years of zoology, genetics or conventional sociology but without a thorough grounding in the biological sciences. All the new course will demand is evidence of numeracy—statistics is a compulsory part of the preliminary year—but, apart from that, it will be open to sixth-formers of all kinds and may even attract the occasional medical student.

COMMUNICATIONS SATELLITES

No Room in the Orbit

WITH the growth of telecommunications based on geostationary orbits, there is growing concern that satellites may become so closely crowded together that they interfere with each other. This is certain to be one of the preoccupations of the conference of the International Telecommunications Union, fixed for 1971, at which the regulations for international broadcasting will be revised, especially so as to accommodate the needs of communications satellites. An article in the current issue of the *Proceedings of the Institution of Electrical Engineers* (**166**, 1304; 1969) by J. K. S. Jowett and A. J. Jefferis consists of a calculation of the capacity of the equatorial orbit to accumulate geostationary communications satellites. Their chief conclusion is that the capacity of the equatorial orbit, with present arrangements, is probably limited to about 2,000 telephone circuits for each degree of the orbit. For practical purposes, this amounts to roughly one satellite in each four degrees of the orbit, which in turn implies that it may take very little further development before parts of the equatorial orbit—over the Atlantic and America, for example—may be overcrowded. The arguments of Jowett and Jefferis may be especially significant as pointers to the British position in the ITU conference, for the authors are with the Telecommunications Development Department of the Post Office.

In the long run, much of the interest which Jowett and Jefferis have made lies in the way they have been able to show how the capacity of the geostationary orbit depends on the characteristics of the system as a whole, ground stations as well as satellites. One of the fixed points in the calculation is that the bandwidth available for the upward and downward paths is the 500 MHz each way at present allocated for the operations of the Intelsat consortium. The capacity of a satellite for telephone conversations, assumed to be dependent on pulse code modulation, seems to increase quite rapidly with the size of the ground station dish up to a diameter of 15 metres, when some 3,000 high quality circuits per satellite should be obtainable within the 500 MHz bandwidth. By the same test, some fifteen television channels of high quality should be available. Another way of putting this is to say that within the present restrictions to a 500 MHz bandwidth for satellite communication, and at high standards of broadcasting, the number of television channels in a 10 degree stretch of the equatorial orbit ranges from thirty-five with ground station dishes 10 metres across to sixty channels with 20 metre dishes. The calculations also show that the telephone capacity of the equatorial orbit could be increased by some forty per cent by increasing the extent of allowable interference between neighbouring satellites or, what comes to the same thing, putting them more closely together.

The most immediate implication of this calculation is to emphasize that there is a natural limit to the capacity of the geostationary orbit. How then can communications satellite systems continue unchecked in their expansion? Technically, there would clearly be great advantages in satellites with highly directional antennae—a development which should also economize in operating power. In the long run, however, the greatest gains are likely to be made in an increase of the amount of bandwidth available for civil purposes, and this no doubt will be one of the tussles between civil and military departments of government between now and the ITU conference in 1971. It also seems clear, however, that the need for liaison between the operators of equatorial satellites is overwhelming, and it would not be surprising if the ITU did not find itself having to lay down the law about the ways in which nations use communications satellites for purely domestic purposes. The conference will plainly be a diplomatic as well as a technical affair.

SPACE

Jupiter Probes Urged

A WELL-TIMED shot in the debate on the future direction of the United States space programme was fired last week in a report by the Space Science Board of the National Academy of Sciences. In *The Outer Solar System, a Program for Exploration*, the board complains of the meagre proportion of the space budget set aside for planetary research, at present about two per cent. According to the board, "current funding for planetary exploration is totally inadequate to take advantage of the opportunities available". This is an echo, almost word for word, of a statement in a similar report prepared by the board a year ago—*Planetary Exploration, 1968–1975*. This year's version, however, is limited to the planets beyond Mars while the earlier report dealt chiefly with the inner planets.

On the face of things, the academy board is thus opposed to the view of Dr Thomas Paine, acting administrator of NASA, who has been saying that he would like to embark on a manned landing on Mars in the 1980s. Dr Paine is talking of a nuclear powered vehicle to carry six astronauts for a ninety day stay in Mars orbit, together with a landing module to ferry three of them to the surface for up to thirty days. With the Nerva engine now being developed at Jackals Flats, an expedition to Mars would be assembled in Earth orbit and would spend nearly two years on the round trip. A suitable launch date, according to Dr Paine, would be November 12, 1981, which would allow the returning spacecraft to benefit from the gravitational field of Venus. The cost estimated by Dr Paine would be roughly that of the Apollo project—$24 thousand million.

The Space Science Board has clearly taken a different line, considering that unmanned probes are at present the best way of exploring the planets. The chief recommendations in the study by the Space Science Board are that NASA should prepare a long-term plan for the exploration of the outer solar system and that a substantially increased fraction of its budget should be devoted to planetary exploration. A series of specific projects, in what purports to be an order of scientific significance, include a Jupiter deep-entry probe and flyby (1974), a Jupiter orbiter mission (1976), a Jupiter–Saturn–Pluto mission (1977), a Jupiter–Uranus–Neptune mission (1979) and a Jupiter–Uranus entry-probe mission (early 1980s). Several of the missions are based on the "grand tour" concept, which makes use of the gravitational field of the planets to direct spacecraft to the outer reaches of the solar system. The board stresses that opportunities for grand tours as favourable as occur in the late 1970s will not recur until the second half of the twenty-second century, although there will be less favourable opportunities for such exploits between 1989 and 1996. Two further missions which the board says need further consideration are to dock with an asteroid to determine its chemical composition and to determine the physical and chemical properties of a comet.

