to the human eye from the Moon is the Great Wall of China." [2].

In a prestigious volume devoted to the Wall published in the early 1980s, a foreword by Jacques Gernet included the admittedly cautious statement: "Proclaimed as the only man-made structure that can be seen from the Moon, the Great Wall of China is a subject of astonishment to westerners."[3]. Perhaps typically, the publishers interpreted this freely and stated categorically on the dust jacket that the Wall was "... the only man-made structure to be visible from the Moon...." Dick Wilson, one of the contributors to the volume, had no doubts at all and posed the rhetorical question: "Had not American astronauts flown through space to prove empirically what everyone below had been saying, namely that the Great Wall of China is the only man made monument visible from the Moon?" [4].

With such claims being published in "serious" books about the Great Wall, it is not surprising that advertisers saw an obvious opportunity in the market place for the use of such a dramatic (and apparently authenticated) claim. As an example, a shipping line in 1983 advertised a cruise along the Chinese Coast with the headline "You can see the Great Wall of China from the Moon. Or see the Moon from the Great Wall", followed by text commencing "Fantastic though it seems the Great Wall of China is actually visible from the

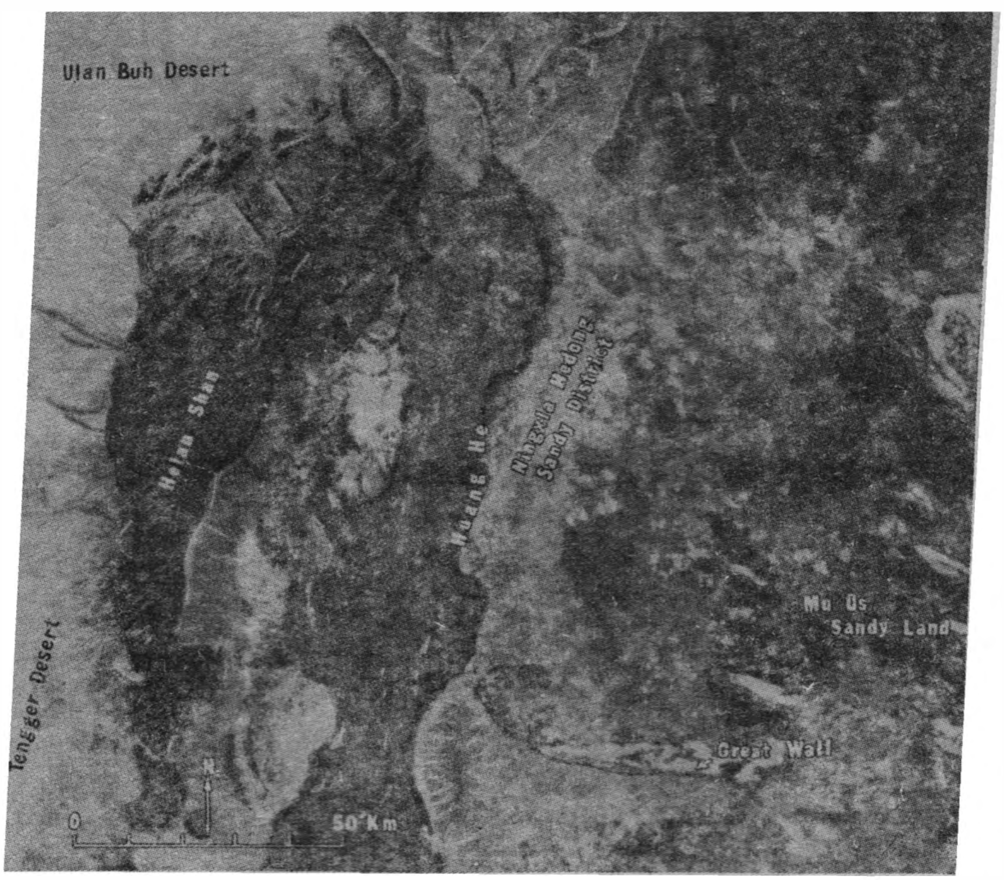


Fig. 1. In this Landsat frame, the location of the Great Wall is revealed by sand heaped up on its northern side but the Wall itself is not visible - see text. *Alta Walker, USGS*

Moon"[5].

