CARNARVON TRACKING STATION

Western Australia

Established and directed by the Australian Department of Supply

On behalf of the United States National Aeronautics and Space Administration

Maintenance and operational services provided by Amalgamated Wireless (Australasia) Ltd.

Issued with the compliments of the Department of Supply
COMMONWEALTH OF AUSTRALIA

CARNARVON TRACKING STATION

INTRODUCTION

In February, 1960, the Governments of Australia and the United States of America formally agreed to co-operate in space flight programs being conducted by the US. Australia undertook to establish and operate a number of tracking stations which would form part of a world-wide network under the control of the US National Aeronautics and Space Administration (NASA).

The Department of Supply is responsible for fulfilling the Australian commitment under this agreement. The construction and operation of these tracking facilities in Australia is financed by NASA.

Design, construction, management and operation are provided from Australian resources, either directly by the Commonwealth Government or by contract to private industry. The first major station was built in 1960 at Island Lagoon, about 14 miles from Woomera. It is concerned with deep space probes. Since then, other stations have been established and those now operating (in addition to Island Lagoon) are at:

- Carnarvon (WA), for manned space flights and scientific satellites (officially opened June, 1964).
- Tidbinbilla (ACT), for deep space probes and manned space flights (March, 1965).
- Orroral Valley (ACT), for scientific and applications satellites (February, 1966).
- Honeysuckle Creek (ACT), for manned space flights (March, 1967).

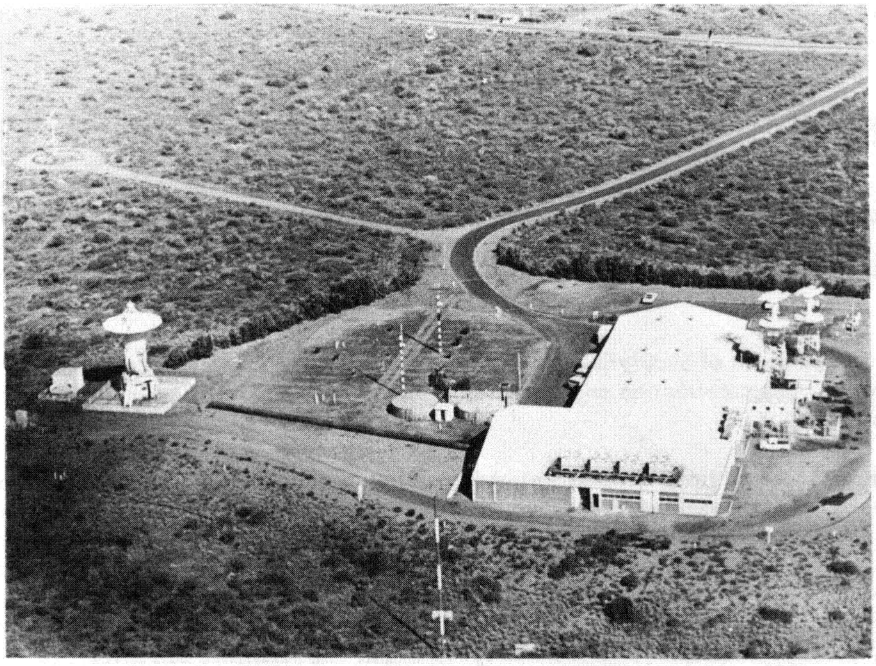
Outside the US, Australia has the largest number of NASA space tracking and communications stations in the world. NASA's capital investment in Australia in facilities and equipment is very substantial. The cost alone of operating the five Australian stations is about $13M a year.

Together, they employ about 700 Australian engineers, technicians and supporting staff.

STATION LOCATION AND LAYOUT

The station has been sited about four air miles from Carnarvon and occupies about one square mile. It is located on a range of low sand hills, named Brown Range after an early settler of the district. Equipment is located in groups which are dispersed about the station to obviate mutual interference and to reduce radio-frequency radiation hazards to operating staff.

