Ian Allan
abc

# ROCKETS and Space Travel

50p

3/-

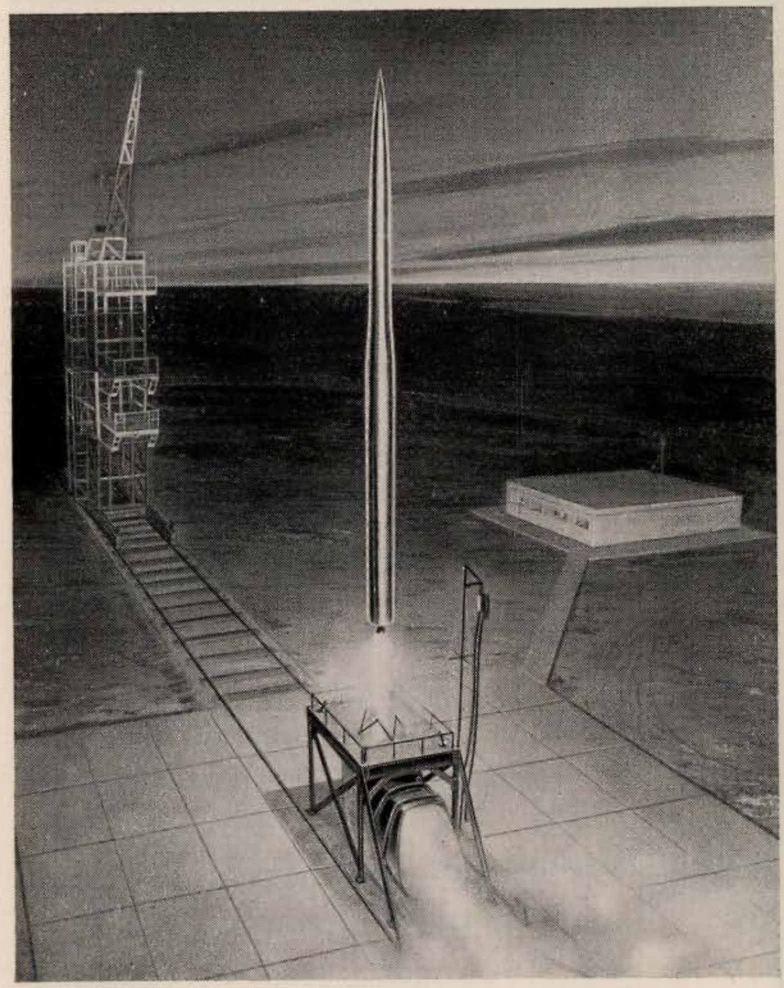
# abc
# rockets
# and
# space travel

**Maurice F. Allward**

**John W. R. Taylor**

LONDON

Ian Allan



*PROJECT VANGUARD*

# Contents

## Thank you . . . . .

- to Kenneth W. Gatland, whose 1951 paper on earth satellites has earned him an honoured place among the pioneers of space flight, for expert guidance and help.
- to the American Museum of Natural History for the photo of a satellite model on page 64, to the Smithsonian Institution, Ministry of Supply, U.S. Department of Defense, *Flight* and the public relations staffs of missile manufacturers for most of the other photographs appearing in the book.
- to Allan Wingate Ltd. for permission to reproduce the drawing on page 49, from *Space Travel* by Gatland and Kunesch.
- to Frederick Cook for drawing the illustrations on pages 43, 52, 53 and 58.

The silhouettes on pages 15-36 were drawn by Maurice F. Allward

# Introduction

ROCKETS have been used for amusement and battle for more than 700 years, but it was not until the first of Hitler's V-2 war rockets fell on Chiswick, near London, in September 1944, that they began to affect the lives of everyone in the world.

There was something particularly menacing about V-2. Bomber aeroplanes were mere man-carrying vehicles. Even the pilotless V-1 flying bomb was just another aeroplane that could be heard approaching and was more often than not destroyed before it could destroy. There was no way of intercepting V-2 and, when it was followed by America's atomic bomb in 1945, the world began to await with ever-growing fear the ultimate weapon—a long-range intercontinental ballistic missile with a nuclear warhead, against which there could be no defence at the target.

Fortunately, it has proved tremendously difficult to develop guided weapons of increased efficiency, and the more simple nuclear bombs already in the world's armouries have maintained an uneasy " peace through fear ". Yet progress has been made and this book contains photographs and data of no fewer than 28 present-day missiles built for war or research.

The distinction is important because, although the money for the research rockets comes from Government funds and is, for the most part, aimed at perfecting new weapons of war, the results are also opening up happier, more exciting and worthwhile possibilities. While politicians and soldiers dream of manned space-stations from which they could control the world, ordinary men, women and children see the space satellite and rocket as stepping stones to the great adventure of interplanetary travel.

War or peace? Annihilation or adventure? Which is the more likely? How far have we progressed towards either or both? These are some of the questions we have tried to answer in this small book, which gives a brief review of current progress and future possibilities. We hope it will help its readers to view in proper perspective the more sensational stories that will appear in the newspapers with increasing frequency now that the first " artificial moons " are about to be fired into space.

M.F.A.

*March* 1956. J.W.R.T.

# Birth of the Rocket

IN an age when a single military rocket with an atomic warhead can destroy a great city, and when engineers are planning space-rockets for journeys to the Moon, the ordinary firework rocket seems a rather feeble affair. Yet, it was once a battle-winner itself and even earned a mention in the American national anthem, which refers to " the rockets' red glare ".

We shall never know who made the first " firework " rocket; or when. But he almost certainly lived in China, where gunpowder was in use at least 750 years ago. He may well have produced his first rocket by accident when a home-made bomb, made by packing gunpowder in a strong paper tube, failed to explode and, burning slowly at one end, began to streak along the ground. Stage two came when somebody suggested tying this form of mobile incendiary bomb to the front of an arrow, so that the tail feathers would make it fly straight and accurately. No doubt, he discovered that, even when the blast burned the feathers off the shaft, the fiery arrows still continued to fly straight. So the rocket was born.

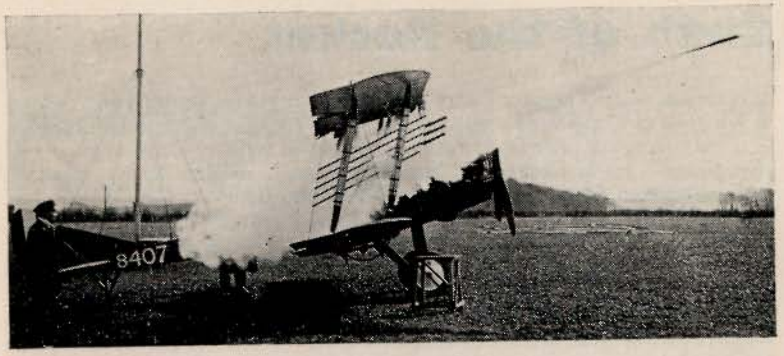
Even in those days, a new invention was usually developed first for war, and invading Mongols were no doubt suitably surprised when the defenders of the city of Kaifeng counter-attacked with a rocket barrage in 1232.

Before long, rockets were being made in many other places, including Europe, both as fireworks and as a primitive and extremely unreliable form of artillery. The only battle in which they achieved any real success was at Guntur in India in 1780. The local rajah, Hyder Ali of Mysore, had developed iron-cased rockets weighing up to 12 lb. and with a range of half-a-mile. Fired in hundreds, they won him a temporary victory and led to the formation of the Royal Artillery Mounted Rocket Corps and other similar units in the British Services.

The person chiefly responsible for this was Colonel (later Sir) William Congreve, who made up his mind that anything the Indians could do he could do better—and did! Working in the Royal Laboratory at Woolwich, he perfected 32-lb. rockets which had a range of two miles and could be fitted with explosive, shrapnel or incendiary warheads. The incendiary variety proved particularly effective. They had a pointed nose, which stuck into the sides of wooden-hulled ships or buildings and then exuded a fiery liquid through rings of holes, which promptly coated the target with flames in the manner of a modern napalm bomb.

Congreve rockets played a big part in the fall of Boulogne in 1806 and in the siege of Copenhagen one year later, when more than 25,000 were fired from specially-built " projector " boats. They were used in many other battles during the Napoleonic wars, including Waterloo, and against the Americans at Baltimore in 1814.

A Frenchman named Frezier first suggested fitting stabilising fins instead of the long wooden stick; but it was again Congreve who proved the practicability of the idea, which greatly improved accuracy of aim. Still greater accuracy followed the invention of the axially-rotated rocket in America in 1815. In this, a proportion of the exhaust gases was simply taken out through a ring of



*These early firework-type* Le Prieur *rockets were fitted to fighters in the* 1914-18 *War, for use against balloons and Zeppelins. Fired electrically, their range was under* 400 *ft.*

---

nozzles inclined at an angle around the main nozzle, so that the rocket spun, rather like a catherine wheel.

By 1840, artillery rockets were being fired through tubes similar to a modern bazooka and they reached an early peak of efficiency in the 1860's when William Hale's spin-stabilised rockets were adopted by both the British and American armies. But the increasing range and accuracy of conventional artillery led to a gradual loss of interest in rockets and, except for the half-hearted use of Le Prieur " firework " rockets against Zeppelins in the 1914-18 War, they faded out of the military scene until their dramatic re-appearance in World War II.

Meanwhile, new uses were found for them. First experiments in the use of rockets to carry life-lines to ships in distress were made in 1807 by Henry Trengrouse in Cornwall: but it was not until the development of the Boxer rocket 48 years later that the rocket-line finally replaced the earlier mortars. Colonel Boxer made use of yet another of Frezier's ideas—the step-rocket, in which endurance and range were increased by having two or more rockets in line, so that as one became exhausted it fired the next one in front. In 1870, life-line rockets were put in use all round our coasts and have since helped to save over 15,000 lives.

Another most significant development had occurred earlier in the 19th Century, when an Italian named Claude Ruggieri fired into the air a number of small animals such as rats and mice inside large rockets, from which they descended by parachute when the powder fuel was exhausted.

Two Russians next took up the story. One, named Nikolai Kibaltchitch, designed a rather primitive rocket aircraft in 1881. But it was his parallel work on the bombs used to assassinate Czar Alexandra II, and not an attempted space-flight, that led to his sudden violent demise in 1908.

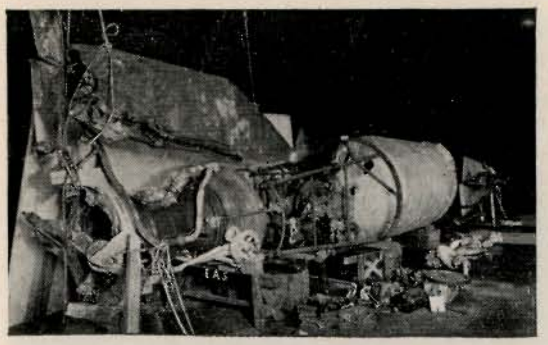
His compatriot, Konstantin Tsiolkowskii, was the first person to show, in 1903, that a rocket could operate in a vacuum. A few years later, the French aircraft pioneer Robert Esnault-Pelterie began his famous investigation of the mathematical possibilities of space-flight. Simultaneously, in America, a scientist named Robert Goddard began to search for new rocket fuels.

Goddard realised that tremendous power would be needed for interplanetary flight and, as early as 1909, suggested the use of liquid oxygen and liquid hydrogen as propellants, and even hinted at nuclear power. By 1916 his experiments with powder rockets had achieved such success that the Smithsonian Institution made him a grant of $11,000 to enable him to continue his work. He put it to good use and within seven years had developed a practical liquid-fuel rocket motor.

After further experiments, Goddard built the world's first successful liquid fuel rocket in 1926. As can be seen from the photograph on this page, it looked very different from our modern idea of a rocket, because the combustion chamber was mounted about five feet above the tanks for the petrol and liquid oxygen propellants, being connected to them only by the two fuel supply pipes. The reason for this strange and structurally poor arrangement was that most early experimenters believed a rocket would be kept straight if its thrust were in front of its centre of gravity. This proved untrue. Nevertheless, Goddard's original rocket covered 184 ft. in 2½ seconds.

*This spidery contraption was Goddard's first successful liquid propellant rocket, fired on* 16*th March* 1926.

*Preparing to test fire an early A*-4 (V-2) *rocket at Peenemunde research station in* 1942.



*When this test* V-2 *fell in Sweden, the parts were flown to England and reconstructed at Farnborough. By this means, we knew a great deal about V-2 before the first one was fired against London.*

Financed next by the Guggenheim Foundation, he began to produce liquid-fuel rockets of more orthodox shape and pioneered the use of gyroscopes to stabilise them by moving control vanes in the exhaust gases.

Meanwhile, in Europe, a Rumanian professor named Hermann Oberth had published in 1927 a remarkable book entitled *The Way to Space Travel*, which quickly became the bible of space flight, or astronautics as it was known by then.

This book might almost have changed the history of the world, for when a space-travel society named the Verein fur Raumschiffahrt (VfR) was formed in Germany in June 1927, its members based many of their experiments on Oberth's theories. At first, they were interested chiefly in rocket-propelled motor cars, railcars and gliders; but soon after Hitler came into power in Germany, in 1933, the VfR was closed down.

Realising the possibilities of rockets for carrying high explosive, rather than research instruments or space travellers, the German Army set up a secret research establishment at Peenemunde on the Baltic coast under the direction of General Walter Dornberger, and obtained the services of Wernher von Braun, one of the VfR's most brilliant young members, as chief designer.

The story of what followed has been told in Dornberger's own book *V-2*. By 1942, under the incentive of war, the scientists of Peenemunde had fired successfully a giant rocket, 46 ft. high and weighing 28,380 lb., designed to carry a ton of high explosive for 156 miles. It took two more years and nearly 65,000 design changes to perfect this weapon, in the face of heavy R.A.F. bombing raids on Peenemunde; but on 8th September 1944 the first A-4 (referred to by Germany's Propaganda Ministry as Vergeltungswaffe Zwei—reprisal weapon No. 2, or V-2) fell on Chiswick, killing three persons.

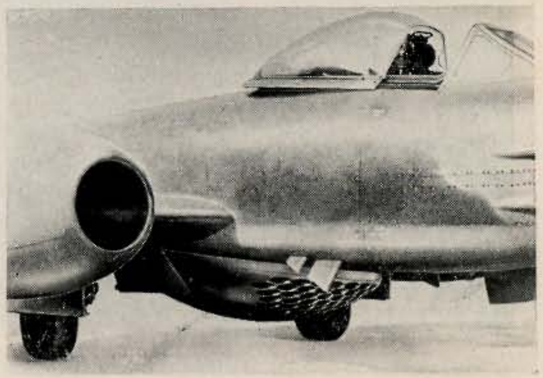
V-2 represented a tremendous achievement. It contained 30,000 component parts. Its 56,000 lb. thrust motor burned alcohol and liquid oxygen and it reached a speed of 3,300 m.p.h. during its climb to a height of 60 miles. Then, its fuel exhausted, it fell towards its target at well over 1,000 m.p.h., so there was no way of intercepting it.

Yet, even more fantastic weapons were being developed in Germany by then.

Mighty Mouse *unguided air-to-air rockets being fired from the retractable belly-pack of a North American F-86D Sabre interceptor.*

They included a radio-controlled V-2 that would have offered greater accuracy of aim; a winged V-2 rocket with a 370-mile range; a winged piloted V-2 for long-range high-speed reconnaissance; the Wasserfall anti-aircraft guided missile with an automatic homing head that would have enabled it to chase and hit Allied bombers no matter what evasive action they took; and the Sanger-Bredt project for piloted rocket bombers able to skim the atmosphere at a speed of 13,500 m.p.h. and with a range of 17,000 miles.

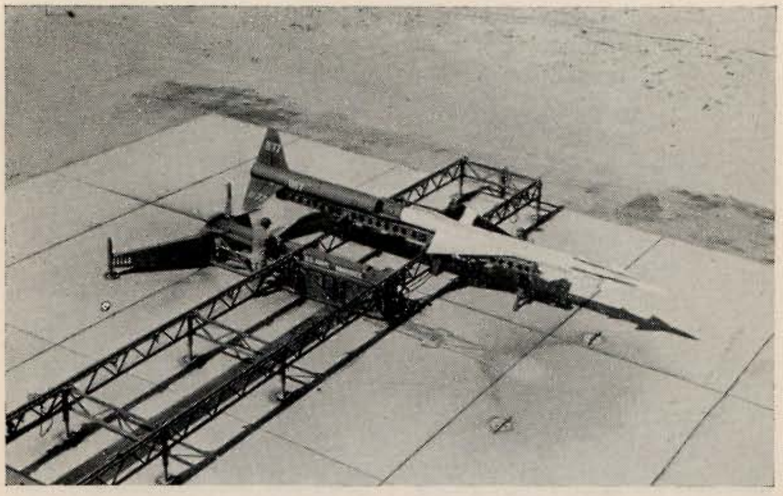
These weapons and projects like the V-1 flying bomb, the Me.163 rocket-powered fighter, the American atomic bomb, and the less complex powder rockets fired against infantry, aircraft, submarines and other targets by both the Allies and the enemy, brought new terror to warfare, and the threat of mutual annihilation. They also opened the door to space travel.



