'The mightiest machine in the world'

Millions of words have been written in the last few days as the world awaits the outcome of the Apollo 11 mission. Not surprisingly the stage has been dominated by the three astronauts who will land on the moon. We join with all men of goodwill in wishing them success. But the welter of publicity focussed on the astronauts casts a long shadow which tends to obscure the extraordinary achievements of the thousands of specialists whose technical accomplishments have made the moon landing feasible.

The astronaut, though a considerable technologist himself, basically plays the role of pilot, albeit a pilot of immense expertise and courage. But it is to the army of technical experts behind the Apollo programme that the accolades should go.

This special issue of *The Engineer*, dealing with the engineering and assembly of the machinery needed to send a man to the moon and the immense technological fallout from the space programme, is intended as greetings and congratulations from Britain's leading engineering publication to all the people involved—engineers, scientists, technicians and administrators. Their many corporate skills, efforts and ingenuity have created the 'mightiest machine in the world'—which may prove to be the most significant technological event of the century.

For the extensive editorial material made available to *The Engineer* we are particularly indebted to:

Eric Lubbock, M.P., Liberal Spokesman on Technology. Congressman George P. Miller, Chairman, Committee on Science and Astronautics. O. B. Lloyd, Jnr., Director of Public Information, NASA. Gerald J. Mossinghoff, Director, Congressional Liaison, NASA. P. A. Gerardi, Technical Consultant on Science and Astronomy, House of Representatives. Dr Alan Mencher, Scientific Attaché, US Embassy, London.

Over the last ten years the United States National Aeronautical and Space Administration has spent over £15 000 million in pursuit of aeronautical and space exploration. This figure is as awesome as the sight of Apollo 11 as it stood yesterday on the launch pad at Complex 39, Cape Kennedy. What hard returns are there for this mammoth expenditure?

Industrial strength. The Apollo programme has its greatest economic significance in the growth of national industrial strength that has occurred in response to the opportunities and challenges of the space programme.

The Communications Satellite Corporation, for example, was made possible and necessary by the NASA work on space communications system. The result has been a many-fold increase in the ability to communicate, a major decrease in the cost of communication, and an international expansion of communications facilities. Satellite-relayed coverage of the Olympics is dramatic, but a 25% reduction in the average cost of a long-distance telephone call is a permanent benefit to every citizen.

Another aspect of economic growth can be seen in the regional levels of space facilities; employment levels, standards of living, educational opportunities, and industrial development have multiplied with the establishment of the Mississippi Test Facility, the Slidell Computer Facility, and the space centres at Cape Kennedy, Houston, and Huntsville.

These contributions are not ephemeral; the demands of space programmes for high skills and superior performance have exceeded the talent pools available and therefore have had to be met by training and upgrading.

High precision. Institutions and organizations, like individuals, benefit from technological demands. The standards of precision and reliability now accepted as commonplace in electronics and machinery simply were inconceivable before the rigour of space exploration required them.

New products and new techniques are regularly introduced from the space programme into the mainstream of commerce and some typical examples of these are described on pages 53—55 of this issue of *The Engineer*.

Disciplines on every front have benefited, with perhaps medical engineering coming off best. However, examples of the use of space technology in industry and other non-medical fields include a 24 oz. battery-operated TV camera no bigger than a packet of cigarettes; bearings coated with a ceramic-banded dry lubricant for use at high temperatures; and a technique for polishing metal masters to shape elliptical glass mirrors.

Basic management concepts and principles developed for and applied to the Apollo-Saturn programme have been effective throughout the entire project and have provided some exemplary results and accomplishments. Since this management approach has proved successful, there has been an active effort by Marshall to transfer this management and technology to interested universities, government agencies, and industrial corporations.

To put two men on the moon's surface and get them back safely to earth again leads to two basic requirements: A spacecraft made up of three modules with its own rocket propulsion system, and a booster powerful enough to lift this complicated, heavy vehicle clear of the Earth's gravitational pull and put it on course for the target—¼ m. miles away.

Three modules. To meet these requirements NASA produced the Apollo spacecraft, and the final version is an impressive assembly, 82 ft tall and weighing 45 tons. Its three units are called the Command Module, the Service Module and the Lunar Module.