Claims about the visibility of the Great Wall from Mars are not as old as those concerning the Moon. The first reference so far located dates from 1923 when in another book devoted to what he called *The World's Eighth Wonder*, L.N. Haynes stated: "Astronomers tell us that of all the works of man's creation the Great Wall is the only one that would be visible to the human eye from Mars."[6]. The date of publication of this book and the phrasing of the statement is such that it is tempting to conclude that Haynes was misquoting the claim made by Warwick in his National Geographic article.

Whatever the origin, Haynes began another theme about the Wall that was handed down the years. Joseph Needham in his enormously detailed, multi-volume work *Science and Civilisation in China* wrote: "Stretching from Chinese Turkestan to the Pacific in a line of well over two thousand miles (nearly a tenth of the Earth's circumference), the Wall has been considered the only work of man which could be picked out by Martian astronomers."[7]. Early in 1988, another shipping line publicised visits to China under the headlines: "It began 400 years before Christ. It is visible from Mars. You can touch it this Spring" going on to begin the text with "Only one man-made landmark can be seen from outer space (sic) without a telescope: The Great Wall ....."[8]. Significantly, this specific reference to seeing the Great Wall with the *unaided* human eye is something that seems to be implied in virtually all the claims. There was no response by the advertisers to a letter from this author requesting a source for the claim.

Finally, there is the more general claim made about seeing the Great Wall "from space". One of the questions dealt with by astronaut Sally Ride - the first American woman to go into orbit - in a magazine article published in the spring of 1986 concerned whether the Great Wall of China was the only man-made object visible from space [9]. Around Christmas 1987, the popular BBC TV programme Blue Peter set its young viewers a puzzle with the cautious words "Some people say it is the only man-made creation that can be seen from space" - to which the intended answer was the Great Wall.

What then is the accuracy of these claims that the Wall is visible from (a) the Moon, (b) Mars and (c) "space" - interpreted to mean Earth orbit - indeed, that it is the only work of mankind to be so visible?

Is There a "Great Wall of China"?

It is vital before proceeding further to define what is meant by the "Great Wall of China". The term implies a coherency or the existence of a single, readily identifiable entity which is in fact difficult to establish. The popular conception is of a single, monolithic fortification the first parts of which were built during the Ch'in dynasty at the end of the third century BC with modifications and extensions taking place over ensuing centuries until major work was undertaken during the Ming period from 1368-1644. Estimates of the length vary but the most widely quoted figures are about 3500 kms for the "main line" of the wall extending from Shanhaiguan on the coast in the east to Yumenguan in the west - with over 2800 kms of loops and extensions in addition [10]. Together with this concept of an enormous and continuous fortification is the impression - gained by westerners visiting a limited part of the wall north of Beijing (which was built by the Ming and is atypical in the excellence of its condition) - of a substantial structure built of stone or rock as much as 10m wide in places and extending to a similar height above the ground, higher in the case of surviving watchtowers.