The main building is the telemetry and control (T&C) building. This accommodates a multi-purpose tracking system (Unified S-Band) which has been developed for Apollo, the US project for sending men to the moon. It also accommodates telemetry, data processing and communications equipment, which is used for the support of Apollo missions and the tracking of other scientific spacecraft. Buildings and facilities at other sites provide for the FPQ-6 radar installation, self-contained scientific satellite tracking equipment (Range and Range Rate), command and voice communications, solar proton alert network (SPAN) observations and electric power generation.



T&C BUILDING AND APOLLO ANTENNA

Associated with the tracking equipment, Unified S-Band, FPQ-6 radar, acquisition aids, and Range and Range Rate, are tall masts which carry small transmitters for calibrating this equipment. These are known as bore-sight masts, because the equipment is directed at the transmitters for calibration and testing in much the same way as a cannon may be directed at its target by sighting along the barrel.

FUNCTIONS AND PROJECTS

The Soviet Union's Vostok flights and the American Mercury flights in the early 1960s demonstrated that it was possible to place a man in orbital flight around the earth and effect a safe recovery. In support of Mercury, two stations were operated in Australia - at Muchea, near Perth, and at Red Lake, Woomera. After Mercury's successful completion, the Muchea station was discontinued. Instead, for the Gemini program, the Carnarvon station was built.

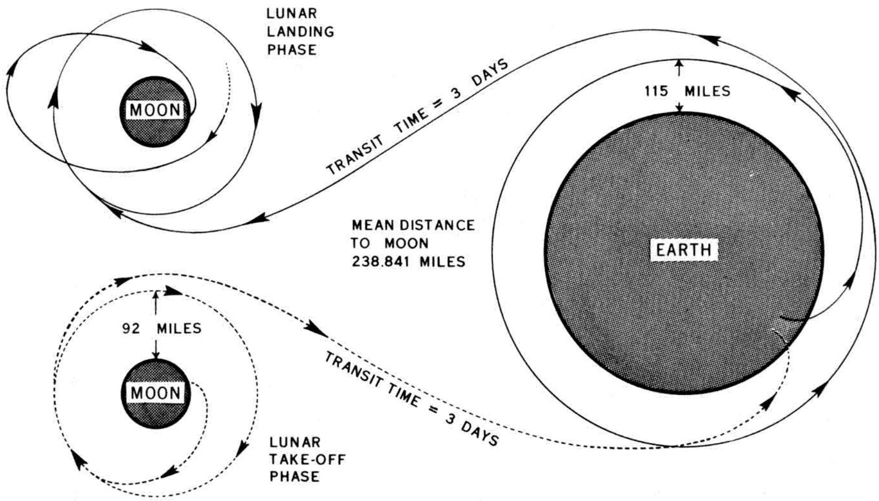
In 1965 and 1966, the 10 two-man Gemini flights demonstrated the technical capability of effecting a rendezvous in space and docking two spacecraft, and the ability of man to endure up to 14 days in space and carry out activities outside spacecraft. The outstanding success of the Mercury and Gemini programs paved the way for the third phase of the manned space flight program, namely the three-man Project Apollo, aimed at manned exploration of the moon.

The Carnarvon Station cost $2.25M to build. Its equipment is valued at $20M and its operating cost is about $2.5M a year. Carnarvon was geographically more suitable than Muchea for tracking in the Gemini program, because generally the earth-orbital paths of Gemini spacecraft were nearer to the equator than those of Mercury spacecraft. This has also applied to Project Apollo.

The first tracking carried out at Carnarvon was in January, 1964, when Ranger VI was plotted during the first few hours of its flight to the moon. Since then a multitude of scientific spacecraft and boosters have been tracked.

Carnarvon's part in Apollo is the tracking of the Apollo spacecraft and its associated space vehicles while they are in earth orbit and while they are leaving the earth or returning to it. Typical spacecraft orbital and earth-moon transit paths are shown below. Carnarvon also provides comprehensive coverage of the monitoring and command of the ALSEP scientific packages left behind on the moon by the Apollo astronauts.