As the Apollo spacecraft stands on the launch pad, the Command Module is in the top position. The five-ton module is the crew compartment, pressurised into a 'shirt-sleeve environment' so that spacesuits are not needed throughout the journey, and containing all the controls.

Next comes the 23-ton Service Module, which carries all the equipment and controls, including the spacecraft's computer. The bottom section is the 17-ton Lunar Module that makes the actual moon landing and sheds its landing platform on lift-off from the moon.

The development of a rocket capable of sending nearly 50 tons to the moon was undertaken in three steps. First of the series was Saturn I, a powerful two-stage rocket with a cluster of five liquid oxygen/kerosene-fuelled engines to power its first stage and a liquid hydrogen-fuelled rocket for its second stage.

Vast power. Saturn V, used for Apollo II, is the giant of the family. The Saturn V launch vehicle stands 364 ft tall including the spacecraft and weighs over 6 000 000 lb. at liftoff.

The first stage (S-IC), manufactured by the Boeing Company at the Michoud Assembly Facility in New Orleans, is 138 ft long and 33 ft in diameter and is powered by five F-1 engines developing a total thrust of 7 610 000 lbf during the two and one-half minutes they burn.

The second stage (S-II), manufactured by the North American Rockwell Corporation at Seal Beach, California, is 81 ft. long, 33 ft. in diameter and is powered by five J-2 engines developing a thrust of 1 150 000 lbf.

The third stage (S-IVB), manufactured by the McDonnell-Douglas Corporation at Huntington Beach, California, is 59 ft. long, 22 ft. in diameter and is powered by one J-2 engine developing 230 000 lbf. of thrust.

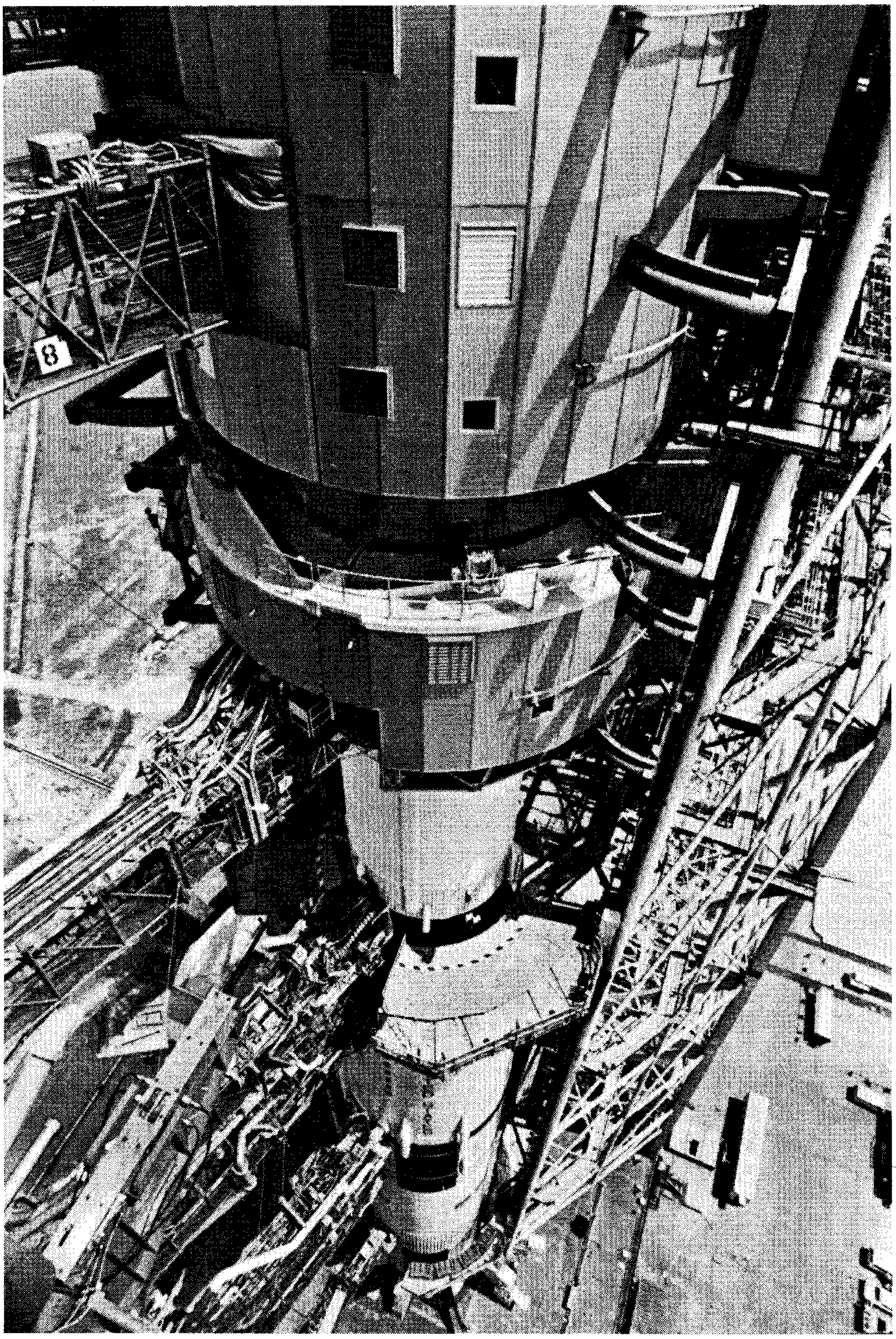
The second and third stages use liquid oxygen and liquid hydrogen as propellants. These are more energetic than liquid oxygen and kerosene used in the first stage.