*Non-retractable pack for* 76 Oerlikon *unguided rockets under the fuselage of a Gloster Meteor fighter.*

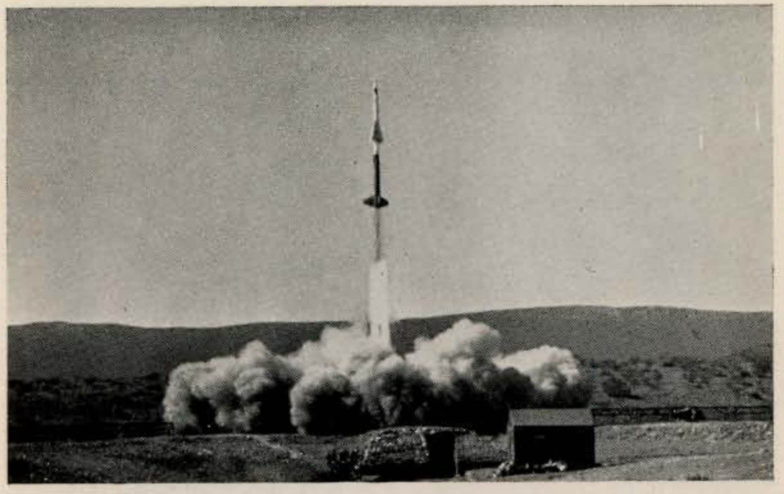
**NIKE BATTERY**

*Designed to destroy aircraft flying up to 60,000 ft. and within a range of 17 miles, batteries of Nike guided missiles already stand guard round key centres in the United States and will soon be seen in Europe.*

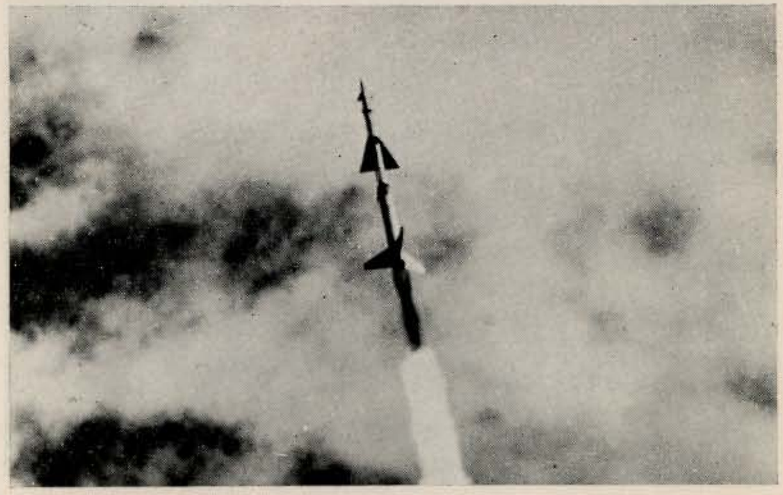


*Drawn from an underground storage magazine, the missile is placed on its launching rack and moved sideways on rails into position.*

*Protective clothing is worn when the Nike is fueled with nitric acid and petrol.*



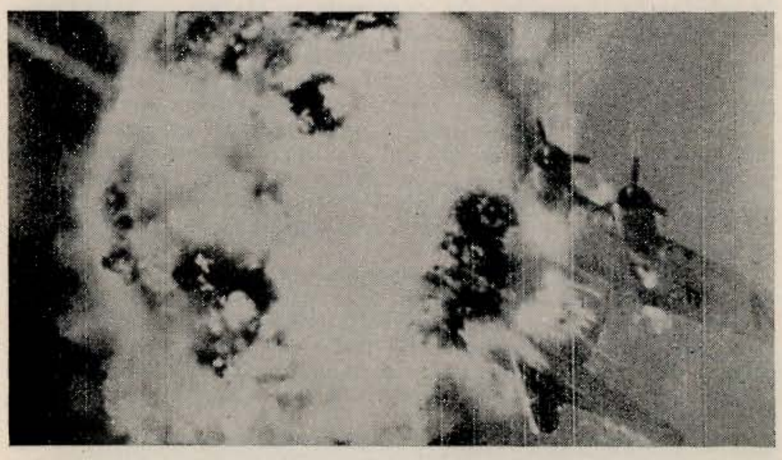
*Assisted by its powerful booster, a Nike leaves its launcher during a demonstration firing.*



*Accelerating swiftly upwards, the booster is about to be jettisoned.*

*The Nike homes on a Flying Fortress drone, remotely controlled at a height of 30,000 ft.*

*Scoring a direct hit, the explosion blasts off the end of the wing and the outer engine rips away.*



*A terrific explosion finishes the bomber. Such tests with slow obsolete bombers fall a long way short of representing operational conditions, where jet aircraft approaching at 600 m.p.h. at 60,000 ft. would be encountered.*

# Modern Missiles

THE guided missile was too late to have any major effect on the course of World War II, but the deadly efficiency of simple unguided powder rockets gave a hint of future possibilities. Small rockets fired in salvoes by Typhoon fighter-bombers massacred German units trapped in the Falaise gap in Normandy in 1944, breaking the morale of even the toughest armoured divisions. Similar rockets, fired by naval aircraft, sank submarines in the Atlantic. Others, of slightly different design, were fired by the thousand from special rocket-ships against beach targets to clear the path for Allied invading armies, and from mobile launching ramps as anti-aircraft artillery.

In parallel, the first radio-controlled Azon bombs were produced and launched from aircraft against Japanese targets in Burma. But it was in Germany that the greatest progress was made.

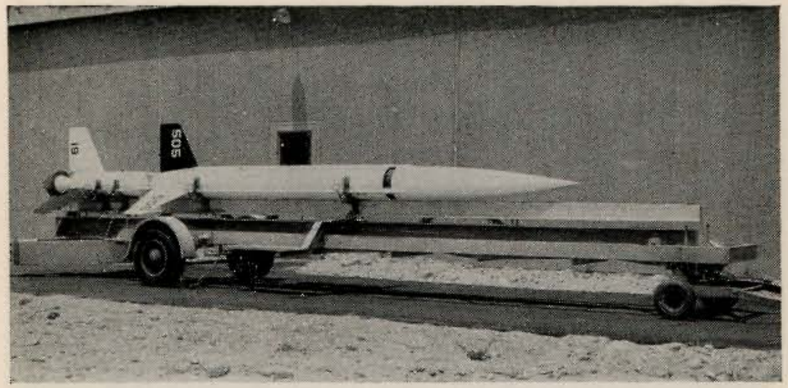
V-2 represented a superb achievement; but it carried only a small warhead and was not sufficiently accurate. Each rocket cost £10-16,000 and took 3-7,000 man-hours to build: yet the 1,115 V-2s that fell on England killed only 2,855 people, whereas 71,379 were killed by a single atomic bomb at Hiroshima. What was needed and what, fortunately, the enemy had no time to perfect, was an accurate radio-controlled V-2 with an atomic warhead.

The Germans came much nearer to success with their R4/M solid fuel air-to-air rocket. Although unguided and with a warhead of only 1 lb. of explosive, it was an extremely formidable weapon when fired from Me.262 jet-fighters with the aid of an EZ.42 gunsight. On one occasion, six Me.262s attacked a formation of U.S.A.F. Fortresses and, staying out of range of the bombers' defensive guns, destroyed 14 Fortresses. The R4/M was planned to be followed by Ruhrstahl X-4 liquid-fuel missiles, controlled from the launching aircraft through fine wires which unwound from bobbins as they raced towards their target.

No less successful was Wasserfall, a radio-controlled anti-aircraft rocket which was like a small finned V-2 and was designed to intercept 560 m.p.h. aircraft at heights up to 60,000 ft. over ranges of 30 miles. And there were many other promising German missiles including glider-bombs like the Fritz X-1 which sank the battleship *Roma* in 1944, and the Hs.293 which was used against Allied shipping at Anzio.

Surprisingly little use seems to have been made of all this " captured " enemy experience. The Americans developed from the R4/M the 2.75 in. Mighty Mouse unguided air-to-air rocket that is standard armament on their all-weather interceptor fighters. They also used V-2s for their early upper atmosphere research programme and as a basis for the design of later research rockets. In Britain, our fighters are still armed with guns, although guided missiles are on the way.

At the present time, original design and research in America, Britain and France seem, at last, to be producing the first true operational guided rocket missiles. Most of them are still shrouded in official secrecy; but all available details of known current missiles are given on the next 23 pages.

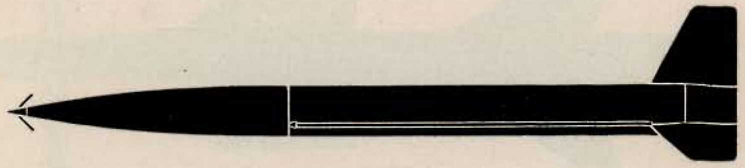


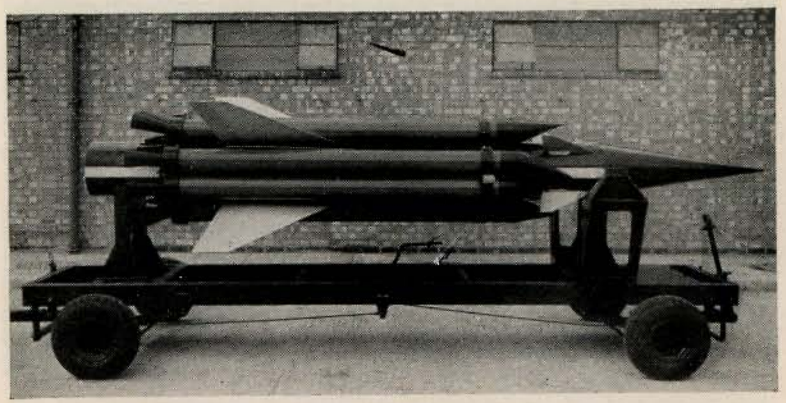
## AEROJET-GENERAL AEROBEE

COUNTRY OF ORIGIN: United States of America.
DUTY: Research: Upper atmosphere.
LENGTH: 18 ft. 10 in. (without booster).
SPAN OF FINS: Not available.
DIAMETER: 1 ft. 3 in.
MAX. SPEED: 2,800 m.p.h.
ALTITUDE: 70 miles.
WEIGHT: 1,665 lb.
THRUST: 2,600 lb. × 45 secs.
MOTOR: Liquid propellant; nitric acid/aniline.
CONTROL: None; fin stabilised.

### REMARKS

One of the most successful research rockets, because of its relative simplicity. Launched from 140 ft. tower using solid booster giving 18,000 lb. thrust for 2.5 seconds. Used to carry mice and monkeys up 40 miles, from which altitude safe recoveries have been made. One has reached an altitude of 123 miles.



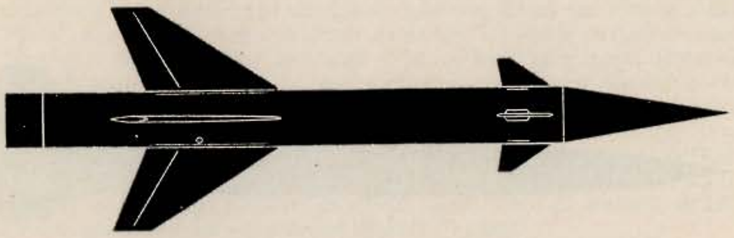


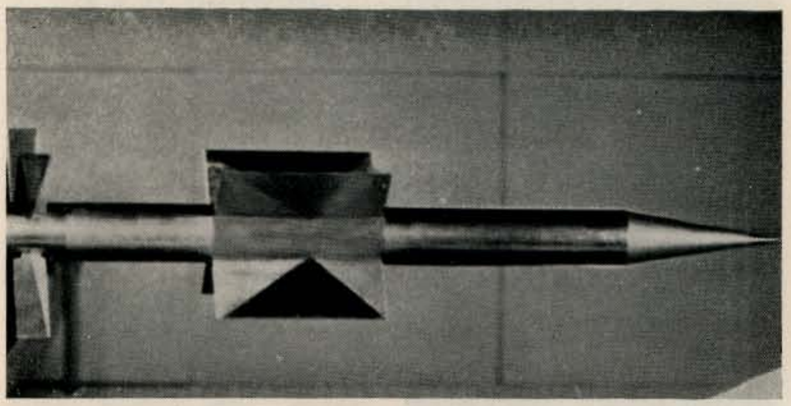
## ARMSTRONG WHITWORTH CANARD

COUNTRY OF ORIGIN: Great Britain.
DUTY: Research; surface to air.
LENGTH: 17 ft. 7 in.
SPAN OF FINS: Not available.
DIAMETER: 1 ft. 3 in.
MAX. SPEED: Not available.
ALTITUDE: Not available.
RANGE: Not available.
WEIGHT: Not available.
THRUST: Not available.
MOTOR: Not available.
CONTROL: Not available.

**REMARKS**

An early dynamic test vehicle developed for testing wrapped boosters. This arrangement of employing several small boosters around the sides of a missile, instead of a larger single booster behind it, follows German wartime practice. The missile utilised eight boosters, arranged in four pairs of two boosters, the front end of each pair ending in a wedge-shape and the outlet angled to direct the exhaust away from the missile.





## ARMSTRONG WHITWORTH MISSILE

COUNTRY OF ORIGIN: Great Britain.

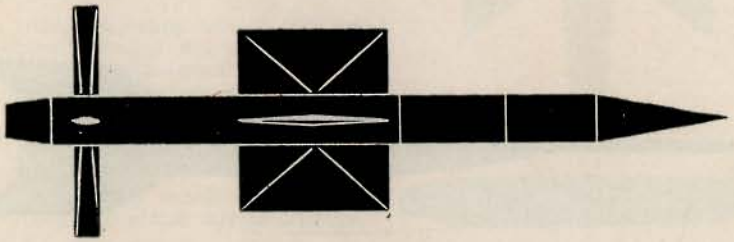
DUTY: Anti-aircraft, ship to air.

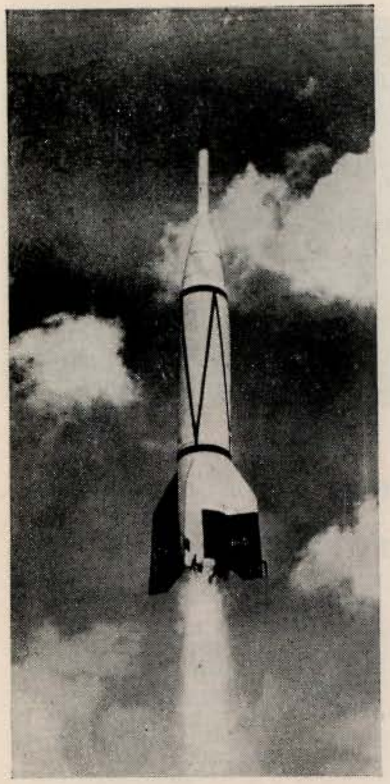
LENGTH: 20 ft. (approx.).

DIAMETER: 1 ft. 3 in. (approx.).

**REMARKS**

The silhouette of this missile was prepared from photographs of a small wind tunnel model displayed at the 1955 S.B.A.C. Show. Apart from the fact that the missile is boosted by 4 twin A.T.O. units attached to the body, all other data is restricted.





## BUMPER W.A.C.

COUNTRY OF ORIGIN: United States of America.

DUTY: Research; Step Rocket.

LENGTH (TOTAL): 60 ft. approx.

SPAN OF V.2 FINS: 11 ft. 9 in.

DIAMETER (V 2): 5 ft. 5 in.

MAX. SPEED (W.A.C.): 5,150 m.p.h.

ALTITUDE (W.A.C.): 242 miles.

WEIGHT (TOTAL): 28,918 lb.