Carnarvon is now a part of the world-wide Space Tracking Data Network (See map page 7)



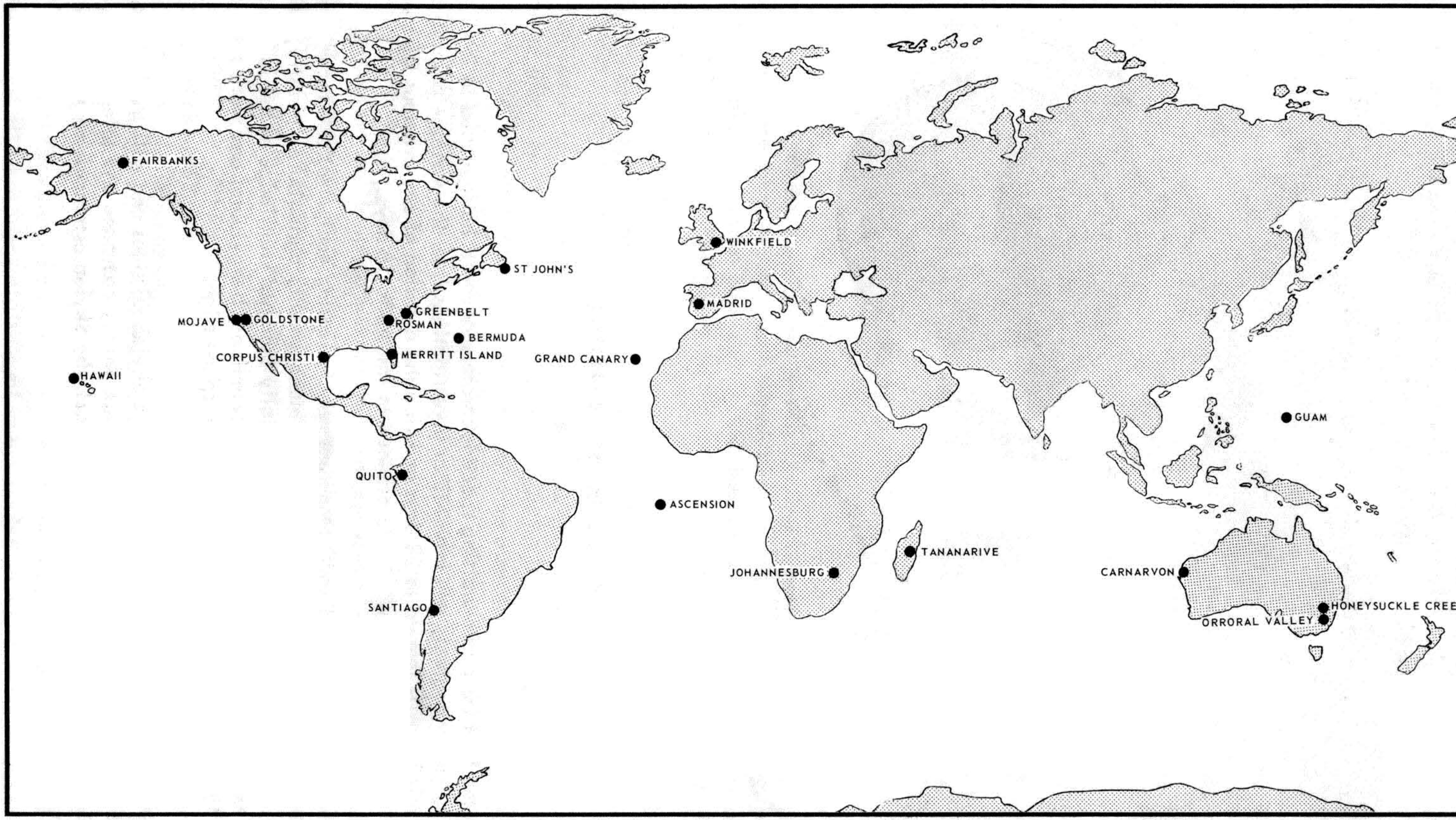
APOLLO MISSION PROFILE

SKYLAB

Skylab is the first US earth-orbiting space laboratory and will be launched in 1973 to conduct scientific, technological, and biomedical investigations from the vantage point of space. The first manned mission will last up to 28 days or twice the duration of any previous US mission. The second and third three-man missions are planned to last up to 56 days.