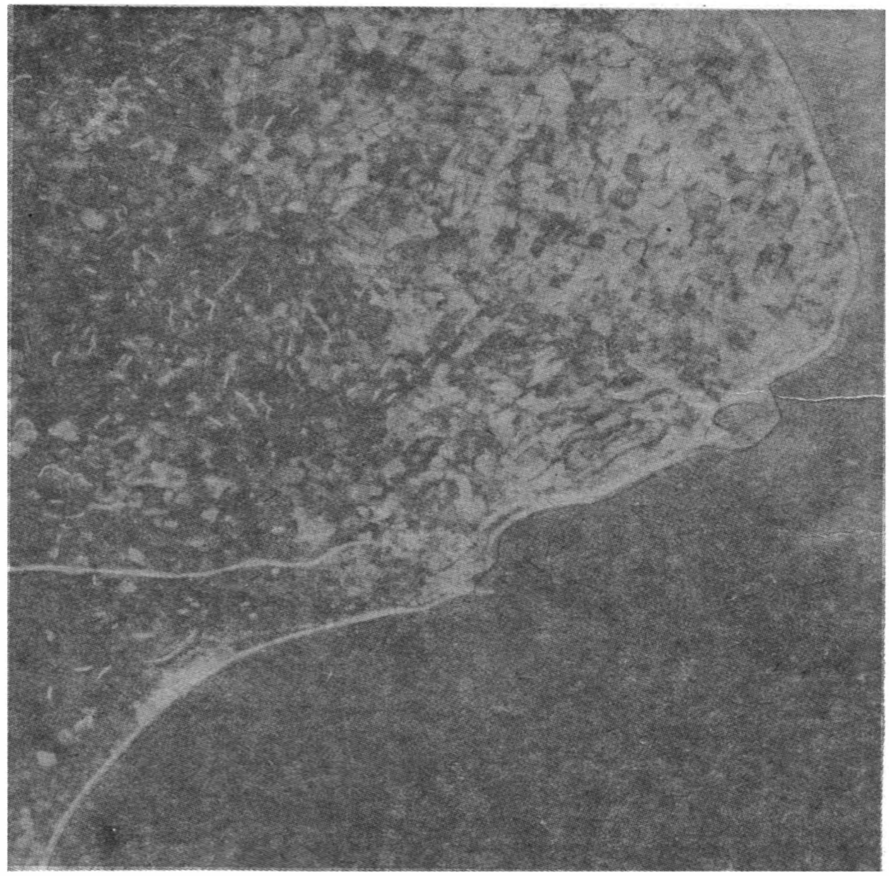


Fig. 2. Although a difficult target with few reported, confirmed sightings the Great Wall is NOT the only man-made artifact visible from space. Large linear features (e.g. airport runways and major roads) which contrast strongly with their background are not infrequently seen under optimum conditions. This picture is a black and white copy from a colour original exposed during the 41-G mission of the shuttle Challenger in October 1984. The area shown is part of the county of Kent in SE England: the M20 motorway running west from the town of Folkestone is clearly revealed - as is the wake of ships in the English channel. *NASA*

The reality is very different. At no time was a decision taken in Chinese history to build a "Great Wall" - and this is true even of major building activity during the Ming period. Innumerable walls and ramparts were built (and decayed) over the long centuries in a haphazard manner which owed little if anything to a coherent plan as rulers came and went and conditions changed. While the omission may be remedied in the future, the fact is that "the Wall" has never been surveyed. Hence estimates of the length, the precise location and the condition are very much conjecture. Arthur Waldron, a contemporary American scholar who is soon to publish a book on the Great Wall, states that all too often the route shown in maps and atlases follows "convention" and that much of what is often asserted about it is "pure myth" - a myth, moreover, that has owed a great deal to Western romantic attitudes [11].

Given the absence of reliable surveys, it is fortunate for the purposes of this analysis that in recent years dedicated and devoted athletes from Britain have on at least two occasions run along large stretches of the Wall to raise funds for charity. One of these was Edward Ley-Wilson who, together with a colleague David Wightman, early in 1988 covered over 1900 kms of the route between the Jiayuguan Pass and Shanhaiguan in 47 days at a daily average of 41 kms. Without doubt this was a far more direct experience of the condition of large sections of the Wall than that available to any other interested party, official or unofficial, whether Chinese or foreign. Mr Ley-Wilson responded to the author's request to evaluate the condition of the Wall as

Fig. 3. The Great Wall varies enormously in its condition and therefore in its potential visibility from low Earth orbit. In the Wuwei area - with a British long-distance runner included for scale - the Wall is generally intact. *Edward Ley-Wilson*

follows:[12]