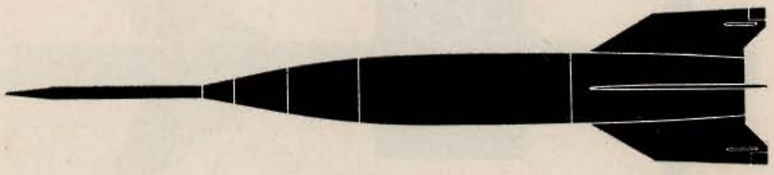
THRUST: 60,000 lb. × 60 sec. (V.2) and 1,500 lb. × 45 sec. (W.A.C.)

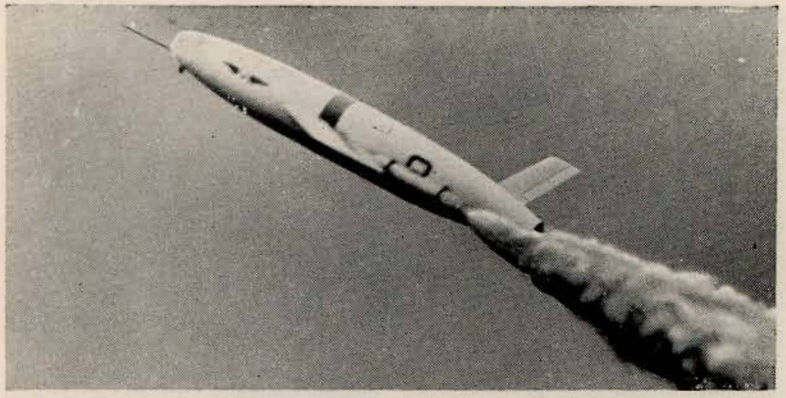
MOTOR: V.2: Liquid oxygen/ethyl alcohol. WAC Corporal: Nitric acid/aniline.

CONTROL: Graphite vanes in exhaust (V.2). None (W.A.C.).

### REMARKS

Eight of these experimental two-step rockets, comprising a modified V.2 and WAC Corporal, were built. No. 5 reached an altitude of 242 miles after a vertical launching at White Sands in February, 1949. Others were turned in flight to obtain maximum horizontal range, the results not being disclosed.





## CHANCE VOUGHT SSM-N-8 REGULUS

COUNTRY OF ORIGIN: United States of America.

DUTY: Ship to surface.

LENGTH: 32 ft.

SPAN OF WINGS: 21 ft.

DIAMETER: 4 ft. 3 in.

MAX. SPEED: 600 m.p.h.

ALTITUDE: Not available.

RANGE: 200 miles.

WEIGHT: 14,522 lb.

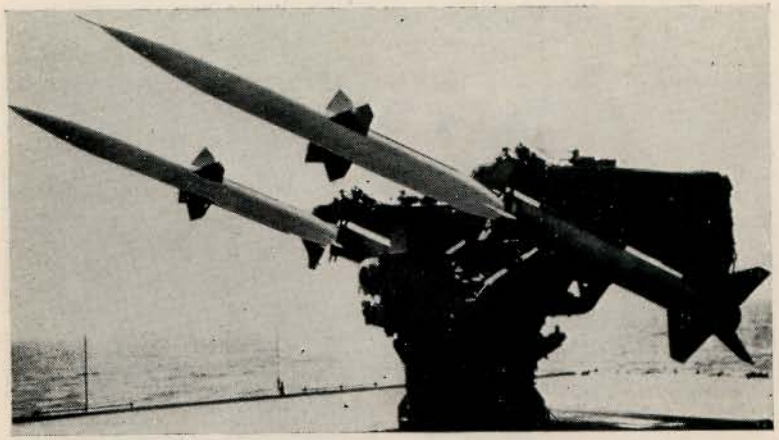
THRUST: 4,600 lb.

MOTOR: Allison J33 turbojet

CONTROL: Radio.

### REMARKS

Although dating back to 1947 and thus obsolescent, Regulus is the only surface-to-surface missile known to be in operational service with any navy. One has been launched from the U.S. Submarine "*Tunny*", and Regulus is to be carried by the atomic submarine U.S.S. "*Nautilus*". Training and KDU-1 target missiles have undercarriages to permit salvage after use.



## CONVAIR SAM-N-7 TERRIER

COUNTRY OF ORIGIN: United States of America.

DUTY: Anti-aircraft; ship to air.

LENGTH: 14 ft. 9 in. (without booster).

SPAN OF FINS: 4 ft.

DIAMETER: 1 ft.

MAX. SPEED: Mach 2.

ALTITUDE: 11.4 miles.

RANGE: 15 miles.

WEIGHT: 3,360 lb.

THRUST: Not available.

MOTOR: Solid propellant; long duration.

CONTROL: Beam rider.

### REMARKS

Developed by the Applied Physics Laboratory, John Hopkins University, under contract from the U.S. Navy Bureau of Ordnance. Twin launchers for Terriers have been installed on the U.S.S. "*Mississippi*", "*Boston*" and "*Canberra*".

## DEACON

COUNTRY OF ORIGIN: United States of America.

DUTY: Research; upper atmosphere.

LENGTH: 16 ft.

SPAN OF FINS: Not available.

DIAMETER: 8 in.

MAX. SPEED: 2,700 m.p.h.

ALTITUDE: 60 miles (balloon launched).

WEIGHT: 200 lb.

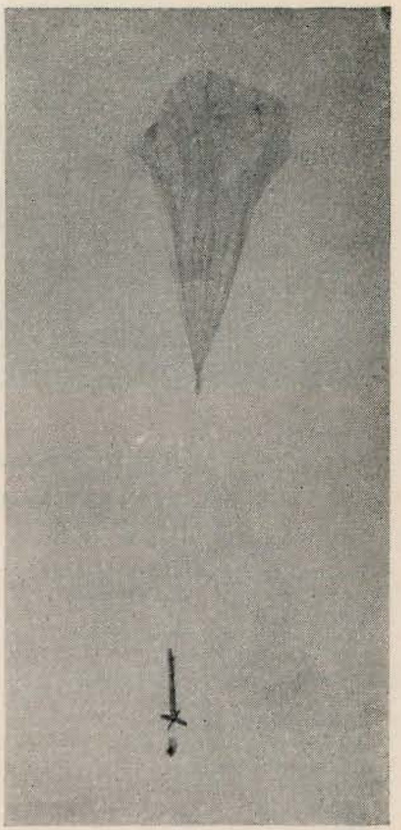
THRUST: 5,700 lb. × 3.5 sec.

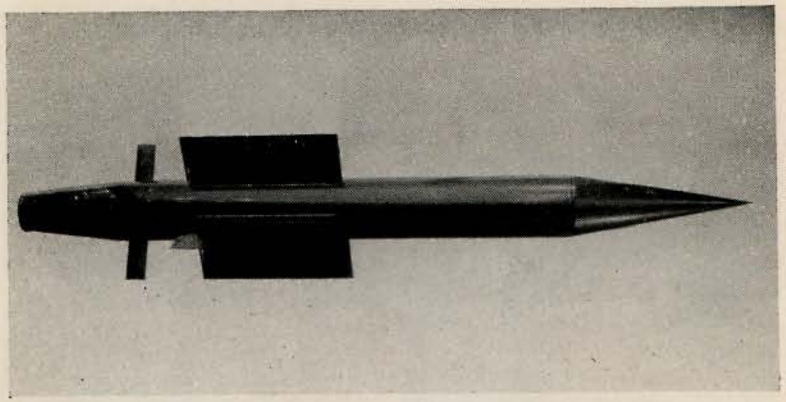
MOTOR: Solid propellant; standard J.A.T.O. unit.

CONTROL: None; fin stabilised.

### REMARKS

Launched from 55 ft. dia. plastic "sky-hook" balloon, at altitudes of between 10 and 15 miles, the Deacon was developed to reduce the cost of upper atmosphere research work. Cost of rocket £280, balloon £140. Rocket is suspended 100 ft. below balloon and fired by timer on barometric pressure switch.



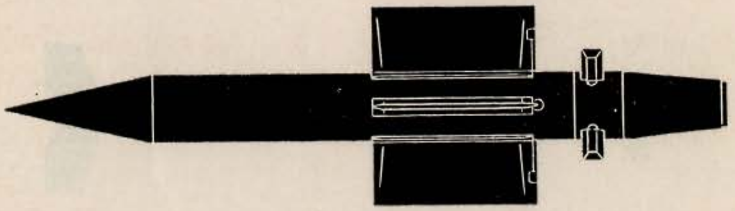


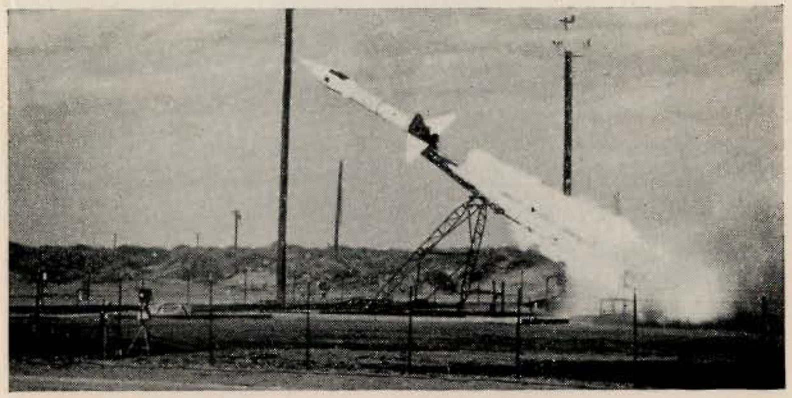
## DE HAVILLAND TEST VEHICLE

COUNTRY OF ORIGIN: Great Britain.
DUTY: Research: Air-to-Air.
LENGTH: 6 ft.
SPAN OF FINS: 1 ft. 8½ in.
DIAMETER: 7 in.
MAXIMUM SPEED: Not available.
ALTITUDE: Not available.
WEIGHT: Not available.
THRUST: Not available.
MOTOR: Not available.
CONTROL: Not available.

### REMARKS

A product of the de Havilland Propeller Co. (Missile Division) this missile has featured prominently in the Company's advertisements for some years. An American report suggests that this rocket—or a later version—may employ an infra-red guidance device, so that it homes on to the hot exhaust of an aircraft's jet engines.



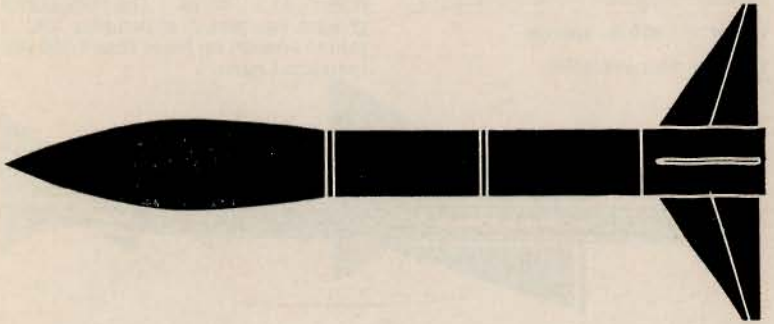


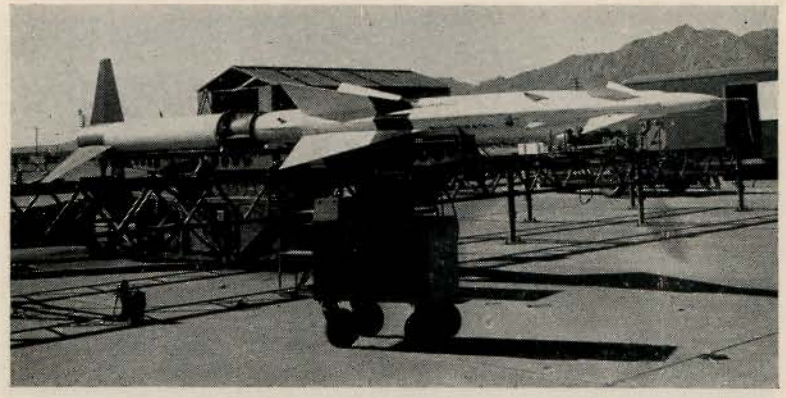
## DOUGLAS HONEST JOHN

COUNTRY OF ORIGIN: United States of America.
DUTY: Surface to surface: artillery.
LENGTH: 28 ft. 2 in.
SPAN OF FINS: Not available.
DIAMETER: 2 ft. 6 in.
MAX. SPEED: 1,100 m.p.h.
ALTITUDE: Not available.
RANGE: 20 miles.
WEIGHT: 6,000 lb. approx.
THRUST: Not known.
MOTOR: Solid propellant.
CONTROL: None, fin stabilised.

### REMARKS

Honest John missiles are in service with U.S. Army field artillery batteries in Europe. Being unguided, they are comparatively simple, but are capable of carrying both high explosive and atomic warheads.





## DOUGLAS SAM-A-7 NIKE

COUNTRY OF ORIGIN: United States of America.

DUTY: Anti-aircraft; surface to air.

LENGTH: 20 ft. approx. (without booster).

SPAN OF FINS: 5 ft. 2 in.

DIAMETER: 1 ft.

MAX. SPEED: Mach 2+.

ALTITUDE: 60,000 ft.

RANGE: 17 miles.

WEIGHT: 1,000 lb. approx.

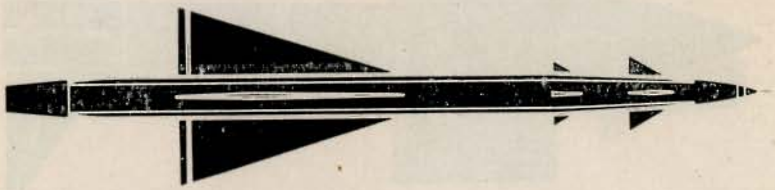
THRUST: Not available.

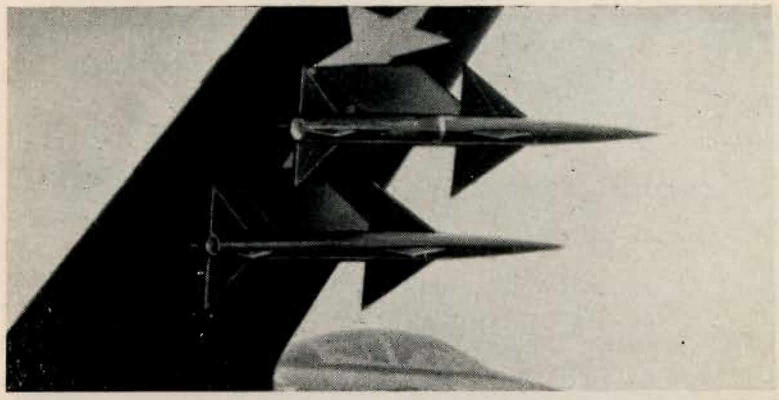
MOTOR: Liquid propellant: Nitric acid/petrol. Solid propellant booster.

CONTROL: Command guidance, with semi-active radar homing.

### REMARKS

First guided missile announced to be in series production. The first batteries of Nikes were established in 1954, at Fort Meade, Maryland; Washington; and Lorton, Virginia. Over 100 batteries now protect 13 major U.S. cities. The associated ground equipment is complex and is said to contain no fewer than 1,500,000 individual parts.





## DOUGLAS-SPERRY AAM-N-2 SPARROW 1

COUNTRY OF ORIGIN: United States of America.

DUTY: Operational: air to air.

LENGTH: 8 ft. 3½ in.

SPAN OF FINS: 2 ft. 3½ in.

DIAMETER: 6 in.

MAXIMUM SPEED: Mach 3.0.

RANGE: 5 miles.

WEIGHT: 280 lb.

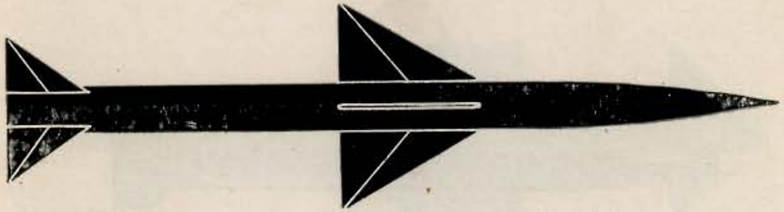
THRUST: Not available.

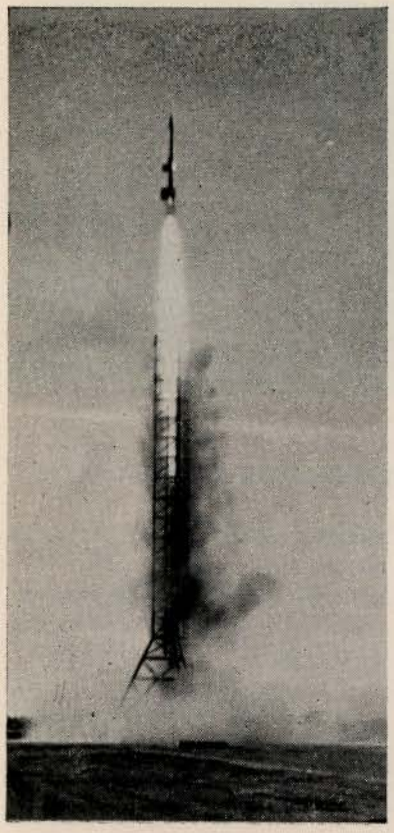
MOTOR: Solid propellant.

