by classical aerodynamics and base their designs on symmetrical geometrical forms. Deeper investigations into the aerodynamics of bodies re-entering the Earth's atmosphere have suggested ways in which aerodynamic configurations could be utilised to effect control over speed, manoeuvrability, speed of the surrounding air and, consequently, of the temperature rise of the skin, the most important of the basic problems of re-entry from orbit.

Many of the designs of orbital craft are characterized by the use of various hypersonic configurations, positive interference, increased pressures, and skipping as a means of attaining higher lift-drag ratios. All this is essential if we are to keep acceleration and the accompanying loads to a minimum in manoeuvres in the atmosphere so that a suitable area can be conveniently chosen for landing and skin temperatures reduced. It is along these lines that temperatures acceptable for existing steels and titanium alloys can be obtained.

Some investigators are contemplating another line of approach, namely the use of magnetogasdynamics for deceleration during re-entry. What they have in mind is to replace a solid aerodynamic surface with an invisible magnetic field. The re-entry of a body into the atmosphere, which is effected at tremendous speeds (12,500 m.p.h. or more), is accompanied by the heating and ionization of the surrounding gas to a point where it becomes a fairly good conductor of electricity. This may be sufficient for an interaction between the gas and the magnetic field and, consequently, a body having no solid aerodynamic surfaces.

Such structures should be capable of withstanding considerable temperature rises (up to 2000° C. in critical areas) while retaining the desired strength and rigidity. At the same time, the cabin and instrument compartments must be heat-insulated, especially during descent from orbit, which should be carried out with a greater lift and for a longer time than is the case with ballistic descent, in order that the craft can be controlled on landing.

The main trends in design revolve around one principal problem, that of developing heat-resistant structures weighing as little as possible. These structures may be divided into "hot" and "cold" types.

Hot structures are those which, when heated, may operate at elevated temperatures for as long as required. Some of the heat is radiated by the bearing or non-bearing insulation, while some of the heat is absorbed. Examples of this type of design have been seen in short-duration ballistic descents from orbit.

Cold structures with passive or active cooling are essential for craft designed to stay in the atmosphere a long time, especially if they are to be used more than once. Possible solutions here may be obtained by using heat sinks of metals, their oxides or graphite, and through convection cooling with gases or liquids. The elastic properties of ceramic heat insulation have also been greatly improved.

The possible solutions of the problem of heat-resistant structures have been listed here in order of increasing difficulty. But the reduction in weight promised by the most difficult of them is so great that their development will be well worthwhile.

Nuclear Rockets: Flight Systems Deferred

An important change has recently been made in America's nuclear rocket propulsion programme which reflects difficulties experienced in the development of a practical in-flight reactor system. The announcement was made jointly by N.A.S.A. and the Atomic Energy Commission on 24 December.

The revised programme places the emphasis on ground-based research and engineering and defers further development of flight hardware. This means (*a*) that ROVER's KIWI (Ground reactor) project is unchanged; (*b*) that NERVA (Nuclear Engine For Rocket Vehicle Application) is being continued but with flight objectives deferred; and (*c*) that RIFT (Reactor In-flight Test) is cancelled. RIFT has been a technological project without actual hardware development to date.

The changes provide adequate funding for continued development of nuclear propulsion and at the same time, by deferring flight systems and tests related to NERVA and RIFT, will save as much as $180 million of planned and programmed funds in FY 1964 and 1965.

A.E.C. and N.A.S.A. will concentrate on ground reactor and experimental engine research, development and tests with particular emphasis on analysing and understanding power levels, temperatures, operating life and the problems of achieving frequent and reliable restart capability.

Work toward the development of the flight systems is deferred until the technology learned from the KIWI and NERVA projects has been satisfactorily established. The continuing projects will be directed toward ultimate use in flight systems.

By reorienting the nuclear programme in this way, N.A.S.A. and A.E.C. officials said they can made effective use of the $450 million investment to date. It also means that the agencies can fund in FY 1965 at a level substantially less than FY 1964.

Phoebus and Nerva

The major elements of the revised programme include a continuation of advanced technical developments, completion of the KIWI reactor effort and its phasing over to the higher-powered Phoebus system, and a redirection of the NERVA engine project.