> Wall clearly discernible and only moderately eroded or broken along its length ...... 22% of the 1900 kms run.
>
> Wall usually discernible but frequently broken/eroded 41%
>
> Wall scarcely discernible, almost totally eroded and running by reference to maps 37%

In parts (in the desert east of Yinchuan, for example) he described the wall as being "massive - 4.5 to 6m high with watchtowers double that". Elsewhere, the wall disappeared totally and the two Britons "ran on endless dirt tracks... just (following)... the compass bearing eastwards." [13]. American geologist Alta Walker has conducted research at first hand in Chinese deserts and described the Wall in the Jiayuguan area of the west as being about "60cm tall and 30cm thick" in places and discontinuous [14]. It seems fair to generalise, therefore, that - to say the very least - the "Great Wall", for large sections of its length, is a discontinuous and decayed structure which is difficult to discern from an aircraft let alone from Earth orbit or deep space.

The Great Wall from the Moon

Fortunately we have the direct evidence of US astronauts who orbited or walked on the Moon during Project Apollo from 1968 to 1972:

> "It is not visible from lunar distance." Neil Armstrong, commander of Apollo 11 [15].
>
> "You have a hard time even seeing continents." Edwin "Buzz" Aldrin, Apollo 11 lunar module pilot - who never saw the Wall and stated he did not think any human could [16]
>
> "(The idea that you can) spot the Great Wall.... with the naked eye from the vicinity of the Moon is absurd!" James Lovell, Apollo 8 and commander of Apollo 13 [17].
>
> "The Great Wall of China is most definitely not visible to the unaided human eye at lunar distances... From the Moon the Earth appears less that the size of a golf ball held at arm's length: the blue-green of the oceans and the bright white of cloud systems predominate and frequently it is difficult to distinguish continents let along a discrete man-made object like the Great Wall." Alan Bean, Apollo 12 lunar module pilot [18].
>
> "(The Great Wall is not visible.) Only desert areas and desert or non-green coast lines are clearly defined to the eye from the Moon." Harrison Schmitt, lunar module pilot of Apollo 17 [19].

Now, while the eyes of different individuals vary in their ability to resolve detail, and extraneous factors (such as contrast, brightness, colour, texture of the object and its surroundings) play an important part, research has established levels of best resolution for different situations The eye is extremely efficient at resolving linear features. Here it yields its best performance and unaided can resolve or "localise" objects with an angular size of a few seconds of arc. With point objects the performance is less good at perhaps one minute of arc [20]. Since the distance between the Earth and Moon is known (384,392 kms) and the maximum width of the Great Wall is known (say 8-10m) we can easily calculate what its angular size at the lunar distance would be. This works out at some 4/1000 (0.004) of an arc second - which is equivalent to being able to see the width of an ice-lolly stick in Glasgow from Birmingham! [21]. Even if generous allowance is made for unknown or unexpected factors, the discrepancy between a few seconds of arc and 0.004 of an arc second is such that it may safely be concluded that it is physically impossible for the unaided human eye to distinguish the Great Wall of China at the lunar distance - a situation verified in practical terms by astronaut testimony.

If all goes well, in early 1990 NASA will launch the Hubble Space Telescope into Earth orbit. The HST carries two high resolution camera systems (ESA's *Faint Object Camera* and the Jet Propulsion Laboratory's *Wide Field and Planetary Camera*) but even with these it has been estimated that the best resolution achieved of the lunar surface will be 100m [22]. While once again we may choose to assume that a linear feature such as the Great Wall might be resolved better than theoretical predictions, this means that even the Hubble Space Telescope would not be able to resolve the Wall if the vehicle were placed in a lunar orbit.

The Great Wall from Mars

Astronauts have not walked on Mars yet so there is no direct testimony on what can be seen on the Earth's surface from that distance. However, amateur astronomers with even large telescopes who have striven to make out gross detail on Mars will readily appreciate the enormity

of the claim made for the Great Wall.