CONTROL: Beam rider, with terminal radar homing.

### REMARKS

In quantity production, this missile is the outcome of an extensive development programme lasting since 1948. The N-2 is to be superseded by the N-3 and N-4, now under development.





## DOUGLAS
## WAC-CORPORAL

COUNTRY OF ORIGIN: United States of America.

DUTY: Research: upper atmosphere.

LENGTH: 16 ft. (without booster).

SPAN OF FINS: Not available.

DIAMETER: 1 ft.

MAX. SPEED: 2,800 m.p.h.

ALTITUDE: 43.5 miles.

WEIGHT: 665 lb.

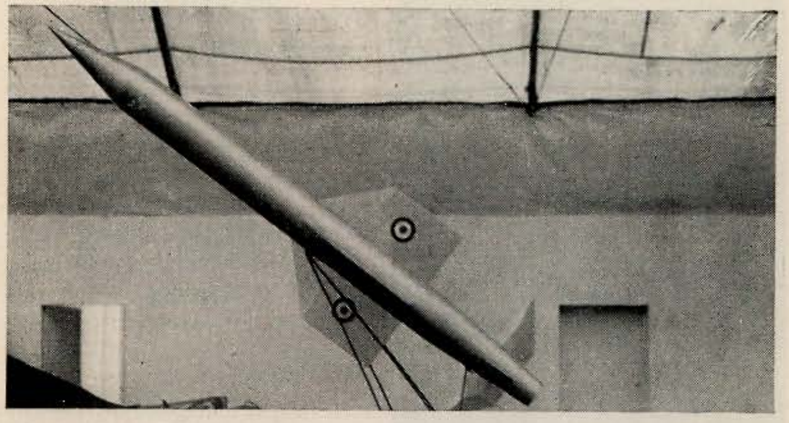
THRUST: 1,500 lb. × 45 sec.

MOTOR: Liquid propellant: nitric acid/aniline.

CONTROL: None; fin stabilised.

### REMARKS

A product of the Guggenheim Aeronautical Laboratory and the Douglas Aircraft Co., this rocket was used to inaugurate the United States' Upper Air Research programme in August 1945, when it reached a height of 43.5 miles with a payload of 25 lb. Launching was from 102 ft. high tower, using a booster giving 50,000 lb. thrust for .5 sec.



## ENGLISH ELECTRIC TEST VEHICLE

COUNTRY OF ORIGIN: Britain.

DUTY: Research: surface to air.

LENGTH: 20 ft. approx.

SPAN OF FINS: Not available.

DIAMETER: 1 ft. 6 in.

MAX. SPEED: Not available.

ALTITUDE: Not available.

RANGE: Not available.

WEIGHT: Not available.

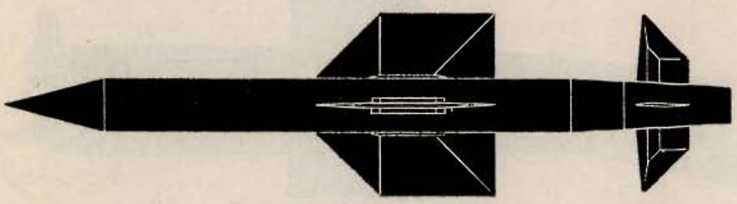
THRUST: Not available.

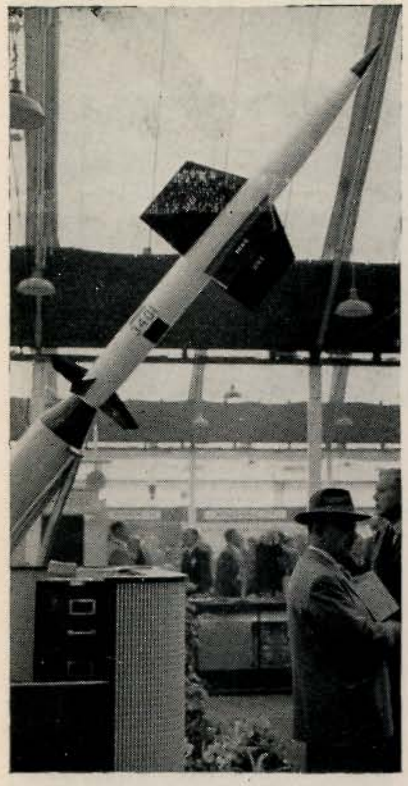
MOTOR: Not available.

CONTROL: Not available.

### REMARKS

Little data has been released on this missile except that subsidiary manufacturers are Napier & Son (propulsion unit) and Marconi (guidance system). It has four twin wrapped boosters.





## FAIREY MISSILE

COUNTRY OF ORIGIN: Great Britain.

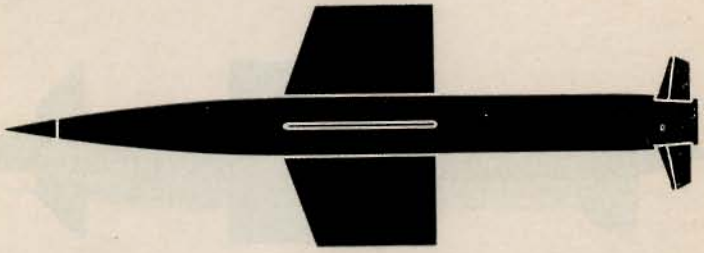
DUTY: Anti-aircraft; air-to-air.

LENGTH: 10 ft. approx.

DIAMETER: 1 ft. approx.

### REMARKS

A full-size model of this missile was displayed on the Fairey Aviation stand at the 1955 S.B.A.C. Show, where it was displayed on a large booster. It appears to be a larger and cleaner version of the Fireflash guided missile which has been ordered into production for the R.A.F. Photographs have shown that Fireflash is powered by two jettisonable solid-fuel booster rockets, and it is believed to be a beam-rider with proximity head.



## FIRESTONE

## SSM-A-17 CORPORAL

COUNTRY OF ORIGIN: United States of America.

DUTY: Surface to surface: artillery.

LENGTH: 40 ft. approx.

SPAN OF FINS: Not available.

DIAMETER: 2 ft. 6 in.

MAX. SPEED: 2,000 m.p.h.

ALTITUDE: Not known.

RANGE: 150 miles.

WEIGHT: 12,000 lb.

THRUST: 20,000 lb.

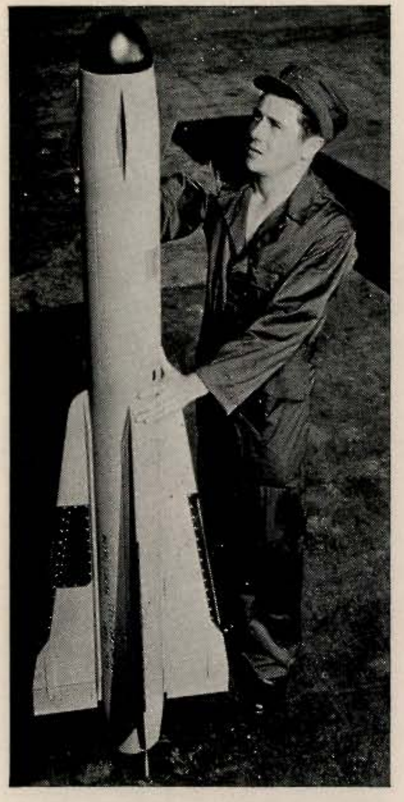
MOTOR: Liquid propellant.

CONTROL: Beam-rider.

### REMARKS

In many respects the Corporal is similar to the German V-2 and employs graphite vanes placed in the exhaust for control purposes. The motor is cut at a predetermined height and speed, and the missile then follows a ballistics trajectory.

Corporals are in service with U.S. Army field artillery batteries in Europe, and are being supplied to the British Army.



## HUGHES

## GAR-1 FALCON

COUNTRY OF ORIGIN: United States of America.

DUTY: Air to air.

LENGTH: 6 ft.

SPAN OF FINS: 2 ft. 6 in.

DIAMETER: 6 in. approx.

MAXIMUM SPEED: Mach 3.

ALTITUDE: Not available.

RANGE: Not available.

WEIGHT: 108 lb.

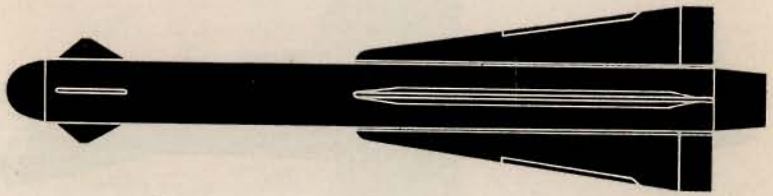
THRUST: 6,000 lb.

MOTOR: Solid propellant.

CONTROL: Beam rider, with terminal radar homing.

### REMARKS

The Falcon is entering service as standard armament of U.S.A.F. all-weather fighters. It is controlled by a Hughes fire-control system and normal airborne radar.



## MARTIN MATADOR TM-61

COUNTRY OF ORIGIN: United States of America.

DUTY: Surface to surface: Operational missile.

LENGTH: 39 ft. 7 in.

SPAN OF WINGS: 28 ft. 8 in.

DIAMETER: 4 ft. 6 in.

MAX. SPEED: Mach 1+.

ALTITUDE: 50,000 ft. approx.

RANGE: 600 miles.

WEIGHT: 12,000 lb.

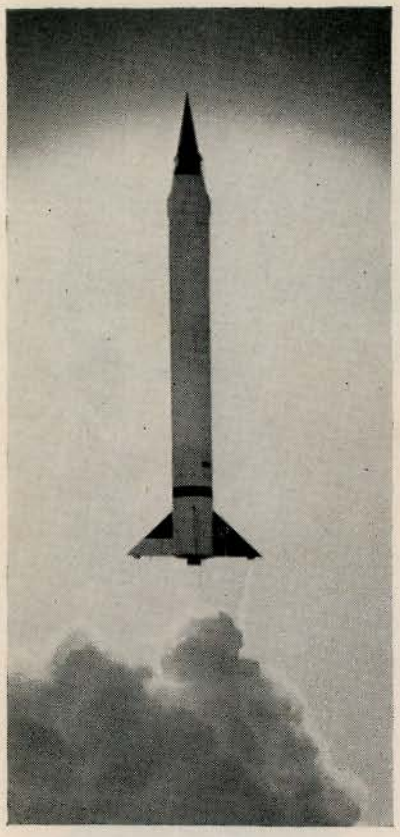
THRUST: 4,800 lb.

MOTOR: Allison J33-A-37 turbojet.

CONTROL: Radio control, with radar intelligence.

### REMARKS

Although the basic design of this missile is 10 years old, its ability to carry a heavy atomic warhead over long ranges at near-sonic cruising speeds at high altitudes makes it still a most formidable weapon. When diving on its target it reaches supersonic speeds so that, like the German V-2, it arrives before the sound of its approach is heard. Latest version is the TM 61B, with longer, less pointed nose.



## MARTIN VIKING

COUNTRY OF ORIGIN: United States of America.

DUTY: Research: Upper atmosphere.

LENGTH: 42 ft.

SPAN OF FINS: Not available.

DIAMETER: 3 ft. 9 in.

MAX. SPEED: Not available.

ALTITUDE: 158 miles (No. 11).

WEIGHT: 14,940 lb.

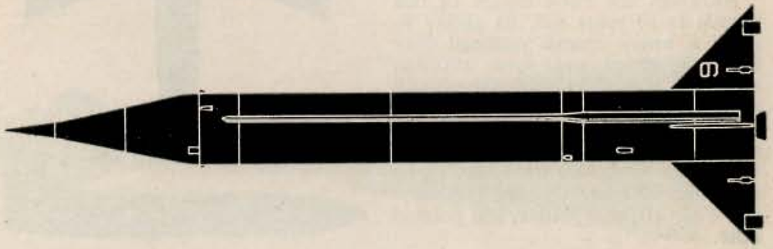
THRUST: 20,500 lb.

MOTOR: Liquid propellant; Liquid oxygen/alcohol.

CONTROL: Pivoting motor.

### REMARKS

One of a series used in extensive programme of upper air research. Viking No. 7, reaching 135.6 miles, was the first rocket to exceed the record summit altitude of the American-modified V-2 (116 miles). Approximate cost of rocket £150,000.



## OERLIKON TYPE 54

COUNTRY OF ORIGIN: Switzerland.

DUTY: Anti-aircraft; surface to air.

LENGTH: 19 ft. 8½ in.

SPAN OF FINS: 4 ft. 2½ in.

DIAMETER: 1 ft. 3½ in.

MAX. SPEED: Not available.

ALTITUDE: 9.3 miles.

RANGE: 15 miles.

WEIGHT: 772 lb.

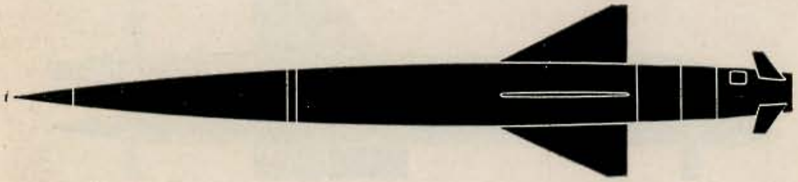
THRUST: 2,205 lb. × 30 sec.

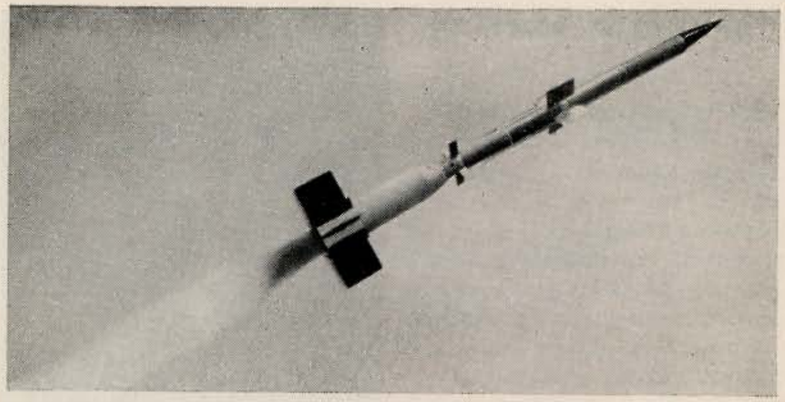
MOTOR: Liquid propellant; white fuming nitric acid/kerosene.

CONTROL: Beam rider.

### REMARKS

This missile contains many interesting features. The cruciform wings move fore and aft to compensate for rapid changes in weight and lift. Rocket motor, in conjunction with tail surface movement, swivels to provide control by thrust deflection. After burn-out, control movements coarsen to compensate for loss of thrust control. For training purposes, the missile can be recovered by parachute.





## RTV-1

COUNTRY OF ORIGIN: Britain.

DUTY: Test vehicle.

LENGTH: 17 ft. approx. (without booster).

SPAN OF FINS: 2 ft. 3 in.

DIAMETER: 9½ in.

MAX. SPEED: 2,000 m.p.h. approx.

ALTITUDE: Not known.

WEIGHT: 260 lb.

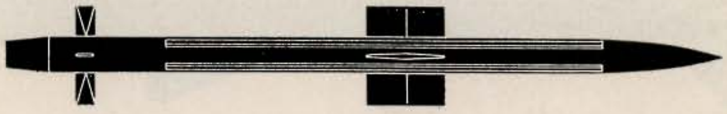
THRUST: 1,000 lb. × 25 sec.

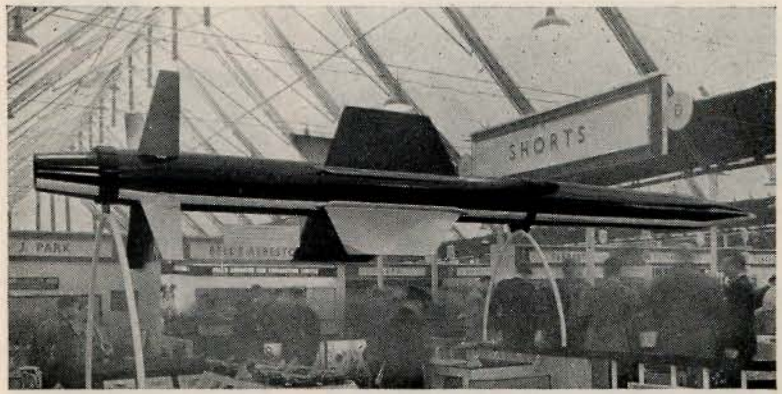
MOTOR: Bi-propellant; liquid oxygen/alcohol.