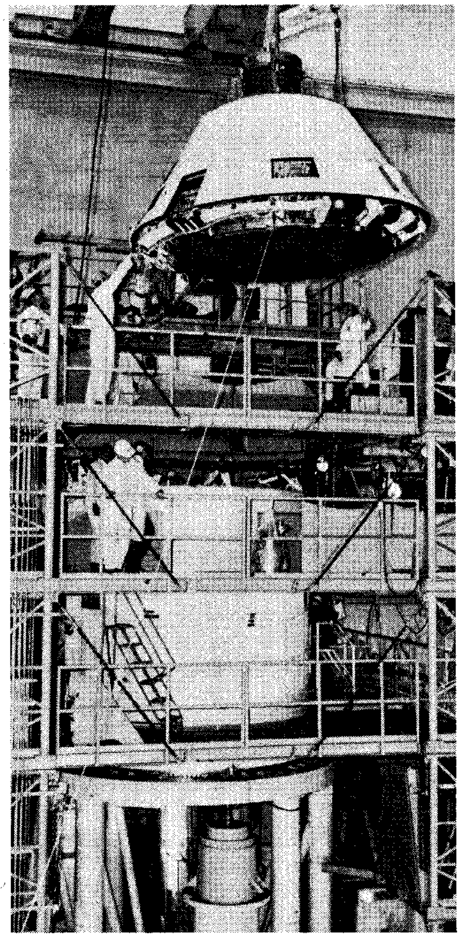
By 1965, only four years after the start of Project Apollo, the first phase of the Saturn launch vehicle programme was successfully completed. Not one of the ten launchings had failed, a feat without precedent in rocket development.

Much of the technology needed for the more powerful Saturns was tested in the Saturn I programme. In the course of the ten launchings the concept of clustered rocket engines proved sound; a guidance system was developed; and experience was gained in handling liquid hydrogen fuel, which is storable only at extremely low temperatures.

The total spin-off from Apollo in economic terms have been cautiously estimated to be £1 000 million a year; their value to a better environment for man may be immeasurable. The continued probing into the mechanics of the universe with exploratory and observatory spacecraft holds the promise of major scientific discoveries; as astronomy once led to the harnessing of nuclear energy, so the space sciences are suggesting even higher regimes of power which if harnessed could free man from reliance on diminishing or expensive fuels.