The HST emphasises the difficult of the task since the *Faint Object Camera* at its highest possible theoretical resolution would only be able to discern objects measuring somewhat over 7 km across on the surface of Mars [23]. If the telescope were in orbit around Mars and directed toward Earth, therefore, the Great Wall - alas - would not be visible.

The Great Wall from Earth Orbit

In terms of space flight, distinguishing the Great Wall from low Earth orbit - say from an altitude of 320 kms - is at the other extreme. Even in this case, however, there have been relatively few sightings reported. Skylab 4 astronaut William Pogue wrote in a book featuring questions and answers about spaceflight: "Yes (we could see the Great Wall of China)... but we had to use binoculars. It wasn't visible to the unaided eye, The first time I thought I had seen it, I was in error. It was the Grand Canal near Peking. Later, I was able to identify the faint line of the wall, which zigzags in a peculiar pattern across hundreds of miles." [24]. Alan Bean, commander of Skylab 3, however, stated that he was not able to distinguish the Wall from the space station's altitude of over 430 kms and pointedly referred to poor visibility over large areas of the Chinese mainland - perhaps resulting from extensive wood burning [25].

A more recent, specific elaboration of the problems is available. Alta Walker of the US Geological Survey supplied background notes and maps when requesting Karl Henize (a mission specialist aboard the 51F or Spacelab 2 shuttle mission in July of 1985) to look for the Great Wall from orbit. Henize commented after the mission:

> "I (carried) some of the maps you sent with me into orbit and had a plan to look for the Wall where it crosses the western leg of the big U-turn in the Yellow River.
>
> "Unfortunately northern China was almost continuously cloud covered during the 51F mission. However, on one occasion I came across north central China in reasonably clear weather. I was able to determine I was in the vicinity of the U-turn by the latitude and longitude given on the portable onboard computer. But when I searched for the U-turn I felt hopelessly lost - river valleys, in general (the Nile being a conspicuous exception), do not stand out when viewed from 200 miles up. Thus I was unable to make any valid observations inasmuch as I had no idea where to look. and as we skimmed across the region, no conspicuous linear features caught my eye.
>
> "Unless large scale water/land interfaces (lakes, seas or oceans) are present, it is difficult to locate landmarks on the surface of the Earth. There is little time for map reading - from the time an approaching area is 45° from the nadir (at which time one can begin to make out a fair amount of detail) until it is slipping under the spacecraft hull is 40 seconds at most."[26].

