GEOS

Salvaged results

Stuart Sharrock reports on some of the preliminary results from experiments aboard Geos

At a champagne breakfast on 20 April at Cape Canaveral, European Space Agency officials were gloomy. Instead of celebrating the successful launch of the Geos satellite they were contemplating the total failure of the whole mission. But within a few days the Geos ground control at Darmstadt had partially rescued the situation—although not in the planned geostationary orbit, the satellite would at least be spending some time in the right place.

This would have been a hollow victory, however, if it had meant no scientific results, so the experimenters had to retrieve what they could. In Munich last week they met to discuss their preliminary findings. Although there are some problems, remarkably, there are already some interesting results. After only four months it is clear that much of the scientific programme is going to be a success. But the role of Geos as the reference spacecraft of the International Magnetospheric Study (IMS) cannot be restored and the success of the experiments makes it imperative that the second spacecraft should be launched into geostationary orbit in the near future.

Geos was planned as the first geostationary satellite devoted solely to magnetospheric research. It followed

the ATS series of satellites which confirmed that a geostationary orbit was ideal for studying the magnetosphere. The intention was to launch Geos 1 into geostationary orbit early in 1977; the second identical satellite, Geos 2, was to be launched into an elliptical geosynchronous orbit in December 1979 by Ariane, ESA's own launch vehicle now under development. The second mission, codenamed Geosari, was to be complementary to the first, providing a wider spatial coverage of the magnetosphere. The only changes to the second payload would be improvements to the experiments found necessary as a result of experience gained during the first Geos mission.

The attractiveness of Geos as a tool for investigating the magnetosphere is based on the uniqueness of its planned orbit and the sophistication of its payload. Its position was planned to lie on magnetic field lines connecting northern and southern auroral zones. In addition, its geostationary orbit would have allowed average conditions to be established, deviations from the average indicating temporal rather than spatial variations. As the near-earth environment is not static this discrimination is important, but it can only be fully achieved by simultaneous use of more than one satellite such as the pair of satellites of the ISEE mission due for launch in October.

Although Geos has lost these advantages because it is not in geostationary orbit the possibilities opened up by the comprehensive nature of the experiment package still largely apply. It is still possible during part of Geos' new orbit to make simultaneous measurements on waves and particles whilst monitoring the background electric and magnetic fields and plasma density.

When the malfunctioning Delta launch vehicle failed to place Geos into the correct transfer orbit it was clear that injection into a geostationary orbit was not possible. ESA's Space Operations Centre at Darmstadt however managed to place it into a 12 h elliptic orbit with an apogee of around 7 earth radii using the apogee boost motor (see diagram). The orbit was chosen because the satellite is visible around apogee for about 10 hours per day from the ground receiving station near Darmstadt.

Initially the local time of the apogee of the orbit was in the evening sector, but it gets progressively earlier, drifting at a rate of 1 hour every 17.5 days. It has just passed the earth-sun line and

will start to move into the night sector around Christmas. The aurora are much more active in the night sector and so any correlated measurements with rocket campaigns will have to wait until 1978.

So far each experiment has been operated independently and there are still a few interference problems to be sorted out before the optimum mode of automatic operation of the experimental package will be known. But the initial data indicate that the Geos payload is sophisticated enough to provide reliable measurements of electric fields and plasma densities outside the plasmasphere. All data obtained so far are from the afternoon sector of the magnetosphere.

In perhaps the most ambitious experiment on board, an electron beam is fired from the satellite perpendicular to the local magnetic field (determined by another Geos experiment). It is deflected by the geomagnetic field in a circular path of several kilometres radius to return to the satellite close to its source. The distance between the source and the point of return depends on the electric field and the gradient of the magnetic field; the two contributions can be sorted out by varying the energy of the emitted electrons and the plasma drift velocity and direction can be determined. This is difficult to verify on earth as a vacuum chamber a few kilometres long would be required in a magnetic field of less than 100 γ . Unfortunately after about one week of operation the oxide cathode of the electron gun became poisoned but, even with only a few days data, the viability of the method was proved.

Another experiment measuring electric fields—in line with the Geos philosophy of providing redundant measurements of important parameters—has also been successful and interesting slow fluctuations have been seen which have yet to be correlated with data from the ULF wave experiment. The electrostatic wave experiment has been able to detect electrostatic waves with the help of information on the plasma frequency provided by an exploratory experiment using the first relaxation sounder to be launched above the ionosphere.

A variety of electromagnetic wave

Geos orbits: planned and achieved

phenomena have been observed, and some have been related with measurements at ground stations. It will be interesting to correlate these results with those from the various particle experiments but there are still some problems. Confusion over the number density and temperature of the plasma, however, may well be resolved by a determination of the energy spectrum of the various particles, but it needs further investigation of the contribution of the observed photoelectron cloud from the satellite itself and of the effects of spacecraft changing. These problems may be solved later in the year when Geos goes into eclipse.