The Apollo issue of The Engineer was edited and correlated by John Mortimer, News Editor and Joe Scott-Clark, Editorial Director

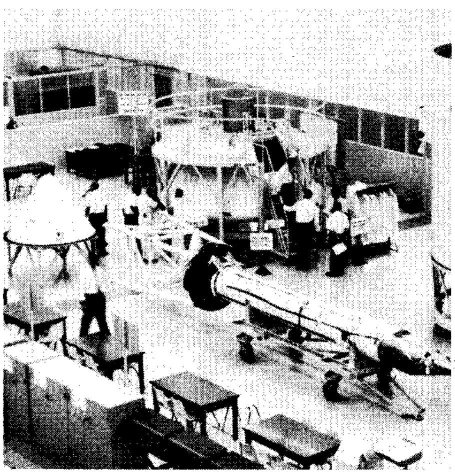




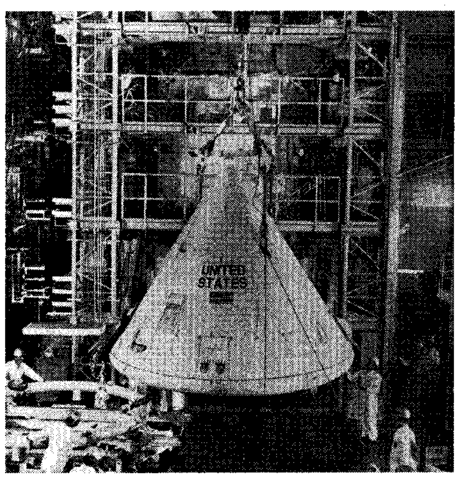
Above: The Service Module houses fuel, electrical power supplies and propulsion units. It is 23 ft high, weighs 23 ton and is constructed of aluminium honeycomb. The total weight of the spacecraft is 95 000 lb

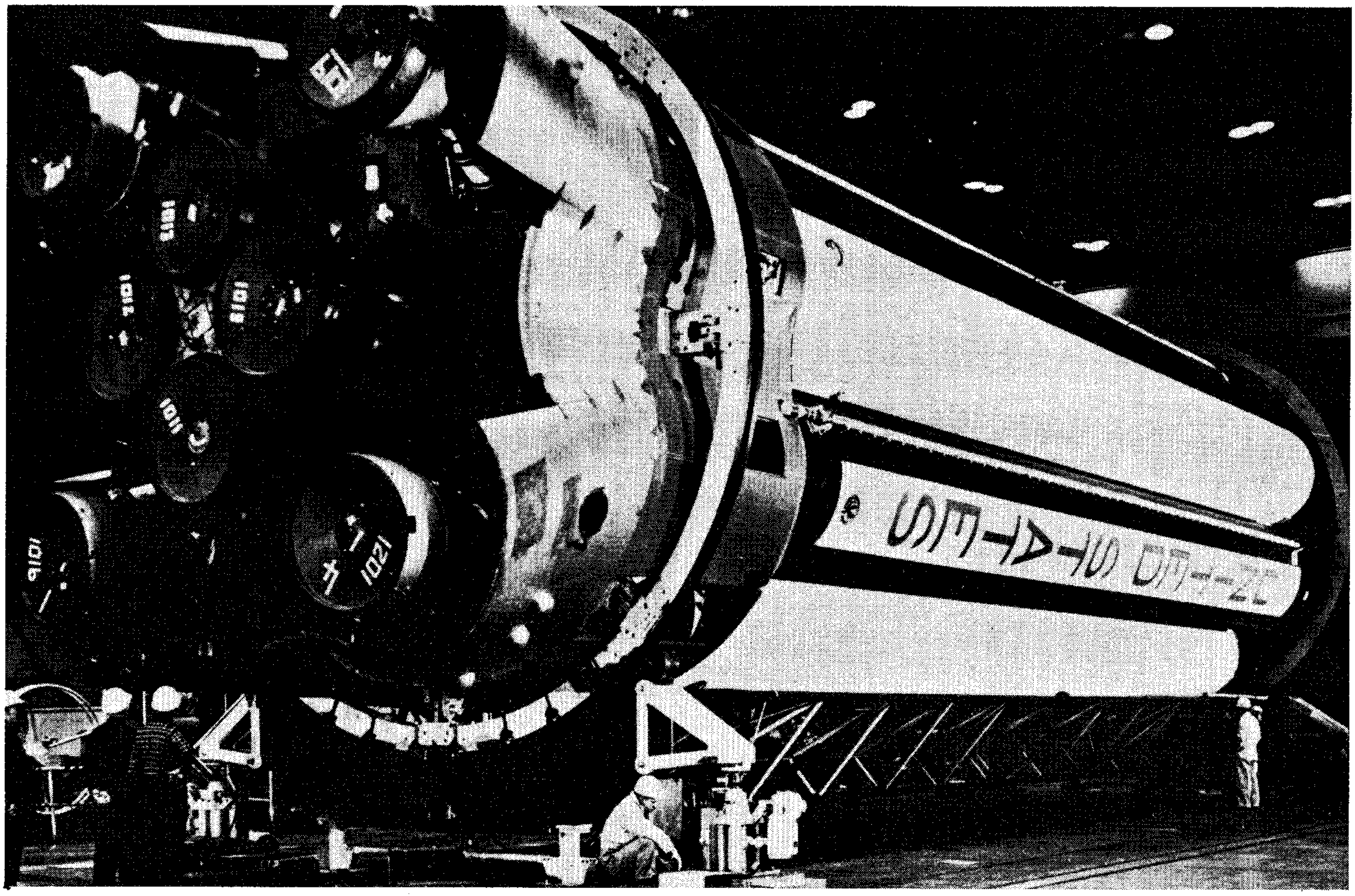
Below: Neil Armstrong, Edwin Aldrin and Michael Collins are living on their way to and from the moon in the Apollo Command Module which, with the Service Module and Lunar Module, form the complete spacecraft