In the opinion of the board, most of the technology needed to accomplish its chief recommendations is already available, and the Titan IIID-Centaur combination is sufficiently powerful to be the launcher. But the report urges NASA to develop a lightweight probe which can descend into the hostile atmospheres of the larger planets and also to develop new spacecraft designs including one which will not become magnetized after passing through the magnetic field of Jupiter.

If anything, the report lacks conviction by failing to put a cost on any of the projects recommended. And one fear is that the manned spaceflight lobby will point out that it is too early to talk about the outer planets when the exploration of the adjacent planets Mars and Venus has only just begun.

The report comes at a time when there is increasing concern among scientists about the priorities of the United States space programme, and while a presidential task force is examining future space policy. Under the chairmanship of Vice-President Agnew, the task force includes Dr Thomas Paine, Dr Lee DuBridge, Defense Secretary Mr Melvin Laird, and Secretary of State Mr William Rogers, and is having to consider a spectrum of possible national goals. As well as the Mars expedition which Dr Paine is expected to recommend and the call by the Academy board for more unmanned probes, NASA has put forward plans for space stations in Earth orbit to accommodate upwards of 100 scientists and astronauts and for an orbiting base for lunar exploration. So far only the programme as far as Apollo 20 has been approved by Congress and partially funded. Clearly the task force is not going to be able to please everyone.

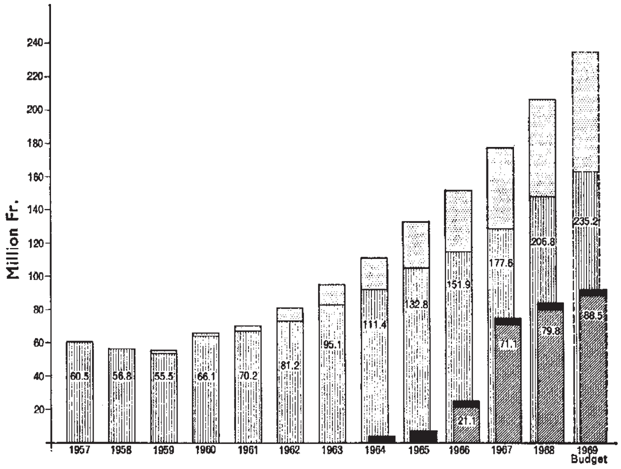
HIGH ENERGY PHYSICS

No Bounds at CERN

In spite of increased expenditure on the intersecting storage rings and the preparatory studies for the 300 GeV accelerator, the CERN laboratories at Geneva are spending more than ever before on basic programmes of research which have nothing to do with either of the machines, according to the CERN annual report for 1968. Some of the largest strides forward in the past twelve months have been in areas that only impinge obliquely on the mainstream of basic nuclear research, particularly in instrumentation and computer techniques.

A new type of wire spark chamber has been built at CERN which obviates the need for triggering by scintillation counters and which therefore increases the repetition rate from the cramping few hundred events per second of conventional chambers. In the new chambers, each wire is itself a proportional counter and the separation between wires is between two and three millimetres. There is no paralysing spark between wires, but merely a feeble pulse which can be amplified to taste. Costs still make it hard to use these new chambers to replace the huge wire chambers, but their use in critical places is a great boost to efficiency.

Streamer chambers also came into their own at CERN during 1968. These have the advantage that, like bubble chambers, they can record complex events involving many particles by the independent development of breakdown processes (known as streamers) in the chamber. A streamer chamber was used in an abortive search for a quark, which would produce about a ninth the number of avalanches as a normal charged particle. Another innovation last year was the successful building of an ultrasonic bubble chamber, which overcomes one of the chief failings of the standard bubble chamber—its very short sensitive time.



Expenditure at CERN since inception (in millions of Swiss francs). The dominant vertical bars represent the basic expenditure of CERN, with the increases due to rising costs represented by lighter shading at the top. The lower bars represent expenditure on the intersecting storage rings and the 300 GeV machine, with the cost of planning and development indicated by solid black shading.

The continuing refinement of measurements on the electromagnetic interaction is a continuing feature of the research at CERN. Accurate measurements of the magnetic moment of the mu meson were carried out last year, and the experiments are being extended to reach an accuracy where the strong interaction should start to show up against the otherwise pure electromagnetic interaction, even for mu mesons. Progress has also been made in finding a theoretical framework for the coupling of strongly interacting hadrons with photons. The most fundamental form of this coupling is through vector mesons such as the rho, omega and phi.

A new type of target has been developed at CERN which performs the important task of aligning the spins of protons that pass through it. The present targets of lanthanum magnesium nitrate in a magnetic field can be made to align some of the spins of free protons, but a new target using butyl alcohol instead of LMN has been found to perform more satisfactorily.