CONTROL: Beam or command radio guidance.

### REMARKS

This is one of two early British rockets of which details were given in 1952. It was built for stability and control test purposes, and for comparative tests of guidance systems. The propulsion unit was developed by the Rocket Propulsion Department, Westcott, Bucks.





[" Flight"

## RTV-2

COUNTRY OF ORIGIN: Britain.

DUTY: Research: surface to air.

LENGTH: 30 ft. (with parachute recovery section).

SPAN OF FINS: 5 ft.

DIAMETER: 1 ft. 5 in.

MAX. SPEED: Not available.

ALTITUDE: Not available.

RANGE: Not available.

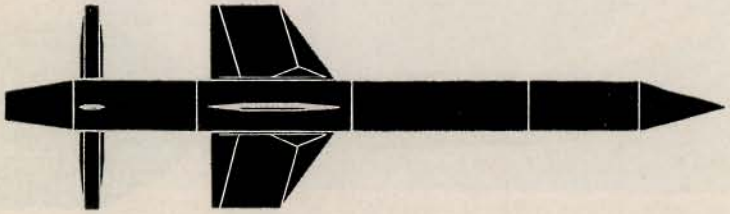
WEIGHT: Not available.

MOTOR: Not available.

CONTROL: Not available.

### REMARKS

This experimental rocket, together with RTV-1, was the principle test vehicle in Britain's guided-missile programme up to 1950, and was used to investigate stability and control at supersonic speeds. It has four twin wrapped boosters. Rocket shown in photograph is improved General Purpose Test Vehicle.



## VERONIQUE

COUNTRY OF ORIGIN: France.

DUTY: Research.

LENGTH: 19 ft. 8 in.

SPAN OF WINGS: Not available.

DIAMETER: 1 ft. 10 ins.

MAX. SPEED: 3,000 m.p.h.

ALTITUDE: 84 miles.

WEIGHT: 2,172 lb.

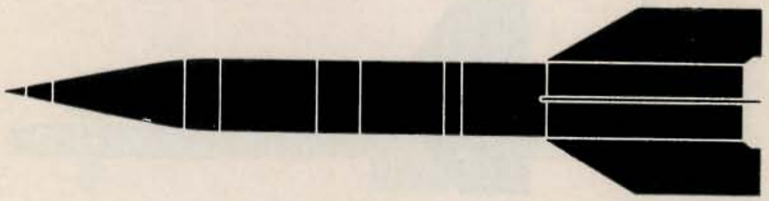
THRUST: 8,820 lb. × 35 sec.

MOTOR: Liquid propellant; Nitric acid/gas oil.

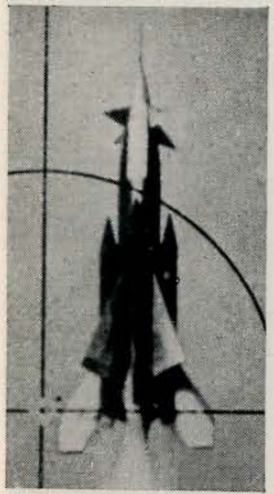
CONTROL: None.

### REMARKS

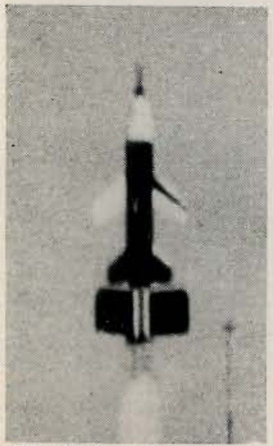
This French research rocket is launched from a simple platform. Four cables, attached to outriggers provided at the base of the fins, unwind from a drum at a uniform rate and maintain the rocket's stability while the speed is too low for the fins to be effective. The outriggers are jettisoned by means of explosive bolts.



## FRENCH MISSILES



Parca *surface to air supersonic guided rocket, boosters attached.*

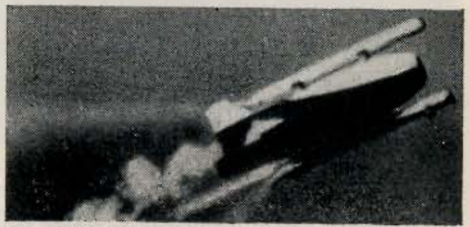


SE 4100 *surface to air guided rocket, with booster. Weight* 287 *lb.*

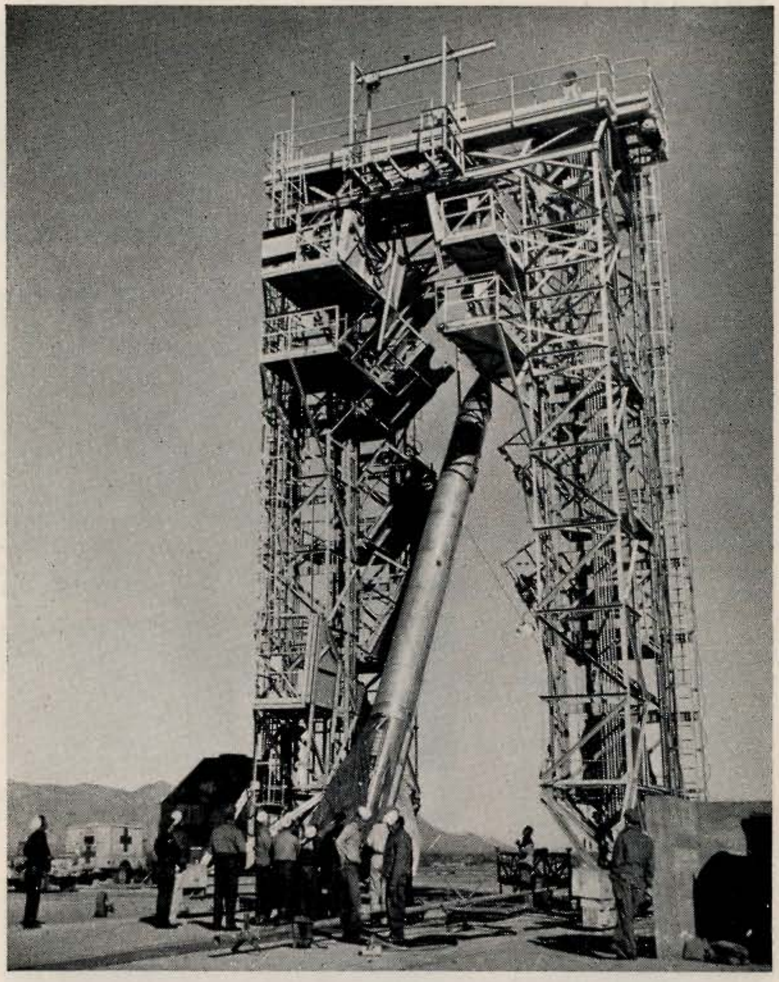
Matra O51 2-*stage solid fuel air to air guided missile. Supersonic. Proximity head. Weight* 350 *lb. Length* 10 *ft.*

Nord S.S.10 *wire guided solid fuel anti-tank missile.* 80% *accurate over* 1 *mile range. Launched from ground or aircraft. Weight* 35 *lb.*

Sfecmas 5103 2-*stage solid fuel air to air guided missile. Supersonic. Proximity head. Weight* 285 *lb. Length* 8.2 *ft.*



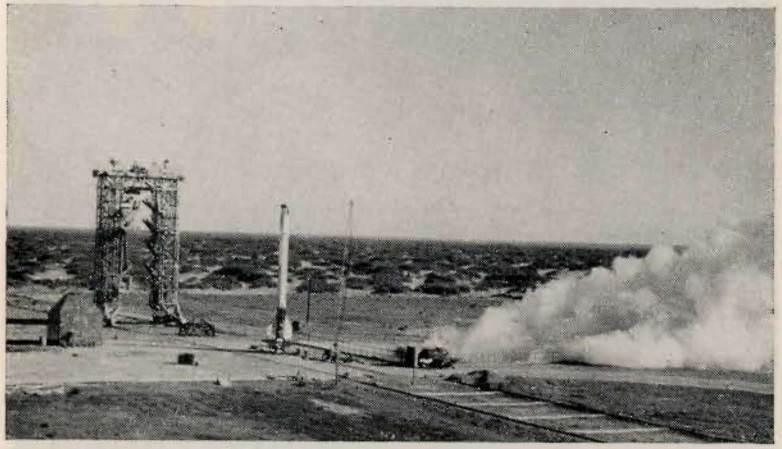
SE 4200 *surface to surface ramjet guided missile, booster rockets still attached. Range* 60 *miles. Speed high subsonic.*



## OPERATION SPACE

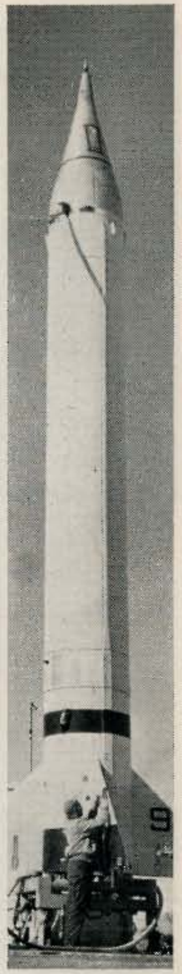
*The Glenn L. Martin Viking rocket was developed to supersede the captured German V-2s used by the Americans in* 1946 *to inaugurate their ambitious Upper Air Research programme. Although these photographs do not all show the same Viking, they give an idea of the complicated procedure required for launching a large research missile.*

*The rockets are made in the Glenn L. Martin Company's factory in Baltimore. Here some of the intricate electrical wiring is being installed.*



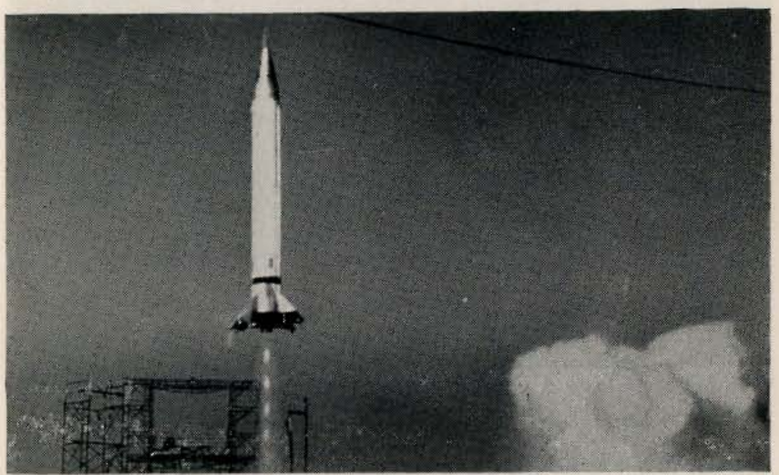
*After travelling by train to White Sands Proving Ground, New Mexico, the rocket is bolted to the launching platform and a test firing is made to check the motor. The hot exhaust gas is directed into a pit filled with water, producing the steam shown on the right of the picture. In the background is the gantry, with hinged platforms at various levels, which is used for servicing the rocket prior to firing.*

*If all goes well, delicate instruments to collect research data are placed in the nose. They can include instruments for measuring air density, cosmic and ultra-violet radiation, the strength of the earth's magnetic field and cameras to photograph the earth. They are recovered by parachute.*



*Nearly ready. The gantry has been moved away and a final adjustment is made.*

*Zero minus one minute. The launching bay, a hive of activity for several weeks, is strangely quiet. Two "firing imminent" flares lie burning on the ground.*



*Slowly, at first, the Viking rises into the air. In a few minutes it will be at the fringe of space.*

# Rockets into Space

So far in this little book we have been concerned mainly with what rockets have done, and what they have been used for, in the past. In the pages that follow, we shall see some of the exciting uses to which rockets will be put in the future, as well as a survey of the experiments being carried out *now*.

The most important non-military use envisaged for rockets in the future is as the engines of orbital satellites and, later, space ships. Now, why is it that only *rocket motors* are suggested as the power plant of space ships? Why could not a big version of one of the latest jet engines be used?

The answer is that almost all the engines used in aircraft, whether they be piston, turbojet, turboprop, diesel, ram-jet or athodyd, require an outside source of air. And, of course, there is no air in the vacuum of space.

A rocket motor, on the other hand, carries all the oxygen required for the combustion of its fuel and is thus independent of an external source of air for its functioning. So a rocket will at least burn in space. But will it work?

Many people still think it will not, because there will be " nothing for it to push against ". But a rocket does *not* work by the gas jet pushing against the air. It is the expanding gases *inside* the rocket that do the pushing, not the exhaust rushing out.

To help you understand just what happens, imagine a metal cylinder, closed at each end, as shown in fig. 1 opposite. Fuel is injected and exploded inside the cylinder. What happens? Nothing—because inside gases impinging on End A are balanced by gases pushing on end B. Similarly, gases acting upwards and trying to lift the cylinder are balanced by equal forces acting downwards.

Now imagine the cylinder open at one end, as shown in fig. 2. The fuel is replaced by a special bomb, weakened across the middle. The bomb explodes, and breaks into two pieces. Once again, the gases acting against the top of the cylinder are balanced by the gases acting downwards. But what has happened to the two ends of the bomb? End A flies to the left, out of the cylinder and away. End B, however, hits the closed end of the cylinder and pushes it along as shown in fig. 3 and 4. The principle of the rocket is as simple as that.

In a real rocket motor, the single bang of the bomb is replaced by a continuous series of explosions; but the principle is the same. The important fact to grasp is that it is not the rearward exhaust that does the trick, it is the pressure of the gas acting on the forward end of the combustion chamber.

It can be shown that the faster the exhaust jet leaves the rocket the bigger is the thrust trying to push it forward. The presence of air behind the rocket tends to impede the free flow of the exhaust and so makes it less efficient. In a vacuum there is no air to slow down the exhaust. So, not only will a rocket work in space, but it will work most efficiently there.

For a rocket to reach the speed of its own exhaust, it can be shown mathematically that it must carry nearly one and three-quarters of its empty weight in fuel. This means that if a rocket, empty, weighed 1 ton, then fully fuelled it would weigh 2.72 tons. This relation between the fuel-weight to empty-weight of a rocket is known as the mass ratio.

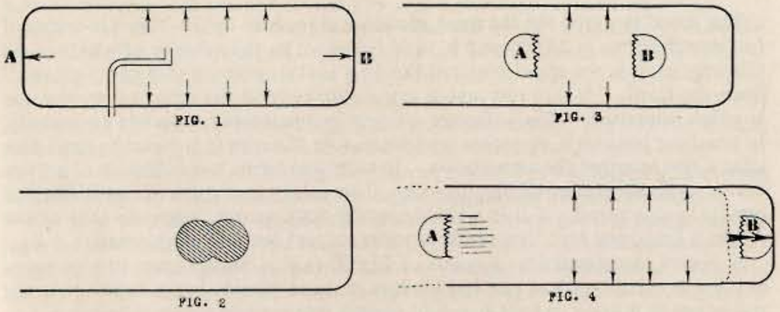


FIG. 1 FIG. 3 FIG. 2 FIG. 4

*How a Rocket Works*

Building a rocket with a ratio of 2.72 to 1 presents no difficulties. The now obsolete V-2 had a ratio of 3.23 to 1, while that of the Viking varies between 4.55 and 2.72 according to the particular payload.

For a speed twice that of its exhaust, a rocket would require a mass ratio of 6.4 to 1. A ratio of 19 to 1 would give a speed treble that of the exhaust (say 15,000 m.p.h.) In theory, a ratio of 1,000 to 1 would give a speed of 25,000 m.p.h., sufficient to overcome the gravitational pull of the earth; but such a ratio is, of course, quite impracticable. It would require a 1,000 ton space ship carrying 999 tons of fuel—leaving one ton for the structure, fuel tanks, instruments, equipment and crew!

In a modern high-duty rocket, the speed of the exhaust is around 5,000 m.p.h. The best mass ratio that seems to be possible is about 6.4 to 1; so the highest speed to which we can look forward seems to be twice that of the exhaust, or 10,000 m.p.h. This falls a long way short of the requirements of even a satellite rocket. But it does not mean that a space ship with a speed of 10,000 m.p.h. could not reach the Moon, or even that the journey would be exceptionally long.