Research and engineering development will continue in such areas as advanced reactors to operate at a variety of power levels and associated non-reactor components such as pumps, nozzles, and control systems. This work will be carried out both in-house at such laboratories as the A.E.C.'s Argonne National Laboratory and N.A.S.A.'s Lewis Research Centre and by industrial and university contractors.

The Los Alamos Scientific Laboratory of the A.E.C. will continue KIWI reactor tests through calendar year, 1964. This Laboratory is, at the same time, beginning an increased effort in the area of higher-powered graphite reactors, a project known as Phoebus, and will provide basic design and technology. This element of the ROVER programme is being carried out with no substantive changes.

The 1000-MW. NERVA engine project being conducted by the Aerojet General Co., and the Westinghouse Electric Co., is now directed towards an experimental ground or non-flight engine system.

The major effort will be on reactor engineering and on other essential subsystems necessary to create an operating experimental nuclear propulsion engine. Those elements essential to the ground test programme will be included. This revised project will require a lower level of funding but contemplates undertaking an eventual flight system development.

The RIFT project, under contract with Lockheed, was directed by N.A.S.A.'s Marshall Space Flight Centre. Almost all of the $14 million of research and engineering effort already undertaken is applicable to the chemical rocket systems under development and the design and engineering work specifically associated with the nuclear systems will be available for eventual application to flight systems. Since no flight hardware fabrication has been started, this project can be terminated now without having incurred the large costs associated with flight system development.

The entire nuclear rocket programme except for the RIFT portion is under the direction of the joint A.E.C./N.A.S.A. Space Nuclear Propulsion Office.

The present ROVER nuclear rocket programme provides the foundations for advanced flight missions which could include a logistics ferry for a lunar base, very heavy deep space probes, and even manned exploration of the planets.

New Research Tasks for the X-15

The X-15 research programme, using three aircraft is conducted jointly by the National Aeronautics and Space Administration, the U.S. Air Force, and the U.S. Navy at the N.A.S.A. Flight Research Centre Edwards A.F.B., California. All missions in 1963 were made in X-15s Nos. 1 and 3. The second aircraft is being modified by North American Aviation, Inc. to increase its speed and capability for conducting aerospace experiments.

The 59,000 lb. thrust aircraft are now being used as flying test beds for experiments conducted for N.A.S.A. and the Department of Defense. Some of the newer studies assigned to them include missions related to refined studies of aero-dynamic heating, ultra-violet stellar photography, measurement of infra-red rocket-engine exhaust signatures, and horizon-sensing stabilization equipment for spacecraft.

About two-thirds of the X-15 research work now is in support of space science. The remainder is for purely aeronautical investigations. Emphasis is on advanced research and technology to assist existing manned and unmanned flight programmes and to provide a basis for more advanced future objectives.

During 1963 the X-15 pilots, engineers and technicians completed major phases of boundary layer studies, Air Force optical degradation experiments, and investigations to determine the effects of air pressure, speed and angle of attack on aerodynamic heating. Experimental work was accomplished on stability and control during re-entry from high altitudes, on advanced flight control systems, structural dynamics, and the measuring of physiological effects on pilots under extreme flight environments.

Because much of its flight time is spent outside the effective atmosphere, the X-15, like the Mercury capsule, is equipped with H_2O_2 reaction controls for maintaining proper flight attitudes. In 1963, evaluation began of a new stability augmentation system which increases the pilot's capability to control the vehicle precisely in regions of low dynamic pressure (very thin atmosphere).

The X-15 experiments with ultraviolet stellar photography are intended to yield data usable in developing the Orbiting Astronomical Observatory under N.A.S.A.'s Office of Space Science and Applications. A separate horizon-definition experiment will test the feasibility of the spacecraft pilot performing the control task required for initial acquisition of a star as a reference. Data obtained will contribute to the development of the navigational system for the Apollo spacecraft. Tests of infrared and ultraviolet spectrometers, photometers, ablative coatings, and numerous gauges and sensors, are also made at a variety of speeds and altitudes.