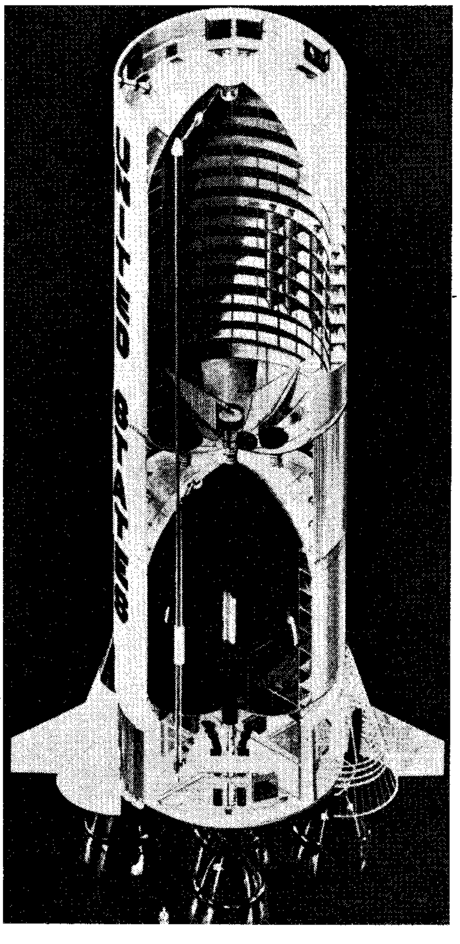
Above: Assembled, Saturn V and Apollo 11 spacecraft stand 364 ft high and from the lofty pinnacle of the massive tower at Launch Complex 39 the complete vehicle is an awesome sight giving an impression of the magnitude of the moonshot project