This eternal quest for speed in space travel should, perhaps, now be explained. It is primarily a question of fuel economy and engineering practicability.

If you lift a heavy weight from one shelf to another you do so as quickly as possible. A rocket also finds it 'easier' to reach space if its initial speed is high.

We can calculate the amount of fuel required to lift a rocket; but this fuel itself will have to be lifted, which requires more fuel. This additional fuel requires yet more fuel to lift it, and so we have a vicious circle of more and more fuel required to lift itself! It is obvious that the slower the speed, the longer any unburnt fuel has to be carried, so that still more fuel will be required initially.

The only solution is to make the firing period as brief as possible. Ideally, the speed required should be attained instantaneously, as envisaged in Jules Verne's classic " *From the Earth to the Moon* ", but the excessive acceleration would kill the crew instantly. Within reason, though, the sooner fuel is consumed and its energy given to the space ship, the more economic it will be.

The speed required for the most economical journey to the Moon in terms of fuel requirements is 25,000 m.p.h., and is known as the velocity of escape. As this implies, it is the speed required before a rocket or space ship can "escape" from the Earth. It will not take a space ship beyond the reach of gravity—as is often supposed. The influence of gravity, in theory, extends to infinity. In practice, because it decreases with increasing distance it is virtually negligible after a few hundred thousand miles. In technical terms, the influence of gravity decreases as the square of the distance. This means that if the height is doubled gravity is quartered; if it is trebled, gravity falls to one ninth, so that as the distance lengthens into thousands of miles its pull becomes very small.

A rocket, accelerated to a speed of 25,000 m.p.h., would start to lose speed as soon as the motor was cut, but the loss in speed would always be less than the reduction in gravity so that it would always retain some forward speed.

It is important to emphasise that this speed of 25,000 m.p.h. is only of consequence whilst we consider the most economical way of reaching the Moon. If unlimited power ever becomes available—as it may when atomic motors have been evolved for use on space ships—then there is no reason why the journey to the Moon should not be made under continuous power at, say, a constant speed of 1,000 m.p.h.

For the moment though, using existing fuels, motors and techniques, the only practicable way to space travel is to accelerate to the escape velocity as soon as possible, cut the motor and then coast the remainder of the way.

*The German* Rheinbote *four-stage rocket was fired operationally against Antwerp in World War II. Take-off weight was* 1.7 *tons and the third step, which carried an* 88-*lb. warhead, achieved a speed of* 3,600 *m.p.h. and range of* 140 *miles.*

It may be of interest to mention here that the speed required to reach the Moon, 240,000 miles distant, is not much below that required to reach Mars or Venus, although these planets are many millions of miles away. The speed required to reach these planets is, in fact, only 26,000 m.p.h. Once again this is assuming the most "economical" routes, which means that for the greater part of the trip a space ship would be under the direct gravitational influence of the Sun. In each case, as during the journey to the Moon, rocket power need be used only for a few minutes at the beginning and end of the journey.

We have seen that the highest speed we can hope to achieve using existing fuels is about twice that of the exhaust, or 10,000 m.p.h. If developments likely to materialise in the near future are taken into account the speed is 18,000 m.p.h.; but even if the most optimistic view is taken regarding rocket motor design, fuel and mass ratio, the highest speed for which we can possibly hope is 20,000 m.p.h. This is still 5,000 m.p.h. below the all important escape velocity but, just when the prospect for space travel appears somewhat grim, a solution presents itself. If we construct a rocket able to carry a certain payload and let that payload consist of another rocket carrying the same percentage of fuel, then the smaller rocket can achieve twice the speed that either rocket could reach by itself. This is called a two-step rocket and, in theory, if we build a rocket with a sufficient number of steps, any desired speed may be attained.

A striking example of the step principle in operation, suggested by A. C. Clarke, former Chairman of the British Interplanetary Society, was provided by the conquest of Mount Everest. Hillary and Tenzing could not, by themselves, have carried the food, tents and equipment needed for the long journey from ground level to the peak and back. Instead, many hundreds of porters started the journey with them. After a time, a porportion of these men turned back, having carried their share of the load: and the remainder pressed on higher, with their loads still intact. In due course, still more turned back. Eventually, Hillary and Tenzing, unhampered by heavy packs, were able to make the final climb to the summit alone, leaving at a lower level the men who would again help to carry the food and equipment needed for the return journey.

Similarly, in the field of space travel, steps may be regarded as a means of overcoming the limitations of present day rockets.

In practice the solution is not the 'cure-all' it may appear. The payload of a modern rocket is about one twentieth of its total weight; thus each step must be about twenty times the weight of the step above. If a payload of one ton is assumed, the total starting weight goes up in this order; One step 20 tons, two steps 400, three steps 8,000 tons, four steps 160,000 tons.

Obviously the idea soon gets out of hand, and if, in the case of a 'Moon-ship' one has to cater for a landing on the Moon and for the return journey, the starting weight of even a 'minimum' ship runs into hundreds of thousands of tons.

At this point, where the whole idea of space travel again gets depressing, yet another solution offers itself. This is the possibility of refuelling in space. Like the step-rocket, the principle is already manifest in a hundred and one ways in everyday life. Some of these are discussed in the next chapter.

# Islands in the Sky

A DEFINITE step towards the conquest of space will be taken next year when the first of the American Vanguard satellites is launched. This tiny man-made " moon " will be the first of many objects which will become our neighbours in space in the years to come.

Its appearance in the night sky will not still all the voices which proclaim that men will never reach the Moon; but some of the doubters will fall by the wayside, and the remainder will be considerably quietened.

The first satellite will probably be equipped with recording instruments and a transmitter, which will send back badly-needed data on various aspects of the atmosphere at extreme altitudes.

This will confirm and add to the information already being obtained by American high altitude research rockets such as the Aerobee and Viking and, probably, by Russian missiles behind the impenetrable screen of the Ural mountains.

The height of 200 to 300 miles estimated for the first satellites, is not completely clear of the atmosphere. Friction of the rarefied air will gradually slow them down, causing them to spiral down to an untimely end in the denser atmosphere as artificial meteors.

Within a few years it should be possible to launch satellites into an orbit some 500 miles above the surface. At this height, in the vacuum of true space, they will continue to circle the earth indefinitely, without any further expenditure of power.

This will not be because they are ' beyond the reach of gravity ' for, as explained in the previous chapter, the influence of gravity extends for ever. It is gravity, in fact, which will retain a satellite in its orbit. The principle is very simple. As the satellite whirls round the earth its centrifugal force will try to take it straight on out into space. Gravity, however, will try to pull it back, and the effect of the two forces, which just balance, will be to make the satellite travel in an orbit, like the Moon.

Because the gravitational pull decreases with distance from the earth, the speed required to make the centrifugal force exactly balance the pull also decreases. This speed is known as the orbital speed, and for the first few hundred miles above the earth is about 18,000 m.p.h.

As soon as possible, every effort will be made to launch a satellite containing an air-conditioned compartment for animals, so that we can study the effects of the unknown qualities of space on living objects. Such a project has been discussed in considerable detail by Dr. von Braun, who is famous for his work on the V-2 rocket and is now engaged on missile development in America.

This ' baby moon ' of von Braun's comprises the top stage of a big 150 ft. high, 100-ton, three-step rocket. Launched vertically the two bottom boosters would be jettisoned when empty, the energy of their fuel having been imparted to the top stage. The designed orbit is 200 miles above the earth, where the slight air friction would enable the rocket to orbit for several weeks.

*Weather forecasting will become a much more accurate science when meteorologists have available continuously information of the kind shown on this picture. It was taken from a* Viking *rocket at a height of* 155 *miles and shows clouds over an* 1,100-*mile wide stretch of Texas.*

Externally the rocket is not particularly impressive, but inside it is crammed full of recording instruments, measuring dials, pressure gauges and complicated electronic equipment. In the extreme nose there is a compartment big enough to hold several monkeys. Von Braun considers it practicable to install television cameras in this, to transmit direct to earth the first exciting pictures of life in space. The monkeys would, for example, provide much vital information on the effect of prolonged weightlessness and other biological aspects of life under zero-gravity conditions.

The slight air friction would gradually slow down the rocket, causing it to fall towards the earth. Once in the denser air layers, friction would heat up the skin and the end would come rapidly. The temperature would rise, causing the skin to glow first a cherry red, then a bright orange and finally to form a white streak as the rocket disintegrated and melted.

To be as humane as possible, it is proposed that a quick-acting gas should be released to kill the monkeys painlessly before the cabin became uncomfortably hot. It is not a happy thought that the way to the stars will necessitate experiments of this nature; but the alternative is that men should venture into the unknown perils of space. The attendant risks are so great that few will query the necessity of using animals first.

Already we can foresee practical uses for orbital satellites, and there are certain to be more when satellites become established facts. One possible use concerns the transmission of television programmes. Television waves normally travel in straight lines and are effective only to the horizon. For this reason the T.V. masts scattered over the United States and Britain are made as tall as possible so that they cover the biggest possible area.

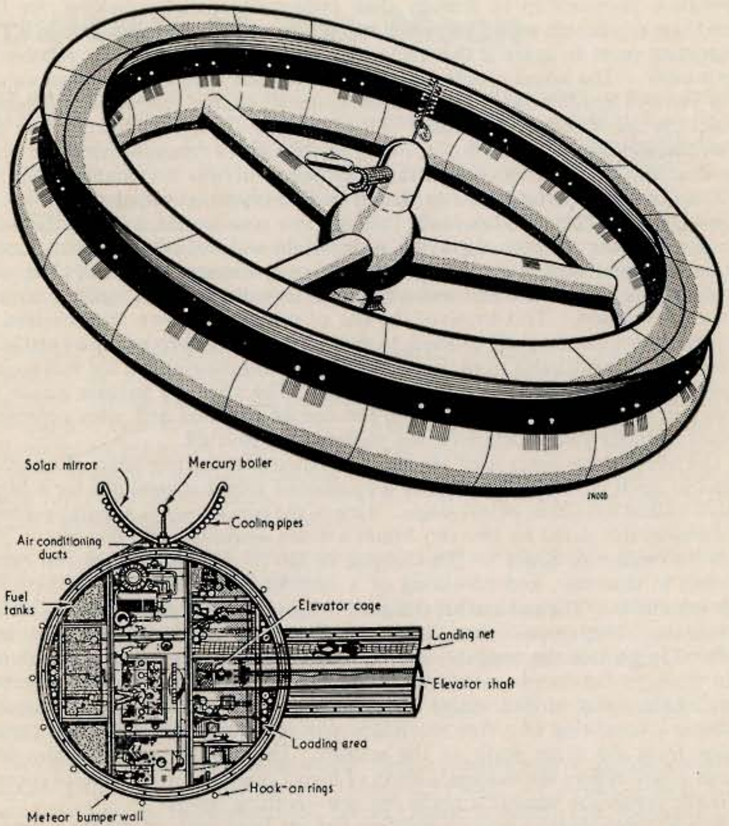
An artificial satellite, suitably positioned in space, could be constructed to receive a television programme from a transmitting station on earth and then re-broadcast it to a *third* of the world. The ideal height for such a satellite would be 22,000 miles. At this altitude, the orbital speed equals the rotation of the Earth, so that the satellite would remain as a fixed point over one particular spot on Earth. Three such satellites, equally spaced, could transmit a television picture over the whole world.

Similar satellites should prove invaluable for the correct forecasting of the weather. At the moment the world's meteorological offices are severely handicapped by a lack of knowledge of the extent of cloud coverage, particularly over ocean areas. An automatic television camera, in a satellite, could give them a constant up-to-date picture of such conditions anywhere in the world.

A tricky problem in the design of both the first small unmanned satellites and the later manned stations, will be the provision of a power source. An atomic pile appears to be the ideal answer, but it is likely to be a long time before these can be made either small or light enough to be a practical proposition. The first satellites will probably carry accumulators, but in time use will be made of a very obvious power source—the Sun—through the medium of either Solar-heated steam-turbine generators or solar batteries of the type announced recently by the American Bell Telephone Laboratories.

In time, perhaps 25 years from now, manned space-stations will be established. It will be much longer before we have lavish holiday-centre-cum-research laboratories of the type often depicted in glossy magazines. The first space station will probably hold only a crew of two or three. Instead of being assembled in space, it might well comprise a specially-adapted top stage of a big multi-step rocket. An advantage of this proposal is that the vessel could be assembled and thoroughly checked and tested on earth before being sent into space. Some loss of payload may be acceptable so that wings could be fitted. Although these would serve no useful purpose in the vacuum of space, except as platforms on which to load and unload supplies, they would enable a glider-style landing to be made back at base if anything went wrong during take-off, or later.

Some of the problems involved in the design of manned stations will be solved during experiments with refuelling in space. In aviation, flight refuelling has enabled aircraft with limited ranges to fly round the world without landing. In the world of space, it promises to make possible flights to the Moon and to the planets beyond.



*Large manned space station, based on the designs of Dr. Wernher von Braun.*

Why is it that orbital refuelling is so important to interplanetary flight? We have seen that there seems little chance of reaching the speed of 25,000 m.p.h. required to get away from the earth either in one go, or even with a step-rocket. The speeds likely to be attainable, however, are sufficient to put a rocket into an orbit around the Earth.

A rocket could take off, climb to its orbit, and then circle the earth indefinitely without further expenditure of fuel. Other rockets carrying additional fuel could then be launched into the same orbit. The fact that refuelling would be carried out with both ship and tanker travelling at a speed of around 18,000 m.p.h. often raises doubts as to its practicability. In fact, in some ways the operation promises to be simpler than present-day aerial refuelling, for the condition of vacuum means there will be no air resistance to worry about. The important point to grasp is that the vessels would appear stationary relative to each other. The actual speeds are of no importance so long as they are equal.

If you still find this hard to believe, ask yourself whether you had any difficulty in getting out of bed this morning? Of course not—in spite of the fact that the floor was moving at 55,000 m.p.h. owing to the Earth's rotation round the Sun. Because the bed was moving at the same speed, it was no trouble at all!

A space station orbiting the earth will be in a condition popularly known as 'weightless'. This does not mean that you lose your weight, but that, because you are obeying the pull of gravity, your weight will not be apparent. It will be a condition which, if not actually harmful over extended lengths of time, will be decidedly unpleasant and awkward. Fortunately, there is again a simple practical solution. This involves the use of centrifugal force and the idea is that the space station shall be made to spin on its axis, so producing an artificial gravity indistinguishable from the real thing. To the crew inside, the wall would become the floor, and "down" outwards. The spinning motion could be imparted by small rockets pointing in the desired direction and, once obtained, would continue indefinitely after the rockets were shut off.

The wheel-shape lends itself readily to rotation and the provision of artificial gravity; so it is not surprising that a number of recent suggestions for a large space station have been of this shape. One of the best known is a design evolved in considerable detail by Dr. von Braun and his associates and featured in the film "*Conquest of Space*". This station is 250 ft. in diameter, the rim being 30 feet in diameter, and consisting of a number of flexible nylon-and-plastic fabric sections. The sections are designed to be carried to the orbit in a collapsed condition. They would then be joined together, sealed against leaks and inflated to provide the necessary rigidity. Internal structure, such as the floors and walls, would then be added to provide the living quarters and laboratories. One of the many novel features of this design is the provision of a 'meteor-bumper', consisting of a thin secondary skin of metal supported a few inches away from the outer walls of the station. This would vapourise any tiny meteors and reduce the damaging effect of bigger ones. It would not, of course, provide protection against a really big one—nothing would!

Readers may wonder why no mention has yet been made of the use of space stations for military purposes. Many eminent authorities consider that manned stations have considerable military significance and that once they appear no area of earth will be safe from bombardment by missiles from them.

A space station, permanently established beyond the atmosphere, might have some use as a super spy-base, under which no nation could undertake preparations for war without being observed. But this seems to be the most warlike use for which space stations will ever be suitable!

We can rest assured that by the time one nation has advanced sufficiently to establish stations capable of launching and guiding missiles to targets on earth, others will have mastered the less difficult task of devising a surface-to-space missile capable of blowing the space station to bits.

# Journey to the Moon

WHEN the first journey to the Moon, 240,000 miles away, is made it will be the longest voyage ever undertaken in the recorded history of Mankind. In recent years this exciting event has been described in hundreds of ways in books, magazines, newspaper articles and films.

Before this particular chapter was prepared, a careful survey was made of the latest engineering thought on the subject. The methods and techniques described and the various impressions given are based on how people currently engaged on the development of missiles envisage the accomplishment of such a journey. They provide an insight into the basic mechanics of a journey through space.