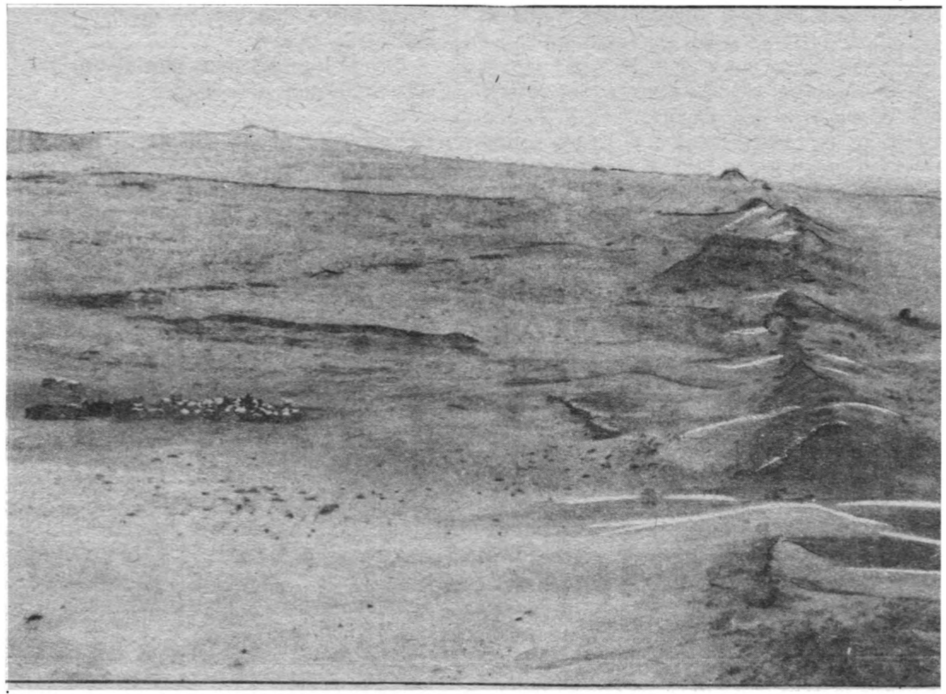


Fig. 4. Between Yinchuan and Dingbian the wall is little more than a slightly raised mound. In both areas shown in Figs. 3 and 4 it would be invisible from orbit to the unaided human eye. *Edward Ley-Wilson*

Sally Ride has also referred to the speed factor in shuttle missions: "In orbit, racing along at five miles per second, the space shuttle circles the Earth once every 90 minutes. I found that at this speed, unless I kept my nose pressed to the window, it was almost impossible to keep track of where we were at any given moment - the world below simply changes too fast. If I turned my concentration away for too long, even just to change film in a camera, I could miss an entire land mass. It's embarrassing to float up to a window, glance outside, and then have to ask a crewmate, "What continent is this?" [27].

In these circumstances familiarity with an area is very important. Gemini and Apollo veteran James Lovell has written: "Seeing man-made objects from space depends on knowing the object (whose details are locked in memory) and knowing exactly where to look. For example, I had no difficulty finding the El Paso airport during my Gemini flight(s) because I know its relationship with the surrounding mountains and had flown over it with aircraft many times. But I could never find the airport at Kinshasa, Zaire even though it was the same size and I knew approximately where to look." [28]. A point that has been well made, therefore, is that confirmed observations of the Great Wall will be more likely when Chinese astronauts (used to flying over parts of their homeland containing the Wall) go into orbit [29].

A few other claims to have seen the Great Wall from orbit have been made but frankly in the absence of detailed examination all must be regarded with a little caution [30]. Richard W. Underwood, a veteran photographic specialist and photo-interpreter at NASA's Johnson Space Centre until his recent retirement, is emphatic: "The Great Wall is small, old, made of native stone dulled by age and never maintained. It blends in beautifully and can't be seen from Earth orbit. One can identify the *contrast* near Peking, where a short portion of it is cleared, maintained and refurbished for the tourists. If you have an accurate map and a photo, you can determine where it is you *think* you see it. But if just handed the photo and told to delineate the thing you would fail totally. I traced some of it on a photo once in an area 600 or so miles west of Peking... *But I might have traced a road parallel to it in a flat area of sand."* [31].

This Underwood comment principally concerns the attempt to locate the Great Wall in photographs with no time constraints. The extreme difficulty for the unaided human eye to locate it at orbital speed is underlined by the theoretical calculation that from an altitude of 250 kms under best conditions the unaided eye should be able to resolve an object about 50m across - that is, about five times greater than the maximum width of the Wall [32].

In fact, this maximum width is such that it is either below or on the limit of the resolution capabilities of remote sensing satellites to which currently we have open access. (The thematic mapper aboard US Landsats has a best possible resolution of 30m while the French SPOT satellite can get to 10m in panchromatic mode.)

To date the only space image found to show a feature associated with the Great Wall (but not the Wall itself) is a Landsat multispectral scanner frame exposed over Western China on October 9 1979. (Frame E 30583-02521 - Figure 1). In the southern Ordos Plain, part of the Great Wall separates the sands of the Mu Us Shadi on the north from the alluvium of the hills and plains south of the desert. It is visible because sand is prevented from blowing over the wall and hence piles up on the north side. The result, as seen in the Landsat image, is an abrupt linear feature representing the edge of the piled up sand. *But we are not seeing the Wall itself* [33].

Strongly contrasting linear features such as large bridges and airports are relatively easily seen (fig. 2), as are other details in some urban areas. The unmistakable circular patterns of centre pivot irrigation schemes in the dry south west of the USA or a few areas of the Middle East are another artifact of man which can be seen from Earth orbit. Then there are enormous areas of lights at night....