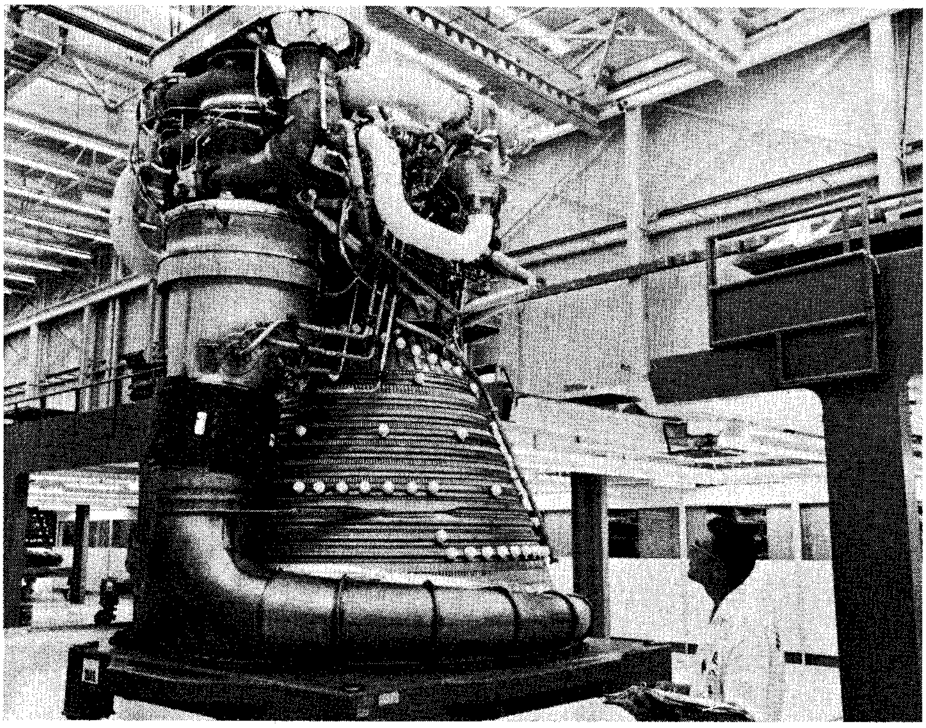


Right: Before it is shipped to the Kennedy Spaceflight Center every Apollo Command Module and its associated equipment undergo stringent check-out procedures at the manufacturers, North American Aviation