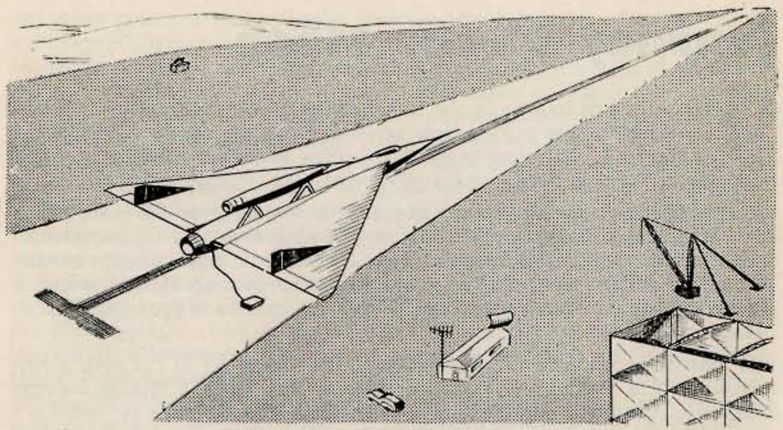
It must be emphasised that, as has happened frequently in the past, a new invention, or a particularly rapid development in one field of science, may completely change the outlook and make the story as out-of-date as yesterday's newspaper. One such 'dark horse', already hovering in the background, is the atomic rocket motor. In fact, whilst agreeing that it will be technologically possible to reach the Moon using conventional liquid-propellant rocket engines, many rocket specialists believe that it will be better to wait a few years until a suitable atomic drive has been evolved.

For the purpose of our story, however, we are assuming that the voyage is made by chemically-powered rocket.

The journey is made in two stages: from Earth Base to an orbit 300 miles up, and from the orbit to the Moon. The first hop is made with the assistance of a delta-winged vessel remarkably similar to some of the supersonic fighters flying today. The Moon-ship is carried through the denser lower layers of the atmosphere pick-a-back fashion by a much bigger and heavier ramjet-cum-rocket piloted aircraft.

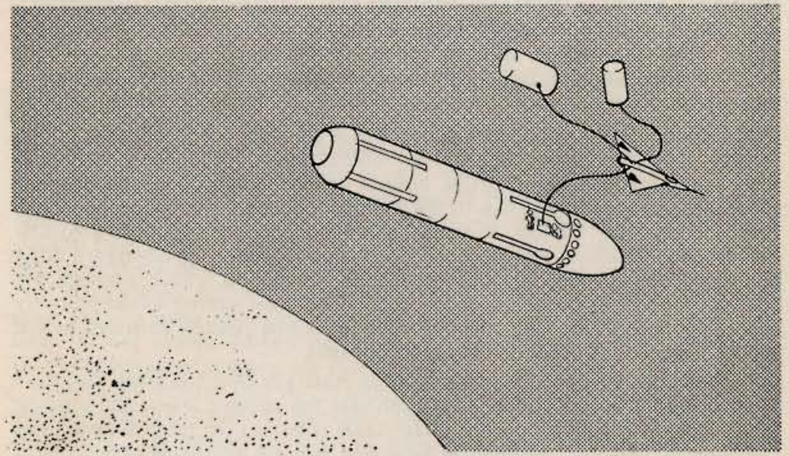
Not all authorities are convinced that this is a better way of achieving orbital velocity than the "conventional" three-step rocket. The pick-a-back idea would certainly be more expensive, both in first cost and in fuel consumption; but this appears to be well offset by the fact that the carrier aircraft, being piloted, could be used any number of times. Elaborate schemes for landing rocket-boosters by parachute, with the final impact shock lessened by downward firing jets, have been suggested, but these appear impractical. Such boosters are intended to alight in the sea, which in any but the calmest weather would probably cause damage. Even those alighting safely would be severely corroded by the action of sea water before they could be salvaged.

For our project, Earth Base is located in Australia near the great Woomera rocket-range. Ideally it should have been near the equator, where the rotation of the earth would have added a useful 1,000 m.p.h. to the take-off speed, but the immense resources available at Woomera are an advantage considered to outweigh that of a bit of "free" speed.

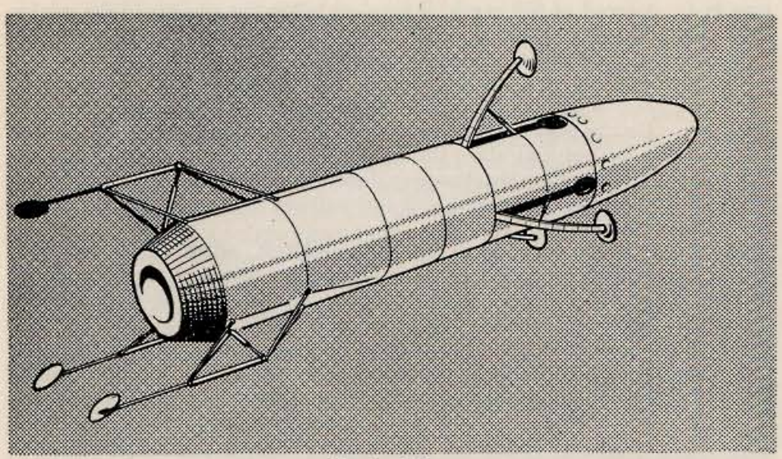


Moon-ship on booster aircraft.

Let us imagine that we have a ring-side view of this imaginary first journey to the Moon. From our point of vantage we can see the great carrier-aircraft, with the much smaller bullet-shaped Moon-ship supported in a cradle on top of its massive wing. The crew of both craft are in position and the time for take-off is imminent.



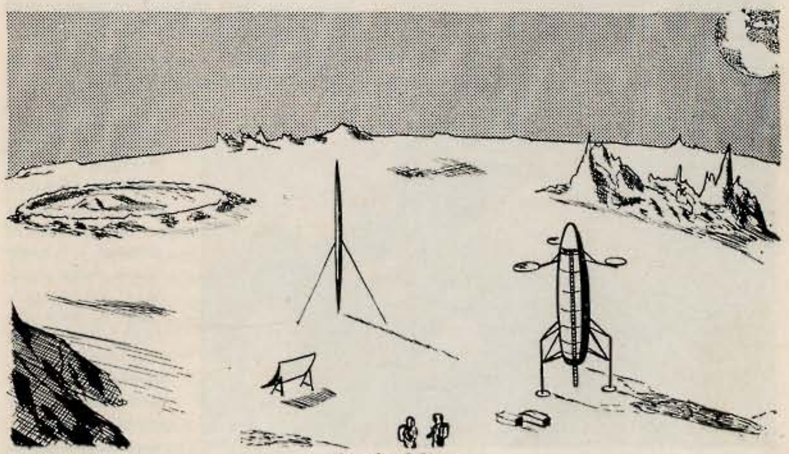
Refuelling the Moon-ship.



To the Moon.

Years of preparations, months of construction, weeks of adjustment and days of checking have preceded this ‘zero-hour’. Contact for firing is made by the Firing Officer in the concrete block-house a hundred yards to one side.

To gain the speed required to enable the booster-craft to lift its heavy load, it accelerates along 10 miles of concrete, forming the longest and flatest runway



On the Moon.

ever laid. A speed of 500 m.p.h. is required before the ramjets of the carrier-craft can function and this is attained through the powerful thrust of Jato rockets before it is half-way down the runway.

The fierce acceleration forces the crew deep into the rubber foam of the take-off couches. There is nothing for them to do except grit their teeth and try not to black out. On this part of the journey only the crew of the carrier are on duty and even they are not controlling the take-off, which is purely automatic. Once airborne there is a noticeable change in direction as the nose of the big craft is lifted for the tremendously steep climb that will end only when orbital height—300 miles—is reached.

Rapidly the height increases to 40,000 ft., 50,000 ft., 60,000 ft. Soon the air is too thin for the ramjets to operate, and the carrier switches over to her rocket motors. Once again the acceleration presses the crew into their couches as the speed builds up rapidly—10,000 m.p.h., 15,000 m.p.h., 17,000 m.p.h., 18,000 m.p.h. Soon after the speed indicator passes this figure, the powerful rocket motors are turned off and the pair of ships, resembling some long extinct bird carrying its young, coast upwards in utter silence. At orbital height, the speed has fallen back to 18,000 m.p.h., which is the speed required for centrifugal force to balance exactly the earth's gravitational pull, and a few short bursts with the steering jets place them in the correct attitude.

Leaving their couches and crossing to an observation port, the crew can just make out the dim shape of two large cylinders, poised in space and only a few hundred yards from them. These are fuel containers, brought up some time previously by carrier aircraft similar to the one which bore the Moon-ship aloft.

*Pressure suits like this, designed to enable pilots to breathe and to prevent their blood from boiling if the pressure cabin of their aircraft failed at extreme heights, would probably be suitable for flight into space.*

Before the ship is fuelled, separation takes place. The great catches securing it to the cradle are withdrawn and then, after a brief burst from jets in the top of the carrier's wings, the two ships slowly part. Although orbiting the Earth at 18,000 m.p.h., they appear stationary in the black emptiness of space.

Hatches in the carrier open and space-suited figures emerge to carry out the fuelling operation. Pipe-lines are joined from the tanks to the carrier and a second line taken from the carrier to connections in the outside of the hull of the Moon-ship. Pumps in the carrier then rapidly force fuel aboard. In about an hour the Moon-ship's weight increases from 50 tons to 300.

There is about an hour to wait before the Moon-ship starts on the second, and final, leg of the journey and the crew of three spend the time checking and rechecking the various gauges and controls which are their own responsibility.

Fifteen minutes to zero-hour, timed so that at the moment of firing the Moon will be in the correct position relative to the earth, and the Captain starts to ' Position Ship '. This means that the ship is turned so that it points in the right direction. This is effected by flywheels; and, as they spin, the ship slowly starts to rotate in the opposite direction.

' Motor-on '. The engineer pulls a lever and a wisp of vapour issues from the open mouth of the rocket motor.

' Run-up '. A second lever is pulled and the trail of vapour turns into a tongue of flame. The noise penetrates the cabin. A dozen gauges are scrutinised; all are functioning as they should.

' Fire '. The engineer pulls the last lever. With a terrific whine the propellant pump rapidly builds up to full thrust. The noise is deafening to the crew and for the third time on the trip they are thrust into the couches. The period of firing is relatively brief and it does not take long for them to gain the additional 7,000 m.p.h. required to reach escape velocity.

' Cut Motor '. The engineer returns all three levers to neutral and with startling suddenness the motor roar dies away.

At the instant the motor cut, the acceleration ceased and, if it had not been for the restraining couch straps, the crew would have shot across the cabin into the wall opposite. They are, of course, weightless. At first it is quite fun " Peter Panning " about the cabin, but a few cracks on the head soon end the fun and games. It is, in fact, extremely awkward. Even a simple act like blowing his nose is liable to start a crew member rotating, catherine-wheel fashion, and an attempt to reach something more often than not results in the person moving away from the object. By fitting on magnetically soled shoes, and using straps when sitting down, some semblance of order is restored.

Now is the time, perhaps, to say a few words about the Moon-ship. Externally it looks very much like an airliner minus its wings, because it is perfectly streamlined, In the vacuum of space this is quite unnecessary, but the first part of the journey was made through the atmospheric envelope.

Recessed snugly into the skin are various radio and radar antennae and the three massive shock-absorbing landing legs. These will be extended during the journey and locked in position.

Internally, the Moon-ship is divided into five main bays. First, in the extreme nose, is the cabin. Behind is a compartment almost as big (or as small, depending upon one's point of view) containing the airlock, stores, oxygen and water storage cylinders and equipment for which easy access will be required during the journey. Then comes the fuel tank section, occupying well over half the length of the ship, followed by a small compartment containing pumps and turbines. In the extreme tail is the huge rocket motor.

The journey commenced at a speed of 25,000 m.p.h. and, because the distance between earth and the Moon is approximately 240,000 miles it might be thought the journey will take less than 10 hours. In practice it will last about five *days*. The reason for this is our old friend (or enemy) gravity. From the moment the motor was cut, the Moon-ship commenced to lose speed, owing to the retarding effect of gravity. However, the reduction in speed is always a little less than the reduction in gravity so that the ship continues to move forward.

Ever more slowly, it will draw nearer to the Moon. Then, when the speed has dropped to a few hundred miles per hour, it will cross over the neutral ' point ' between the earth and Moon, where the gravitational pull of each body cancel one another out. This occurs about 22,000 miles above the surface of the Moon and, once over this point, the Moon-ship will be under the influence of the Moon's gravitational pull. It will start to accelerate at ever-increasing speed and, if unchecked, would crash into the surface at 5,200 m.p.h.

Long before this can happen, the flywheels will be manipulated and the ship rotated so that it approaches the Moon tail-first. The actual landing area will almost certainly have been surveyed earlier from low altitudes by robot rockets because, at the moment, even through our most powerful telescopes, we cannot distinguish objects on the Moon less than several hundred feet across. The so-called ' plains' and the centres of many of the craters appear smooth and flat, but they might well be strewn with great boulders, or be scarred by deep crevices wide enough to swallow a space ship whole. To reduce the possibility of such a catastrophe, reconnaissance rockets will have obtained close-up pictures of the surface and trial landings will have been made by robot craft.

The Moon-ship falls freely towards the Moon until it is within a hundred miles of the surface. For the same reasons that it is more economical for a rocket leaving the earth to accelerate as rapidly as possible, it will be more economical for the Moon-ship to lose speed quickly. If it started to slow down too soon, precious fuel would be wasted. The procedure is likely to be rather complicated and the last few miles of the descent will almost certainly be made under automatic control. The main task will be to keep the ship dead vertical, so that the rocket jet is pointing straight downwards.

When the ship is within a few feet of the surface, its speed is neutralised and the shock of final touch-down is taken by the landing legs.

This, then, is the way to the Moon. It requires no new " inventions ", just steady development and improvement of existing fuels, rocket motors and techniques. It is an event on which work has already started. There is a good chance that many of the younger readers of this book will witness the climax on their home television screens some time before the turn of the century.

# Ships of Space

ALTHOUGH it will be many years before journeys through space become practicable, it is already evident that several different types of space ship will be needed.

Basically, it seems that there will be two main types: a winged ferry-ship to take material, supplies and crews up to orbits round the Earth, and then return, and the " deep-space " type of ship, which need never land on any planet.

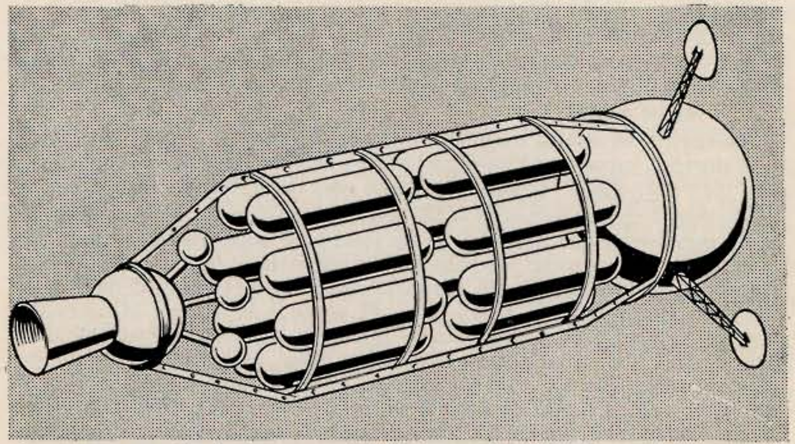
The ferry-ship may be similar to the carrier-Moon-ship combination described in the previous chapter, or it may be the winged top stage of a three-step rocket. A design for such a rocket has been worked out in detail by Dr. von Braun and his associates. Designed to lift 36 tons of cargo into an orbit 1,075 miles above the earth, it stands 265 ft. high at take-off, which is as tall as a 24-storey skyscraper. Fully fuelled it weighs nearly 7,000 tons, of which over 6,000 tons are propellants. It is driven by three huge power plants, each made up of a number of small rocket motors. The power plant of the bottom stage comprises 51 rocket motors developing a combined thrust of 14,000 tons. Thirty-four rocket motors, with a total thrust of 1,750 tons power the second stage; while the winged top stage, the ferry-ship itself, has five motors giving a thrust of 220 tons.