The claim made for the uniqueness of the Wall as seen from Earth orbit is the same as that made in the case of the Moon and Mars - that it is the only man-made object that can be seen. *This is manifestly untrue.*

On all counts, then, the claims fail. Why were they ever made?

Background to the Claims

It is possible to consider the claims against the background of the Schiaparelli reports of seeing "canali" (or channels) on Mars - dating from 1877 onwards - and the extensive elaboration of the idea some years later by Percival Lowell who proposed them to be the creation of an intelligent civilisation. Shiaparelli talked of the canali being 120 kms wide and (this is very relevant in the context of the Great Wall) with a length of 4800 kms. Lowell was propounding his theories about the artificiality of the canaii in a series of books published between 1903 and 1909 - and it may not be pure chance that the first reference to the visibility of the Great Wall (though admittedly from the Moon) appeared in Geil's book published in the US in 1909 [34].

The earliest reference to the Wall's claimed visibility from Mars did not appear until 1923 and it has already been suggested that this may have resulted from an error. However, the debate about the existence or otherwise of canali and of life on Mars continued after Lowell's death in 1916.

Somebody writing a popular (or indeed learned) work on the Great Wall would understandably seek to employ a dramatic and colourful means of emphasising its enormous proportions. And what better way of doing so than to claim that it could be seen from a great distance - from the Moon or Mars, with all the attendant romance? In the pre-space era there would be little hard evidence to suggest otherwise, particularly if the writer were aware of the debate over Martian canali.

Whatever we may wish to think and hope about the Great Wall, and despite its undoubted and major role in the western conception of Chinese history, the simple fact is - **it cannot be seen from the Moon, it cannot be seen from Mars and (while only to be seen with great difficulty because of its structure and condition) it is not the only man-made object that can be seen from Earth orbit.**

If they have any regard for accuracy and - dare one say? - the truth, writers and advertisers must seek some other way to emphasise the grandeur of the Great Wall.

Acknowledgements

I am indebted to Dr. Alta S. Walker, Branch of Geophysics of the US Geological Survey, for providing information on the theme of this paper and for valuable exchanges of view. I also greatly valued the scholarly guidance of Professor Arthur Waldron of the Department of History at Pnnceton University in giving me an introduction to the history of the Great Wall.

Former Apollo astronauts Neil Armstrong, James Lovell and Harrison Schmitt responded to my letters of enquiry and I particularly appreciated a more extensive briefing from Alan Bean. Other trans-Atlantic assistance came from Frederick J. Doyle, Scientific Advisor for Cartography, USGS; Lee D. Saegesser of NASA HQ; Dr Farouk El-Baz, Director of the Centre for Remote Sensing at Boston University; Ray Villard of the Space Telescope Science Institute; and - on yet another occasion - from my good friend Dick Underwood, until recently of the Johnson Space Center, Houston.

Closer to home I received help from Professor John Marshall and Dr. F. W. Fitzke of the Institute of Ophthalmology at the University of London; Dr. Ian Dowman of the Dept of Photogrammetry & Surveying at University College, London; Dr. David Hughes of the Department of Physics at the University of Sheffield; Dr. Frances Wood of the Chinese Section of the British Library; from C.B.F. Walker of the British Museum and Mrs Jessica Rawson, Keeper of Oriental Antiquities at the Museum; Sir Claude Moser and A.F. (Pat) Thompson of Wadham College, Oxford; Brian Millo (who was kind enough to check my mathematical calculations); and Peter Foley of the British Astronomical Association.

Finally - as somebody who had run along some 1900 kms of the Great Wall to raise funds for charity (and been arrested six times for his pains) - Edward Ley-Wilson was able to give a first-hand description of the structure which was quite invaluable.

