Thermoelectric Generators Provide Power During Space Missions

Orbiting satellites, whether their purpose is communications, weather observation, as an aid to navigation, the mapping of natural resources, or for space research, all require a reliable source of electrical power, as do the stations at present working on the surface of the moon and on Mars. In the short term this electricity may be available from previously charged storage batteries but for prolonged use it has to be produced during the mission.

Fuel cells have proved to be satisfactory generators of electricity but the necessary fuel gases must be carried on the flight. Solar cells, powered by sunlight, are a widely used source of electricity on space missions but suffer from a number of disadvantages. The sunlight is collected by antennae which must be correctly orientated to receive it, and these are readily damaged by intense heat, by radiation and by meteorites. In addition the cells cannot function in sun shadows, or in remote areas where the sun's energy is too weak, although the power they produce elsewhere can charge batteries for use in such areas. Nuclear generating systems have none of these disadvantages and two different types have successfully provided electrical power during space missions. Radioisotopic thermoelectric generators (R.T.G.s) have been used by the United States of America on no fewer than 19 space missions since 1961 and have proved to be a useful source of both electricity and heat. Nuclear reactors, the second type of nuclear generating system, have so far been little used by the U.S.A. in their space programme although they may be developed to meet growing demands for much larger power sources.

The two functional parts of a R.T.G. are the heat source, and the converter which turns this heat into electricity. The heat is produced by the natural decay of an unstable radioisotope, and the material generally used for space applications is plutonium dioxide (plutonium-238), which takes 88 years to lose half its radioactivity. Although the thermal output of the fuel is continually dropping, this relatively long half life means that the generator can have an operational life of several years, and as no moving parts are involved high reliability can be expected.

The heat produced is converted into electrical energy by its action on a number of thermocouples—over 300 of them in the newer modular units. In early devices these couples were made from telluride materials but better conversion is now obtained with silicon-germanium, while selenium alloys are being considered for future use.

It is obviously necessary to contain the plutonium-238 during both normal operational and potential accidental conditions. These may include blast-off or launch pad abort, a mission life which could last for several years, possible descent—with associated high temperature heating on re-entry, followed by impact with the earth and exposure to a variety of terrestrial environments before recovery. Clearly, all components and materials must be completely reliable but at the start of the U.S. space programme no single alloy possessing all the necessary properties was available. The concept of multiple layer encapsulation, where one alloy compensates for the shortcomings of another, was therefore adopted. At the same time development of more suitable alloys was undertaken with the aim of producing a single alloy cladding which would fulfil all the stringent requirements of safety, reliability and performance.

In 1961 a R.T.G. was first used to provide 2.7 watts of auxiliary electrical power on a U.S.A. navigational satellite and since that time there has been a steady increase in the power available from such generators. The units placed on Mars in 1976 by Vikings I and

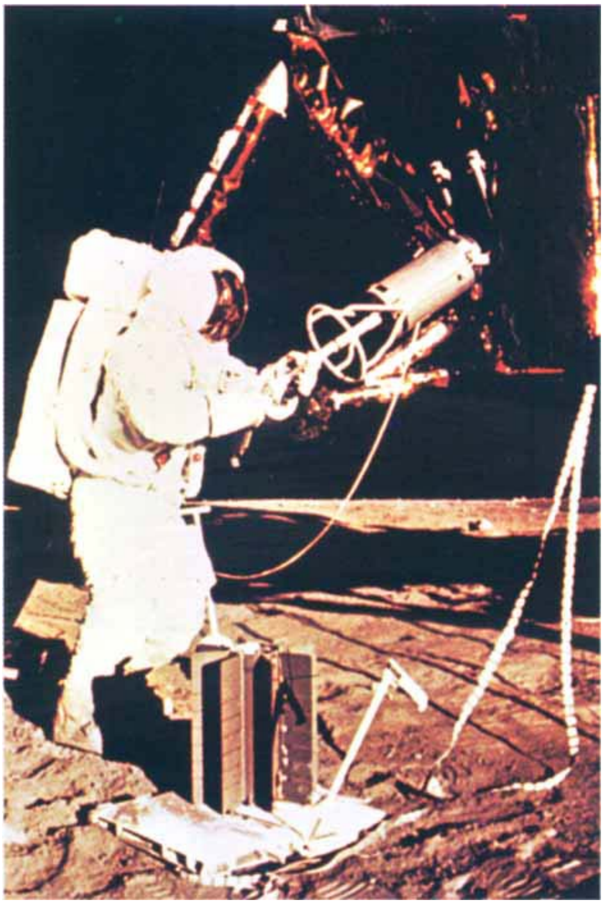
II are both powered by two R.T.G.s, each rated at 35 watts and still exceeding this output.

Platinum Group Metals Encapsulate Radioisotopic Source

The R.T.G.s on Mars are powered by decaying plutonium-238 which is contained in a number of materials. A molybdenum-46 per cent rhenium alloy in contact with the hot radioisotopic fuel serves as an oxygen barrier and is contained in a tantalum-10 per cent tungsten liner which in turn is surrounded by a tantalum-8 per cent tungsten-2 per cent hafnium member to provide strength and structural integrity. The outer cladding is platinum-20 per cent rhodium to provide oxidation stability and additional assurance of containment; further protection is given by a graphite heat shield.

The larger Multi-Hundred Watt generators now employed on satellites can initially deliver more than 150 watts at 30 volts and it is expected that even after 10 years' service they will still be producing 115 watts. Of course, greater output can be obtained by using more than one generator. On the Voyager spacecraft launched towards Jupiter and Saturn in 1977 all the electricity is produced by three R.T.G.s and here the twenty-four spherical plutonium-238 sources are first encapsulated with iridium -0.3 per cent tungsten and then with thick fibrous graphite to form 2.5 inch diameter fuel spheres which are packed in graphite re-entry aeroshells designed to withstand extremes of temperature and impact.

The problems in material development and component fabrication which have had to be overcome during the development of containers for space mission power sources have been considerable, and much valuable information has been gained which could probably be utilised in other applications. A later article in this journal will review some aspects of the development of platinum group metal alloys, their properties and fabrication, resulting from this work. I. E. C.



In November 1969 a radioisotopic thermoelectric generator was first installed on the moon. Here U.S. Apollo-12 Astronaut Gordon Bean is removing the plutonium-238 heat source from its container on the outside of the lander module. As soon as the source was placed in the finned generator, at his feet, the unit began producing 73 watts of electricity; and it is still powering both lunar experiments and the transmission, back to earth, of the data obtained from them

Photograph by courtesy of U.S. National Aeronautics and Space Administration