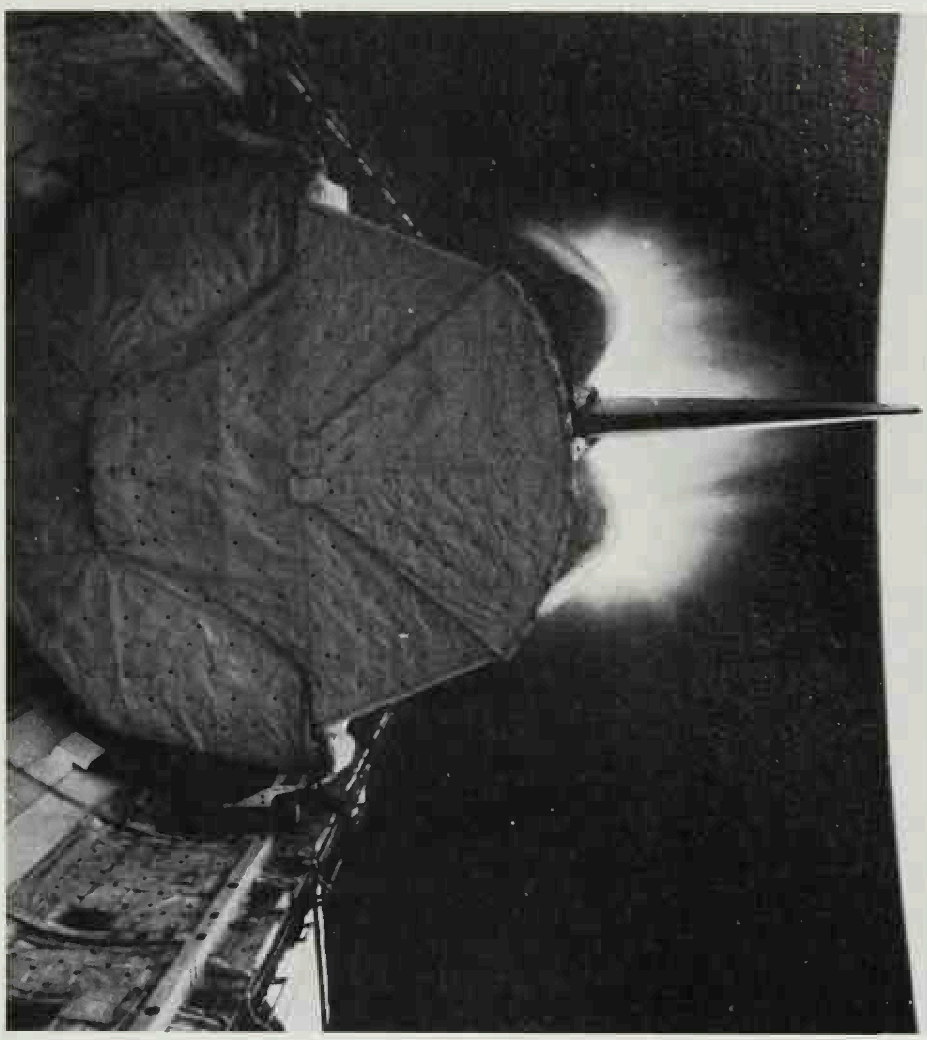
the planets may considerably modify the orbits, and even cause the probes to be ejected from the Solar System.

Although there has been a lull since the phenomenal success of the many planetary missions such as the Mariner, Viking, Pioneer and Voyager probes, activity has by no means ceased. Various nations have many different spacecraft either under construction or being designed, and we can expect missions to examine the Sun and comets, as well as Venus radar and atmospheric probes and a return to Jupiter with the Galileo orbiter and atmospheric entry capsule. In addition, plans are being made for the adaption of relatively 'ordinary' satellites, such as are used for communications and meteorological and remote-sensing purposes in Earth orbit, to missions further out into the Solar System.

Many of these space probes are expected to be launched by the Space Shuttle, which will also have the task of recovering satellites that have reached the end of their useful (or design) lifetimes. The Shuttle will also carry many short-term experiments into space, each usually being devoted to one aspect of the study of astronomical problems, as well as the Spacelab laboratory. The forseeable manned space stations in Earth orbit will also undoubtedly carry many astronomical experiments, such as the solar instrumentation carried aboard Skylab.



The Space Shuttle, here shown manoeuvring in orbit, is capable of transporting many astronomical satellites and experiments into space.

High-energy astronomy

This is astronomy concerned with the high-energy radiation bands – XUV, X-rays and γ-rays – and with primary cosmic ray particles, and special observing techniques have to be used. For cosmic ray particles, both those received in space and those which reach the Earth, a similar technique is used because both can cause ionization in a liquid, a gas, or even in a suitable solid semi-conductor type of material. In space, detectors are either gas-filled or solid. Ionization is caused, too, by γ-rays and X-rays, and similar detectors are used, the gas-filled being particularly suitable for the longer wavelength, less energetic X-rays. However, detection of the presence and strength of any high energy particles or radiation is only part of the problem: the astrophysicist also wants to know the direction of the source. A conventional telescope is fine for ultraviolet studies, but X-rays and γ-rays will penetrate the mirrors of a reflector, so some other directional system is required for an X-ray or γ-ray 'telescope'. The most effective method is to use the principle of grazing incidence, whereby a beam of X-rays will be reflected from a metal surface (or metallic film on glass) if the beam grazes it at a steep angle of the order of 87° or more. Using special hyperboloidal and paraboloidal surfaces (one after the other) it is possible to make a telescope that will form an image. The highly successful HEAO-2 satellite (renamed Einstein) used a set of such surfaces, arranged concentrically, in its X-ray telescope. This has given many new insights into the high-energy processes which are occurring in all sorts of astronomical objects, from nearby stars to the most distant quasars. However, this method is only of use down to certain wavelengths, typically around 1 nm. For shorter wavelengths a series of circular rings, alternately opaque and clear, is used to give an image by diffraction. Such a **zone plate** device is small and needs a strong influx of X-rays to work, so that at present it is used only in solar observation. Other devices using crystals can determine the degree of polarization of X-rays and also act as X-ray spectroscopes because certain crystals reflect X-rays at specific angles depending on their wavelength.

More conventional optical techniques – albeit using special material – can be employed for most ultraviolet work. Here again phenomenal success has been achieved by one spacecraft, the International Ultraviolet Explorer (IUE) satellite, which over its long lifetime studied many energetic objects. This has led to a new understanding of the processes at work in both single stars and binary systems.

The extension of work into the γ-ray region has been slow, because of the difficulty of devising suitable detectors. However, the COS-B satellite has proved a pioneer in this field, and it has already been mentioned (page 70) how the detection of γ-ray bursts by various spacecraft in different parts of the Solar System, even though they were relatively insensitive to direction, has led to the discovery of the enigmatic gamma-ray bursters.

Longer wavelengths

At lower energies and longer wavelengths, spacecraft have begun to show their potential. Particularly successful has been the Infrared Astronomical Satel-