The take-off procedure is envisaged as follows: Initial firing would be vertical, but after a few seconds the rocket would tilt into a shallow path almost parallel to the surface of the earth, so that the first stage, instead of struggling against gravity, could devote all its energy to building up speed. It is calculated that the 5,000 tons of propellants in the booster would be used in the incredibly short time of 84 seconds, after which a speed of 5,256 m.p.h. would be reached. The now-empty booster would be jettisoned and the motors of the second stage would fire, increasing the height to 39.8 miles and the speed to 14,364 m.p.h. The second-stage would then be jettisoned, to land " at a distance of 906 miles from the launching site, slowed down by the braking power of small solid-fuel rockets functioning just before ditching ". Now on its own, the motors of the winged top stage would fire to push the speed up to 18,468 m.p.h. This would be achieved at the surprisingly low height of 63 miles, and the vessel would then coast upwards until it was 1,075 miles above the surface of the earth.

If the various firing periods had been accurately controlled the vessel would by then be very near its desired position. However, even a small error would result in a " miss " of several miles and final positioning would be made by short bursts from the small steering jets.

After transferring its cargo, whether it be propellant tanks, supplies, crew members or the pre-fabricated parts of a space-station or space-ship, the vessel would return to earth.

If left to itself the craft would continue to orbit the earth indefinitely, in the manner of a space-station. Because its speed would prevent it from ' falling ' back to earth, the only way it could return would be by losing this speed. It is not commonly appreciated that such a move if effected entirely by rocket braking would require as much fuel as that required for the initial build-up to orbital



*Possible layout of a deep space rocket. The crew would be housed in a spherical cabin at the nose, separated from the rocket motors by a ring of fuel tanks. Streamlining would be unnecessary in space.*

velocity! This would impose a crippling weight penalty on the design of the ferry-ship; but fortunately a simple but ingenious solution to the problem has been suggested. It is called aerodynamic braking and would work as follows:

First of all the rocket would be " turned round ", either by the use of small steering jets, or flywheels, so that its main motors pointed in the direction of motion. The motors would then be fired for a few seconds, to reduce speed slightly. The circular orbit would become elliptical, with the result that the ship would in effect fall back towards the earth, grazing the atmosphere for a distance of some thousands of miles. With the vessel pointing once again in the right direction, air resistance would tend to slow it down. Next time round it would cut a little deeper into the atmosphere, the increased resistance reducing the speed still further. As speed was lost, air friction would heat the machine, perhaps to red heat, and care would be necessary to ensure that it did not become too hot and end its days as a " manned meteor ". After two or three circuits, most of the unwanted speed would have been lost and the rocket would remain wholly within the atmosphere.

Towards the end of the trip, braking parachutes might be used, and the final touch down would be made glider fashion, at a speed probably less than that of many aircraft flying today!

Aerodynamic braking is of immense importance in the future picture of space travel. It not only promises to reduce dramatically the fuel requirements of re-landing on earth, but also for landing on *any* planet that has a sufficiently dense atmosphere, such as Mars and, perhaps, Venus.

Should the ferry-ship be of the type that is carried aloft by a mother aircraft, a delta-wing design would probably be simpler than the narrow swept wings envisaged on the von Braun top stage. The re-landing technique, however, would be identical to that already described.

As envisaged in the chapter describing the journey to the Moon, early Moonships may well be adapted from ferry-craft. For reasons of safety and convenience they will probably be assembled on earth and then modified in space by the removal of such unwanted items as wings, fin and undercarriage and the attachment of additional fuel tanks and shock-absorbing legs for the touch-down on the Moon.

In time, it will be more economical to construct them entirely in space. This brings us to the second main type of space ship, which will be used for true interplanetary travel. Assembled from prefabricated parts carried up to an orbit by the ferry-craft, their function will be to travel from an orbit round the earth to an orbit round the Moon, Mars or any other planet. These ships, never intended to land on the surface of any planet, will differ in one basic respect from the ferry-craft. Operating only in the vacuum of space they need not be streamlined, and will probably be quite unlike the popular conception of a space ship.

There will be no need for the propellant tanks to be squashed one behind the other so that they can be neatly faired in. The tanks can be of any shape, held together by light structural members in whatever pattern engineering considerations deem best.

Another important difference between these deep-space type of ships and the ferry-craft, is that they would not have to withstand the heavy forces imposed on ships taking off from the surface of the earth. Starting from an orbit round the earth, the desired speed could be built up slowly, the process taking hours or even days.

Deep-space ships need therefore be strong enough only to withstand the forces produced by gentle acceleration and light turning manoeuvres. These will probably be about one hundredth of those of a ferry-ship, with a consequent valuable saving in structure weight—and reduction of weight in space ships is going to be even more important than it is in aircraft today!

Smaller types of space ship might include a space-taxi, for journeys from ferry-craft to space stations and deep-space ships; and what Dr. von Braun has expressively named landing-boats. As the name implies, these would be used for landings on planets with atmospheres, so that aerodynamic braking can be used to lose unwanted speed. On a journey to, say, Mars, one or two such craft would be carried by larger parent ships, the wings being assembled in orbit upon arrival. Such a technique was cleverly presented in the film *Conquest of Space*.

If one looks far into the future, one further type of space ship will be required. It is now almost certain that, except for crude vegetation, there is little chance of finding life on any of the planets of our solar system. The most exciting life that can be expected is, perhaps, a low type of animal on Mars.

If, then, Man is ever to gain the supreme experience of all time and make the acquaintance of other beings on planets that undoubtedly exist near other stars in the galaxy, it is to the stars that his eyes must ultimately be turned. (Unless, of course, they visit us first!) And, once journeys to the stars are contemplated, the whole conception of space travel changes, because of the tremendous distances involved.

Proxima Centauri, the nearest star to our own solar system, is 24,696,000,000,000 miles away, a figure so unwieldy that in astronomical circles it is usually referred to as 4.2 light years—a light year being the distance covered in one year by light, travelling at a speed of 186,000 miles a second.

A spaceship travelling at 25,000 m.p.h. would take over 100,000 years to cover such a distance, with an equal time required for the return journey. Such a voyage, although theoretically possible with a special type of space-ship, is rather outside that normally envisaged for a "journey"!

It is obvious that extremely high speeds will be required if even the nearest stars are to be reached in any sort of reasonable time.

As we understand things today, the maximum possible speed is that of light, or 670,000,000 m.p.h., for as this speed is approached some peculiar things begin to happen. For example, it now seems certain that, as the speed of light is approached, time appears to slow down. At the speed of light, time would appear to stand still! This is very hard to believe, but already has been partially demonstrated experimentally.

The sort of effect that can be expected on a journey to another star can be imagined if we think of a space ship accelerating continuously at 2 gravities for about one year. So far as the crew are concerned a speed equal to 98 per cent of the speed of light would be reached in that time. To observers on earth, however, the ship would have been accelerating for over *five* years.

Thus, speeds near that of light might make it possible for crews to travel to a star and back in a single lifetime, although the return would be to an earth that had 'aged' much faster than the crew!

Travel to the stars is theoretically possible at more reasonable speeds and with the kind of space ships already referred to. These would resemble miniature worlds, containing air, fuel, food and water sufficient for hundreds if not thousands of years. They would, in fact, be completely self-contained, supporting whole families. The occupants would have to be prepared to exile themselves in space; and it would be children of about the fifth generation that finally arrived at the star and those of the tenth generation that would be alive upon the return to earth. They would, of course, return to conditions quite unlike those existing when their forefathers had set out. The suggestion for such a space ship is not so ridiculous as it may at first seem, for we are already taking part in such an interstellar voyage on a massive "space-ship" called Earth!

# The Journey has Started

TWO years ago Major Arthur Murray of the United States Air Force was launched like a bomb in the bullet-shaped Bell X-1A research aircraft from the belly of a Superfortress mother-plane 35,000 ft. over the Californian desert. After firing the four barrels of the aircraft's 6,000 lb. thrust rocket-motor, he pulled back the control column and began a steep climb that carried him to around 90,000 ft., higher than any man had ever been before.

90,000 ft.—17½ miles—is not much compared with the 240,000 miles that separate us from the Moon. Or is it? Perhaps it sounds more if we recall that at the peak of his climb Murray was above 96 per cent of Earth's atmosphere, that as he levelled out he experienced the weightlessness of space-travel. If he had taken the pencil from his knee-pad and released it anywhere inside the small cockpit, it would have remained suspended in mid-air. Little wonder that jet-pilots find this sudden weightlessness disturbing at times, and that its long-term effects are one of the unknown quantities of space travel.

To find out more about the effects of weightlessness, U.S. pilots have carried out a programme of test flights in the rocket-powered Douglas Skyrocket, in which they have climbed steeply, then begun to flatten out like the trajectory of a shell. In this way, they have sometimes remained weightless for up to half a minute at a time, with no apparent ill effects—but it remains to be seen how the body reacts to hours and days of weightlessness.

Acceleration itself is another problem, because the average human being finds an acceleration of 4 "g"—four times the acceleration of gravity—about as much as he can take without blacking out. Anyone who has seen a film of a V-2 or other large rocket taking off will know that it starts unbelievably slowly, lifting only a few feet in the first few seconds. But later on its acceleration is very much more rapid as its fuel is burned and its weight reduced.

Here again, a start has already been made. Giant "whirling arm" devices called centrifuges have been built in many places, including the Royal Aircraft Establishment at Farnborough, in which men can be subjected to varying accelerations and decelerations to study their reactions. At the moment, such tests are concerned, not with space travel, but with deciding the performance safety limits of the new generation of rocket-fighters, supersonic bombers and research aircraft taking shape in our factories. There would be little sense in producing a fighter able to climb to 60,000 ft. in one minute if the pilot were unconscious when it got there! But, of course, the centrifuge test results will be valuable when the time comes to send the first man into space in a rocket.

He will not be the first living creature to make the journey. Ruggieri's rats and mice probably did not fly very high in their "firework" rockets in the 19th Century; but a number of fruit flies were carried to a height of 106 miles in a V-2 rocket in America in 1947. Their cabin was ejected from the rocket when it began its descent and they dropped the last 100,000 ft. under a large parachute.

This proved that short exposure to cosmic rays above the screen of our atmosphere is not fatal to life: and it was decided to extend the experiments to test

Bell X-1A *research aircraft being carried to its launching height under an EB-29 Superfortress mother-plane. The X-1A has reached a height of* 90,000 *ft. and speed of* 1,650 *m.p.h.*

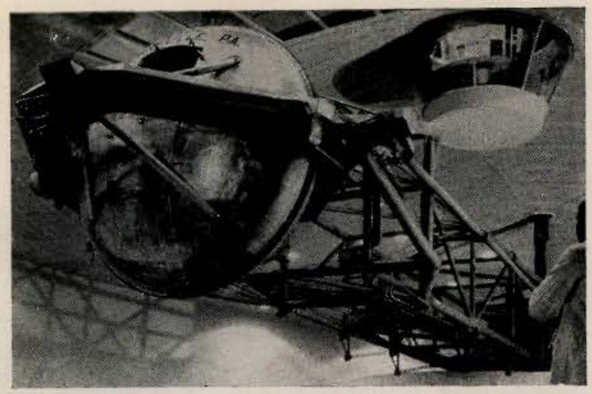
also the effects of acceleration and weightlessness on larger creatures. As a start, five monkeys were sent up more than 80 miles in a V-2. Each was given a morphine injection before take-off, so that it became unconscious, and was then sealed into a pressurised capsule in the rocket, complete with its own oxygen mask. Instruments attached to the monkeys' bodies measured their blood pressure, heart action, pulse and breathing, and radioed the data back to Earth continuously throughout the flight. Unfortunately, only one of the capsules reached the ground safely at the end of the experiment and the monkey it contained died of exposure before it was found.

Later experiments had a happier ending. In 1952, for example, two mice and two monkeys survived a flight to a height of about 37 miles in an Aerobee rocket, during which they were subjected to an initial acceleration of 15 " g " for nearly a second and 3-4 " g " for the next 45 seconds. The monkeys, being unconscious, knew nothing about it and were none the worse for their journey into space. The mice were not made unconscious and their movements were filmed throughout the flight. Apart from a certain amount of panic on the part of one of them, when he found himself suspended in mid-air in the cage for three minutes during the " zero-gravity " period, they too seem to have found nothing disconcerting in their experience.

No doubt many more animals will follow these monkey and mice pioneers into the dark emptiness of space before the first men are able to do so. But the first human space-flight may take place sooner than we think, and in an aircraft not far developed from the ultra high-speed research machines of today. It was announced in 1955 that the North American Aviation company have been given a joint U.S.A.F.-U.S. Navy-N.A.C.A. contract to develop a rocket-powered research aeroplane able to reach a speed of 6,600 m.p.h. at a height of 50 miles and an ultimate height of 100 miles—nearly six times as high as Major Murray's unofficial " record " climb. There is no reason to believe they will fail to do so.

Ten years ago, there were many sceptics when Bell Aircraft were reported to be working on an aircraft to fly at nearly 1,700 m.p.h. Many pilots had been killed trying to crash through the so-called " sound barrier " at only 660-760 m.p.h. Today, the sound barrier is only a yardstick by which we measure performance and a Bell X-1A *has* flown at 1,650 m.p.h. Already, the Bell X-2 has been built to carry on the work at speeds up to 2,300 m.p.h., where it will run into another " wall "—the heat barrier.

*This giant centrifuge can achieve accelerations of up to* 45 *"g" in under* 7 *seconds. The man under test sits in an aircraft seat in the pressurised gondola, which can be rotated to simulate high-speed turns, dives and pull-outs.*



Ordinary aircraft materials would soften and the airframe would break up at such speeds, because of heat caused by friction of the airflow over the aircraft's skin. At 2,600 m.p.h., for example, the skin would heat up to 900 degrees F. in a minute if nothing were done to stop it. Something *will* be done and the problem will be overcome by the combination of careful design, new materials, refrigeration systems, perhaps even a " perspiration " system in which a substance such as liquid helium will be forced through tiny pores in the skin so that it vapourises and carries off much of the heat.

The lessons learned in building such aircraft will help to pave the way for space flight: and the experiences of the pilots who fly to 528,000 ft. in the North American aircraft and 2,300 m.p.h. in the Bell X-2 will help to prepare space-pilots for some of the effects they will encounter.

There are many unknowns at the moment, apart from the effects of acceleration and prolonged weightlessness. Most important may be to learn more about the potential danger of long exposure to cosmic and other radiation; and this is something we shall not be able to investigate until we have earth satellites large enough to contain animals. Similarly, we believe that the danger of damage by meteorites is small; but we shall not be certain until we can send a rocket into space for days on end.

A start on the task of accumulating this final vital knowledge will be made in the next two years with " Project Vanguard ", under which the Americans plan to launch a number of artificial satellites into orbits between 200 and 800 miles above the earth in 1957. Cost of the project will be about £10 million.

As many as 12 rockets will be launched, of which it is hoped that at least five will be successful. Each will be a three-step rocket, the third step carrying the

PROJECT VANGUARD. *The earth satellites which will be established in space within two years under America's £10 million Project Vanguard will be about the size of this model, which has a perspex shell to reveal equipment inside.*

satellite, which will be about the size of a beach-ball and filled with scientific instruments to measure and telemeter back to Earth data on such things as ultraviolet and cosmic radiation and air density.

After tests of the individual steps, the complete Vanguard units will be fired from Patrick Air Force Base, Cocoa, Florida, and the " baby moons " are expected to orbit the Earth every 90 minutes at a speed of 18,000 m.p.h. for at least 30 days. Their path will be observed visually by astronomers from Harvard University, and by hundreds of other scientists, all over the world.

Even Project Vanguard may seem small stuff compared with the sort of space-flight projects we read about in the comics and science fiction. But if it is successful, it will represent a tremendous step forward in the conquest of space, lifting rocket speeds in one jump from 5,100 to 18,000 m.p.h.—the speed needed to make manned space-flight possible, via the stepping stone of orbital refuelling.

How quickly we advance beyond " Project Vanguard " is anybody's guess. The £10 million it will cost is a pittance to the United States, which will spend over £2,400,000,000 on military aircraft alone during the 1957 Fiscal Year. But it may be reluctant to spend more on an enterprise that appears to have no military value. Russia, the only other country that could afford to finance the exploration of space, probably feels the same, despite the " prestige " attraction of being first to send even an unmanned rocket to the Moon.

So, true space-flight, as opposed to the establishment of satellites, may have to wait until nations either settle their differences or, at least, find some way of reducing the vast sums they now spend on armaments—unless some cheap, revolutionary new fuel is discovered. It is part of the wonder of our age that great discoveries often come suddenly. Who knows? Perhaps we in Britain, with our pioneer leadership in atomic science, may discover the source of energy which will make the Moon itself a mere stepping stone to the stars.

Published by Ian Allan Ltd., Craven House, Hampton Court, Surrey and
Printed by Crampton & Sons, Ltd., Sawston, Cambridge