The Skylab program will test earth resources remote sensing equipment and techniques to gather information on ecology, oceanography, water management, agriculture, forestry, geology and geography. Astronomy experiments will substantially increase knowledge of the sun and its effects on man's existence on earth. Habitability, biomedical, behavioural and work effectiveness experiments will further evaluate man's capabilities in space flight.

Carnarvon will be involved in all phases of the Skylab missions and will track the orbiting workshop, record experimental data and TV and provide voice, command and teleprinter communications to and from the spacecraft. It will also track the Skylab astronauts on their way to and from the workshop in the command service module.



SPACE TRACKING DATA NETWORK

STATION EQUIPMENT

Apollo Antenna

The Apollo tracking system (Unified S-Band system) was installed primarily for manned lunar missions but it is also used to track some scientific spacecraft and the ALSEP packages. It has a 9 m diameter antenna located in front of the T&C building. The system provides a link between earth and the spacecraft which may be used for a number of purposes including :

- Voice transmission to and from the astronauts,
- Reception of telemetry and television from the spacecraft,
- Transmission of commands to control spacecraft systems.

At the same time, the system is able to measure spacecraft range, velocity and angular position.

Sensitive receiving equipment and a 20 kW transmitter are built into equipment compartments in the antenna structure. The remainder of the system occupies a large room in the T&C building and is interconnected with most other equipment in the T&C area.

FPQ-6 Radar

This radar stands alone on a hill to the north of the Station. It has a 9 m diameter antenna mounted next to a two-storey building which houses its electronic equipment.

The radar transmits pulses which a spacecraft will reflect, or, to which it will respond if suitably equipped, by transmitting return pulses. These returned signals are used to measure range and angular position. The FPQ-6 is one of the most accurate tracking radars in the world.

The equipment includes a computer which is used for predicting satellite orbits and for processing measurements made by the radar. It corrects predictable errors and converts the tracking data into a form suitable for transmission to computers in the United States.

RARR

The Range and Range Rate (RARR) system is a facility designed for the tracking of scientific satellites up to moon distances or about 250,000 miles from earth. Because it is required for tracking satellites which are mostly at greater distances, the RARR system is designed to make accurate measurements of distance and speed rather than angular position.

Since it was installed in 1964, the RARR system has tracked satellites of the Interplanetary Monitoring Platform (IMP) and Orbiting Geophysical Observatory (OGO) series, and a number of others. In 1966 a small adjunct to the system was installed to provide special facilities for sending radio commands and receiving measurements from the biological (BIOS) series of satellites. This equipment was used in the experiment with the orbiting monkey "Bonny" in July 1969.

SPAN

One of a network of three stations around the world, the Solar Proton Alert Network (SPAN) consists of an optical and radio telescope which is used to monitor solar disturbances. Large flares on the surface of the sun can affect the earth by disturbing radio communications. They also emit high-energy particles which arrive in the earth-moon vicinity from one to two hours after the onset of a flare. This is a potential hazard to astronauts.

The three SPAN stations provide a continuous means of monitoring the sun's activity. Immediate warning of major flares can be sent to the Mission Control Center in Houston, Texas, so that astronauts can be returned to earth if necessary.

Telemetry

During an Apollo manned satellite pass, information is gathered on thousands of measurements being made in the spacecraft. This information is transmitted over a small number of radio links (usually less than 10) from the satellite radio transmitter and received by using the Unified S-Band and acquisition aid antennas. Much of the complexity of the telemetry system results from the requirement to take a complete set of measurements in a period of one second.