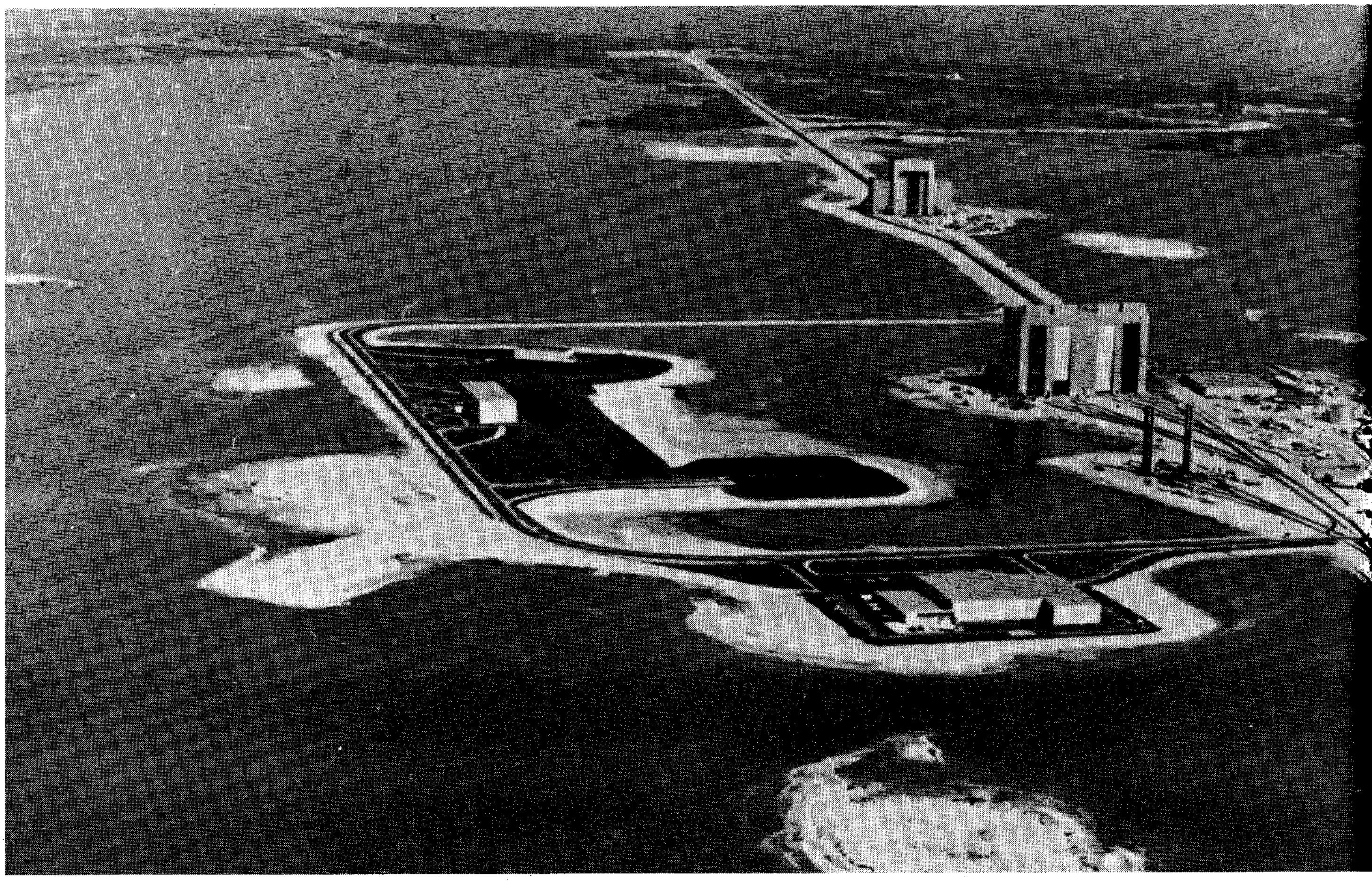






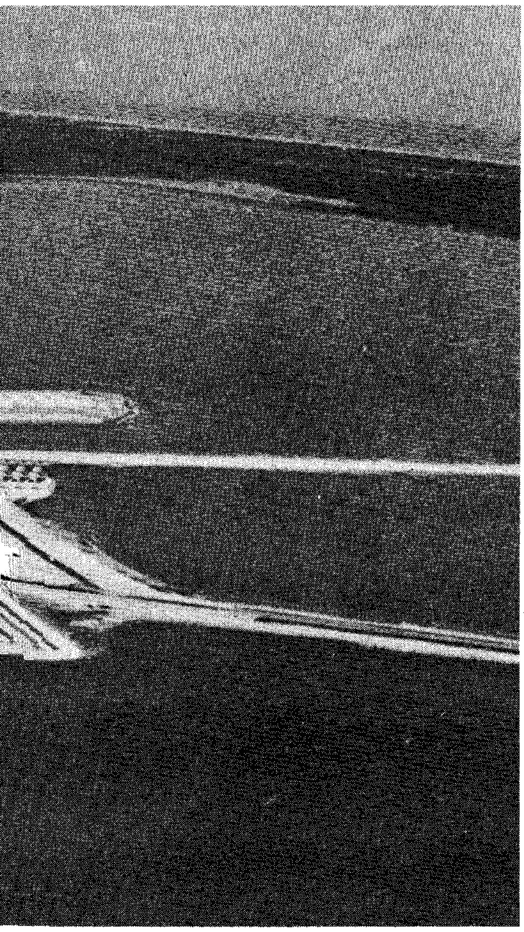


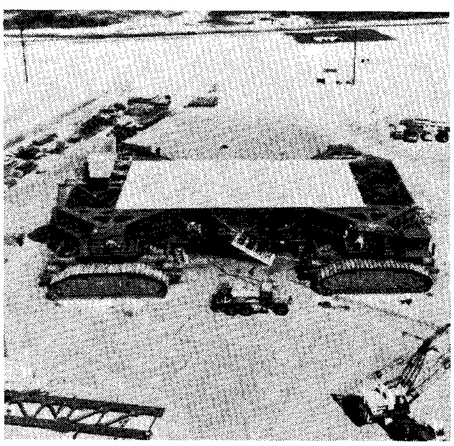
Top: The first stage of the Saturn V launch vehicle is powered by five F-1 rocket engines which together develop 7 610 000 lbf thrust from a mixture of liquid oxygen and kerosene. The Saturn V engine measures 33 x 138 ft. Left: Ten first stages for NASA's manned lunar landing Saturn V launch vehicle were built at NASA's Michoud Operations by Boeing for the Marshall Space Flight Center. Above: Rocketdyne's F-1 rocket engine is a single-start, fixed-thrust bipropellant unit giving 1 522 000 lbf of thrust. The four outer engines are gimballed for rocket control; the centre engine of the F-1 assembly is fixed