References:

1. The Great Wall of China; Sturgis & Walton (New York) 1909; p.17.
2. "A Thousand Miles Along the Great Wall of China"; Volume XLIII, No. 2 - February 1923; p.113.
3. The Great Wall, edited by Luo Zewen; McGraw-Hill 1981 (US) Michael Joseph 1982 (UK).
4. Zewen, ibid; p. 180.
5. Archaeology; Jan-February 1983; advertisement by Salen Lindblad Cruising Inc., New York; p.1.
6 The Great Wall of China; Kelly and Walsh (Shanghai) 1923; p.2.
7. Volume 4 Physics & Physical Technology; Part III Civil Engineering & Nautics; Cambridge University Press 1971; p.47.
8. For example, in the San Diego Union, January 31 1988; advertisement (page not known) by the Royal Viking Line.
9. "Above & Beyond; Single Room, Earth view"; Air & Space, April/May 1986; p.16.
10. Needham, ibid; p.55.
11. "The Problem of the Great Wall of China"; Harvard Journal of Asiatic Studies, Volume 43, No. 2 - December 1983; p.643-663. Waldron is Assistant Professor of History and East Asian Studies in the Department of History at Princeton University in the USA.
12. Letter to the author June 29 1988.
13. Action News (published by ActionAid); August 1988; p.8.
14. Letter to the author May 31 1988.
15. Letter to the author February 1 1988.
16 Quoted in The New York Times, March 20 1983; p.E17
17. Letter to the author February 8 1988.
18. Letter to the author January 27 1988.
19. Letter to the author February 2 1988.
20. See: "Optical and Retinal Factors Affecting Visual Resolution", F.W. Campbell and D.G. Green; J. Physiol Lond, 181, (1965); p.576-593. "Optical Quality of the Human Eye", F.W. Campbell and R. W. Gubisch; J. Physiol Lond, 186 (1966); p.558-578.
21. An anglicized modification of an analogy first suggested by Dr. Alta Walker, US Geological Survey.
22. Letter to the author October 10 1988 from Ray Villard of the Space Telescope Science Institute, Baltimore, USA.
23. Villard letter, ibid.
24. How Do You Go to the Bathroom in Space, William R. Pogue; Tom Doherty Associates 1985; p 75.
25. Bean letter to author, ibid. Also telephone conversation January 6 1988.
26. Letter to Alta Walker November 1 1986. The "U turn" is located in Ningsia, where the river turns abruptly north and flows in that direction for about 300 kms; turns sharply east for 400 kms; and then south for around 700 kms, following which it turns east and flows towards the sea.
27. Ride, opcit p.14.
28. Lovell, op cit.
29. Letter to the author from Lee Saegesser, NASA HQ, May 2 1988.
30. (a) John B. McDonald wrote in the New York Times of April 3 1983 (p.14E) that shortly before joining the White House staff in 1972 - at the time of President Nixon's visit to Communist China - he had included in a speech a reference to a claim by a Soviet cosmonaut (whose name McDonald did not give) to have seen the Great Wall from orbit. The report emanated from Moscow. (b) On October 19 1988, Mir Cosmonaut Alexander Alexandrov participated in a phone-in programme on Washington DC PBS and, in response to a question, reported that he had seen the Wall from orbit during his lengthy stay aboard the space station in 1987. (Report communicated to the author by Lee Saegesser October 27 1988.) (c) US Senator Jake Garn of Utah, who flew on shuttle mission 51D in April 1985, also claimed to have see the Wall - the fulfilment of a wish made when the Senator visited the Wall in November 1984.
31. Letter to the author August 2 1988
32. Letter to the author from Frederick J. Doyle, December 5 1988.
33. "Deserts of China", Alta Walker; American Scientist, Vol. 70 No. 4, July-August 1982; p.366-376. It was Dr. Walker who first identified the Wall in this MSS image and published it.
34. For a lucid and succinct account of the "canali" debate and its aftermath, see "The Legacy of Schiaparelli and Lowell", F.I. Ordway; Journal of the British Interplanetary Society, Vol. 39 1986; p.19-27.