In order to achieve this, the data is "time multiplexed" prior to transmission from the satellite. That is, during the first 1/4000th of a second, a particular measurement is transmitted, followed by a different measurement during the next 1/4000th of a second and so on. In this way, the satellite can transmit 4000 different measurements per second over on radio link. However, since particular types of measurements must be sampled more frequently than once per second, a complete one second "frame" of data usually contains information on only 500-1000 different items. The use of a number of radio links can increase the capacity of this system.

The primary function of the telemetry system is to receive this information and convert it back to its original form, i.e., thousands of discrete measurements. Special purpose computers are programmed to detect the first measurement of a sequence, label it as the first measurement and convert it into a form which may be fed into the main station telemetry computer. Having achieved this, the equipment proceeds to the second measurement and so on.

During an Apollo pass, data is input to the main telemetry computer at a rate of approximately 20,000 measurements per second. Even at this rate, the machines have time to "ask" the computer if the previous measurements have been received and if it is ready for the next input.

This "conversation" which goes on between measurements ensures that in the event of a radio link failure or a spacecraft failure, a complete field of data containing all measurements taken during the one second preceding the failure remain stored in the memory of the main computer.

The telemetry equipment also has the capacity to collect together all the samples of any particular measurements and display it on a chart recorder, meter, etc. For example, an astronaut's respiration and electro-cardiogram may be observed side by side on a chart recording. Discrete events, such as the operation of a gas valve, may be recorded or displayed on a light.

This onsite capability to display any chosen group of measurements is used extensively during scientific missions when the data link to Houston is not in use.

A number of sophisticated tape recording systems form part of the telemetry system. These provide the facility to look back at previous events as the mission proceeds or to record information which may be transmitted from the satellite while the main computer and decoding equipment is occupied on other links.

The machines can be "cued" automatically to a previous GMT (Greenwich Mean Time) by using the time recorded on one of their fourteen tracks. They have the capacity to record telemetry data (and many other types of data, including TV) in its raw, unprocessed form.

Computers

The tremendous capacity of digital computers to carry out calculations quickly and accurately and to make decisions and initiate actions with similar speed, according to pre-arranged plans, finds many uses in tracking stations. Computers are included in much of the equipment at Carnarvon. A number of computers, associated mainly with the Apollo tracking system and the Apollo flight control room, are in a room in the T&C Building.

The computers perform a multiplicity of tasks, one of which is the conversion of Apollo telemetry signals (i.e., signals from the Apollo spacecraft which indicate the values of hundreds of measurements made in the spacecraft) into a form suitable for transmission over a communications satellite link provided by the Australian Overseas Telecommunications Commission to Mission Control Center, Houston, Texas.

Radio Commands

Radio commands enable unmanned spacecraft to be controlled in such things as direction of motion and also provide a means or relieving astronauts of unnecessary duties and of controlling their spacecraft from the ground in an emergency. The Apollo tracking system includes facilities for sending commands to spacecraft.

Another independent command transmitting system is located near the power station. This system was installed in 1964 for the Gemini Project and for use with some scientific spacecraft.

Communications

Two-way voice communication between astronauts in spacecraft and flight controllers at the station is provided by the Apollo tracking system and by separate systems of conventional radio transmitters and receivers. The latter are controlled from a console in the T&C building.

Before the age of communications satellites, the station depended on circuits provided by the Postmaster-General's Department and by the Australian Overseas Telecommunications Commission (OTC) for voice and teletype communications to other tracking stations and to control centres in the US.

Since 1966, direct radio communications have been possible via an Intelsat communications satellite stationary 22,500 miles above the Pacific Ocean.

The ground radio station, which forms a part of this link, is on the north end of Brown Range near the "T" junction and is owned and operated by OTC.

Internal Communications

Co-ordination between staff who are checking or operating equipment is assisted by an elaborate intercommunication system.

