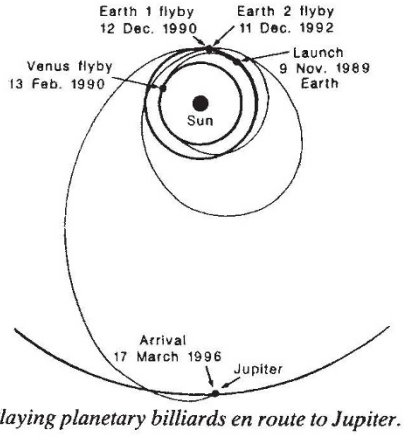
Space probes

Planetary tour for Galileo

Pasadena

THE fastest way to Jupiter is not via Venus, but for the long-delayed Galileo Jupiter probe and orbiter that may be the only way to make the trip. With a trajectory that evokes images of a complex billiard shot, the plan is now for Galileo to take a gravity boost from Venus and then two more from the Earth before heading out toward Jupiter. The multiple fly-bys will add more than three years to the mission but, project scientists at the Jet Propulsion Laboratory (JPL) all agree, it beats sitting on the ground.

Galileo was scheduled for launch aboard the space shuttle in May of this year. Had everything gone according to plan, a Centaur liquid-fuelled upper stage would have sent the spacecraft on a direct trajectory toward Jupiter. But the January Challenger accident, in addition to halting all launches, prompted a re-evaluation of shuttle performance characteristics. Even using a powerful Centaur upper stage, launch weight restrictions had mission planners considering an Earth gravity assist to change Galileo's velocity with respect to the Sun, a so-called delta VEGA trajectory. In June, however, the National Aeronautics and Space Administration (NASA) decided the safety risk of carrying the Centaur with its volatile fuel inside the shuttle was too high, forcing Galileo's



Playing planetary billiards en route to Jupiter.

managers to look elsewhere for an upper stage (see *Nature* **321**, 800, 1986). By using the IUS solid fuel booster rocket already launched aboard the shuttle, coupled with a kick stage and expanded fuel tanks aboard the satellite, Galileo could make it to Jupiter using a delta VEGA trajectory. But that plan died when new safety margins for launch abort landings prompted NASA to lower cargo weight.

Prospects for the mission looked bleak in mid-July. Then Roger Diehl became involved. He had been responsible for designing Galileo's orbital tour of Jupiter's moons, taking a gravity boost from each moon to power a visit to the next. Diehl substituted the Sun for Jupiter in the software used for the satellite tour, treating the planets as he had the moons of Jupiter. He discovered that using the counter-intuitive approach of launching toward Venus in late 1989, then returning to Earth, he could arrive back at the Earth at just about the right time to hook into a previously calculated delta VEGA trajectory proposed for a Titan launch in 1990. Now he knew there was an orbit that would not only provide the proper energy to reach Jupiter's orbit, but would also arrive when Jupiter was in the right place.

The new trajectory, christened VEEGA for Venus-Earth-Earth-gravity assist has its drawbacks. In addition to the extra travel time, new heat shielding will have to be added to the spacecraft for the trip close to the Sun. But the trajectory has advantages as well. It can be achieved using the shuttle and the IUS upper stage without an additional kick stage, and it no longer requires a major mid-course burn to achieve the correct fly-by angle for the final pass of the Earth.

Project scientists are elated by the VEEGA trajectory. Now mission scientists at JPL must hope that NASA headquarters will agree that Galileo is important enough to launch aboard the shuttle once flights resume. Galileo's launch window is very close to one needed by Ulysses, the collaboration between NASA and the European Space Agency for a polar orbiting mission. Political pressures are great to launch Ulysses as soon as possible, and there is some doubt that both will make a 1989 launch date. Still, VEEGA has given Galileo scientists hope that their spacecraft may someday leave its earthbound hibernation for a more fulfilling role in orbit around Jupiter.

Joseph Palca

Biotechnology

Genetic engineering minus glamour

Washington

CHEMICAL industry gave a vote of confidence to the potential of genetic engineering to improve industrial processes last week with the formation of a new company, Celgene. A spin-off from the $3,000 million Celanese Corporation it will be headed by former Monsanto chairman, Louis Fernandez.

The industrial chemicals business has always lacked the glamour of pharmaceuticals. No hepatitis vaccines or growth hormones here: the cream of the research crop will be agents that thicken toothpaste and ripen cheddar cheese. The products need not be pure, but they must be plentiful. And cheap; whereas a recombinant drug might sell for $10,000 per gram, a gram of industrial enzyme usually costs less than $1.

The market potential is enormous. According to the US Office of Technology Assessment, the US chemical industry as a whole will be buying $14,000 million worth of recombinant products annually by the year 2000.

To achieve that expansion, existing industrial enzymes will be improved to enhance the substrate specificity, product control and processing economics and novel enzymes designed for new tasks. But so far only one recombinant product for industrial purposes has cleared the Food and Drug Administration: a heat-stable alpha-amylase made by CPC International. Approval took two years, and the enzyme is still ensnared in environmental assessments. "The expense and time it takes for regulatory approval just doesn't make sense for a product that sells for $2 a pound," admits a manager at CPC's Moffett Technical Center.

Indeed, cost is what has made the enzyme industry reluctant to embrace biotechnology with the fervour of the pharmaceuticals. Genencor's Jonathan MacQuitty points out that manufacturing costs comprise about 6 per cent of the sales price for pharmaceuticals, but as much as 60 per cent of the costs of industrial enzymes. The industry simply cannot afford expensive production techniques. While prices should fall as high technology becomes routine, many companies are adopting a "low-tech or no-tech" approach.

Walter Goldstein, who heads the biotechnology group at Miles Laboratories, has formulated an algorithm to determine the feasibility of making a bioindustrial product by a given means. He says more research on organisms and substrates is required to make biotechnology pay in the biocatalysis business. Industry prefers filamentous fungi and *Bacillus* bacteria to the cultures used in pharmaceutical production, and they are difficult to engineer, and will take time to perfect. Scale-up provides another problem: while drug doses are measured in milligrams; speciality chemicals come in trucks.

Even when the enzymes industry reaps the harvest of recombinant technology it is likely to remain reticent. Biocatalysts are often intimately related to customers' proprietary processes. To preserve confidentiality, companies like Celgene and Genecor favour partnerships and contract agreements to research on products for general distribution. It is likely, says MacQuitty, that the most spectacular enzymes will always remain "the most secret of secret things."

Karen Wright