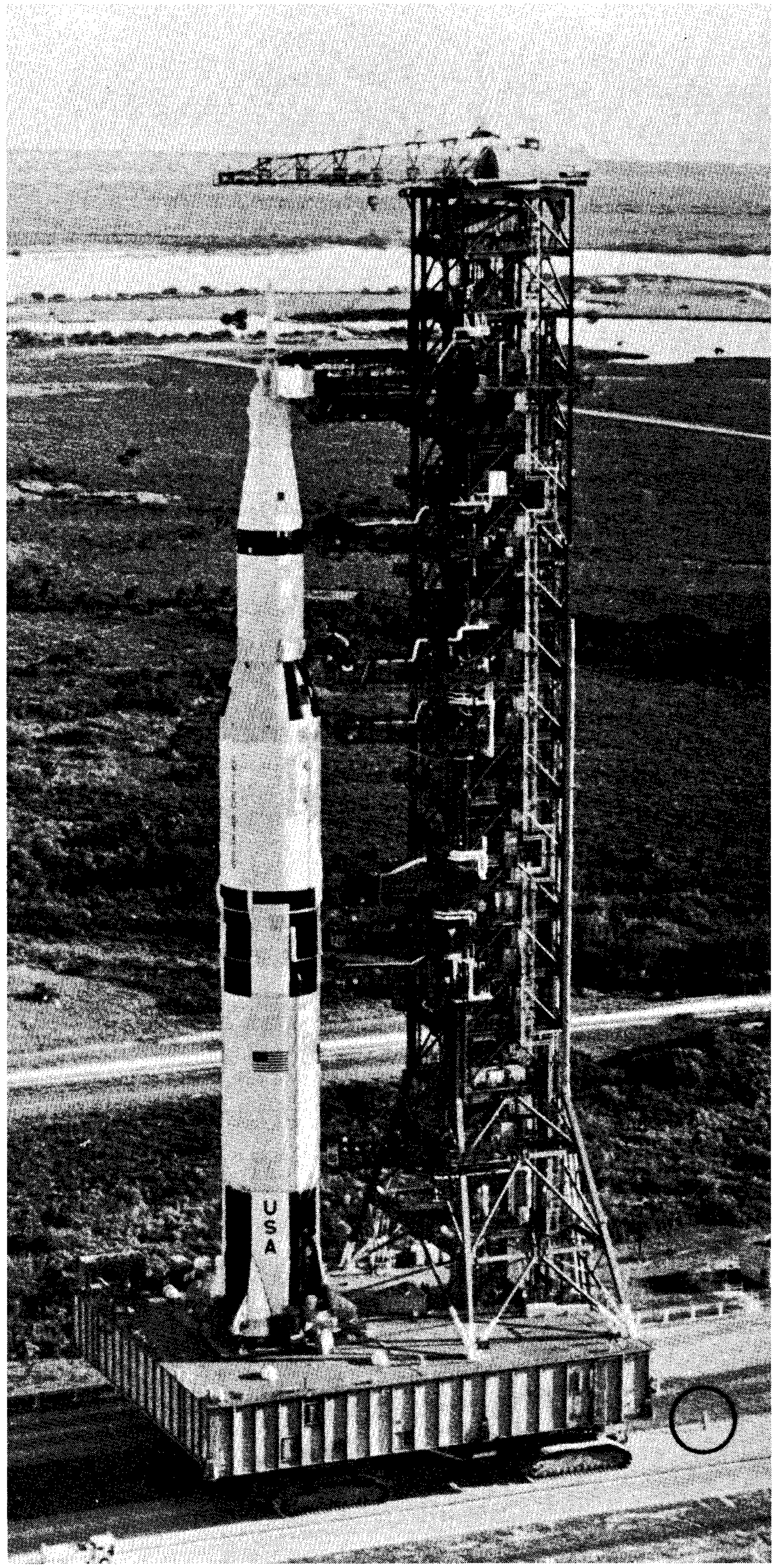
Above: Merrit Island, Florida, where the launch pads are—Pad A and Pad B—and the Vehicle Assembly Building where launch vehicles and spacecraft were assembled

Right: The assembled vehicle is moved from the VAB to the launch pad on one of three mobile launchers, propelled by one of two crawler transporters. The journey, a distance of 17 000 ft, takes a cautious six hours





Above: The transporter can pick up a load that is equivalent to 6 000 ton and move it and its own weight of 3 000 ton in either direction. Each track has 57 links each weighing 2 200 lb



Right: The transporter can negotiate a curve of 500 to 600 ft radius. It can be driven into the VAB, come up from underneath the launcher, and with a hydraulic system, pick up the launcher, lifting it up about 2 ft