All operating positions and many odd places, such as equipment shelters on antennas, are provided with a telephone enabling the operator to talk on one of a number of circuits inter-connecting groups of operators.

Timing

Accurate time keeping is of vital importance to the Station and the timing equipment includes several atomic clocks. The Station's cesium beam primary standard is so accurate that if it continued to operate for ten thousand years, it would not have gained or lost more than one second.

It is necessary, not only to be able to determine the position and course of a spacecraft with great precision, but also to be able to "time-tag" such a set of measurements with great precision. An appreciation of the need for precise timing information may be gained from a consideration of spacecraft speeds which often exceed 30,000 feet per second.

Timing signals are distributed throughout the Station for use by equipment and to operate time displays.

Power Supplies

All tracking equipment at the Station depends on the uninterrupted supply of electrical power. A power failure, at a period when all equipment is prepared to track, could result in a disruption and deterioration of tracking capability from which the Station might not recover for several hours.

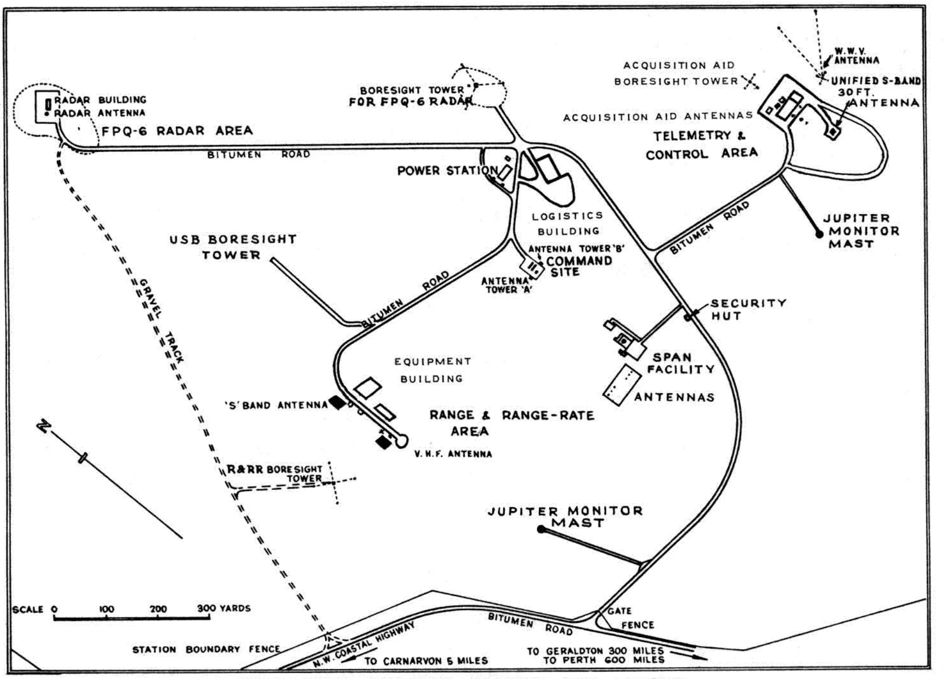
Power is generated by eight diesel generators. Two distribution systems are used, one providing power for electronic equipment and the other for utilities such as air-conditioning, lights and domestic needs.

Each system is equally vital, because in many cases electronic equipment cannot operate satisfactorily without air-conditioning.

STAFFING

At Carnarvon, the operational responsibility is vested in a Station Director who is a senior officer of the American Projects Branch of the Department of Supply.

The Australian Government policy of using the resources of private industry in this sphere of activity has been extended to Carnarvon by the award of a contract to Amalgamated Wireless (Australasia) Ltd for operating and maintenance services. About 180 professional, technical and administrative people are engaged on this task.



CARNARVON TRACKING STATION SITE LAYOUT

PRINTED BY DEFENCE PRINTING ESTABLISHMENT, DEPARTMENT OF SUPPLY, BRUNSWICK, VICTORIA, 3056.