Some experimenters have been unable so far to completely understand their results through the lack of reliable attitude data necessary to sort out spin modulation effects. But it should be only a matter of time before the relevant analysis programs are fully working.

The experiments measuring high energy particles are least affected by these problems. Preliminary results from a sophisticated mass spectrometer for measuring ion composition, indicate the presence of the doubly charged ions $^4\text{He}^{++}$ and $^{16}\text{O}^{++}$ deep in

the magnetosphere. The new orbit of Geos is almost a bonus in this case because ion compositions can be measured as a function of distance from the earth. Another unexpected bonus of the new orbit is the fact that Geos now spends considerable time near the geostationary satellite ATS-6. Earlier attempts to persuade NASA to drift ATS-6 past the planned geostationary position of Geos were unsuccessful but now the possibility of correlated measurements with similar instruments on the two satellites has become a reality.

The progress that has been made in such a short time after the disappointment of the failed launch is impressive and prospects for the future look bright. But most of the Geos programme in which coordinated measurements were planned with ground-based campaigns has had to be abandoned. Indeed the rocket campaigns from northern Sweden have been persistently plagued with bad luck. The rockets are supposed to pass through the transient auroral arcs and correlate their measurements with satellites poised at magnetically conjugate points above the equator. On the first launch ATS-6 was in position but the rocket exploded.

Geos should have been in position for the second rocket but delays had pushed back the Geos launch date and it was still on the ground. ATS-6 had meanwhile moved on. These difficulties are increased by the refusal of Norway to allow the rockets to overfly their territory and the consequently restricted rocket range makes it very difficult to hit the aurora. There are two rockets planned for 1978 and the rocket team hope their luck will change and that the second Geos spacecraft will have been launched into geostationary orbit.

Geos 2 has already been refurbished and will be of flight standard by the end of the year. It can either be launched into geostationary orbit by NASA early in 1978 using another Delta launcher, or it could wait until late 1979 to be sent up on ESA's own launcher Ariane. An early reflight on a Delta is what the experimenters want—from the way they have evaluated their data in such a short time they have in a sense earned it—and from some view points this appears the most likely option, but the extra cost to ESA will be about \$14 million and it is unclear where this will come from. ESA is expected to decide early in October. □

USA

Opening a biological pathway

The signing of the Panama Canal Treaty last week has implications for the ecology of the Atlantic and Pacific Oceans. Colin Norman reports

AMID the diplomatic fanfare and loud political protest which greeted the signing last week of the Panama Canal Treaty, muted rumblings of a scientific controversy were also faintly audible. The controversy centres on a little-noticed article in the Treaty committing the United States and Panama to conduct a joint study of the feasibility of building a sea-level canal within a few miles of the existing waterway.

The idea of carving out a direct, sea-level link between the Pacific and Atlantic Oceans has been investigated many times in the past, but political, economic and technical problems have so far kept it from becoming a reality. In fact, in spite of the renewed official interest in the idea, it is still considered unlikely that the channel will ever be dug. Nevertheless, the possibility is worrying some marine scientists, who fear that a sea-level canal would damage the ecology of the surrounding oceans.

The worry stems from the fact that

the tropical Pacific and Atlantic Oceans have been separated for perhaps five million years, since North and South America were joined by the isthmus or Panama. Consequently, marine life has evolved independently in the two oceans for long enough to ensure that few species are common to both. Blasting a sea-level link across Panama would open a biological pathway which may result in the migration of plants and animals into a new environment, a process which some marine scientists believe could have considerable impact on the oceans' ecology.

Very little migration takes place through the present canal because a freshwater lake in the middle of the waterway provides a barrier to most marine life, and the large number of locks along the canal means that there is little flow of water through the system. A sea-level canal would, however, be an entirely different prospect. Tidal ebb and flow through the canal, coupled with the fact that the average sea level on the Pacific side is slightly higher than that on the Atlantic side, could result in the transport of plants, animals, larvae and other organisms through the channel.

Among the more dramatic consequences that have been predicted as

a result of breaching the land barrier are the possibility that the yellow-bellied sea snake, a poisonous reptile which now lives only in the Pacific water, could become established in the Caribbean, and that the crown-of-thorns starfish might similarly invade the tropical Atlantic coral reefs. Other potential worries are that fish travelling through the canal might carry pathogens or viruses which are not known to native species. The central problem in such interchange is that the introduction of flora or fauna into a new environment might upset the ecological balance because there may be no natural predators and native species may not have evolved an effective defence mechanism against the newcomers.

Such possibilities are, of course, highly speculative, and some marine biologists contend that it is very unlikely that major environmental damage would result from opening a sea level channel. Nevertheless, there are several sobering examples of previous experience with the introduction of animals and plants into a new environment. For example, the building of a canal to bypass the Niagara Falls, providing a channel joining the Great Lakes to the Atlantic, has resulted in invasion of the lakes by a predatory fish-like creature called the sea lamprey. The lamprey has spread throughout the Great Lakes,