## The long arm of the celestial repairman

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The recent mending of a broken spacecraft that was meant to study the sun is only the latest in a line of successful long-distance resuscitations

The long arm of the celestial repairman

IF THE prospect of fixing your own car or television seems daunting, imagine trying to rectify a faulty space probe as it hurtles through the vacuum, millions of kilometres away. Yet over the years, as various spacecraft have explored the inner and outer reaches of the solar system—and often gone wrong in the process—ingenious and resourceful engineers on earth have found ways of doing just that.

The latest triumph of these celestial mechanics is the revival of the Solar and Heliospheric Observatory ( SOHO ), a sun-watching satellite operated jointly by the European Space Agency and America's space agency, NASA . SOHO stopped talking to its controllers in June.

Since then, engineers at NASA 's Goddard Space Flight Centre in Greenbelt, Maryland, have located SOHO at a distance of 1.5m km (930,000 miles) from earth, using the world's largest radio telescope, the 305-metre-wide dish at Arecibo, Puerto Rico, as a radar. They have subsequently coaxed it into replying by broadcasting various different wake-up calls to it for 16 hours a day over six weeks, until it responded; charged up its batteries in the 20 seconds out of every minute that the spinning craft's solar panels were facing the sun; painstakingly thawed it from -120°C to its operating temperature of 20°C, using its recharged batteries to power its on-board heaters; stabilised it by firing its thrusters (which use jets of hydrazine gas that had frozen solid); tested eight of the 12 scientific instruments on board; and, on October 12th, coaxed a picture of the sun out of its cameras. By the end of the month the craft should be fully operational again—and SOHO will have been added to the long list of probes that have been repaired, re-engineered, reprogrammed and jury-rigged by remote control over the past 25 years.

## All in a days work

Yet the recovery of SOHO is by no means the most spectacular example of the long-distance mechanic's art. The laurels for that probably belong to the rescuers of *Voyager 2* , the second of two probes launched towards Jupiter and Saturn in 1977.

The pictures transmitted by the *Voyager* s showed the two giant planets, and their assorted moons and rings, in unprecedented detail. And yet it is a miracle that *Voyager 2* managed to send anything back at all, for its main radio system failed soon after launch, and its back-up system proved to be faulty.

The problem with the craft's back-up radio was that it could only receive signals in a very narrow frequency range—which turned out to vary according to its temperature. That, in turn, depended on the angle and amount of sunlight falling on *Voyager* , and the amount of heat generated by its various components as they were switched on and off. As a result, an elaborate computer model had to be created on earth to predict the temperature of the receiver, so that outgoing signals could be transmitted at the right frequency.

To cap that, having looked at Jupiter and Saturn, *Voyager 2* 's controllers decided to extend the mission by taking pictures of Uranus and Neptune as the craft continued on its journey out of the solar system. By now, one of its motors had failed altogether, so that its camera could no longer pan from side to side.

This was solved by rotating the craft through a right angle, so that panning was possible with the motor that had previously been used for up-and-down movement. *Voyager 2* 's two computers were also extensively reprogrammed to take advantage of new image-compression software that had been developed since the craft had been launched. That meant that pictures could be transmitted from these remote planets in "real time", rather than being stored up for later broadcast.

Earlier craft had even greater difficulties than this. A particularly accident-prone probe called *Mariner 10* was sent to Venus and Mercury in 1973. It suffered from short-circuits, faulty radio and power systems, an unreliable tape-recorder, a sticky camera platform, and the loss of much of the gas that supplied its stabilising thrusters—a problem overcome by repositioning its solar panels and main antenna so that they acted as solar sails, stabilising the probe via the gentle pressure of sunlight.

More recently *Galileo* , a probe now investigating Jupiter, has been the beneficiary of the long-distance fixers' art. *Galileo* 's main antenna, folded up like a giant umbrella, failed to open properly after launch. The probe was repeatedly turned towards and away from the sun, in the hope that thermal expansion and contraction would free the antenna, but to no avail. Next, the antenna-deployment motors were switched on and off thousands of times, but the antenna remained jammed. Further attempts involved switching on the motors while spinning *Galileo* on its axis, and also when it reached the point of its maximum acceleration around Jupiter.

Eventually, the *Galileo* team gave up on the main antenna and reprogrammed the craft to use its smaller secondary dish, which transmits data at a hundredth of the speed of the main one. But by using compression software and getting *Galileo* to record data on its tape-recorder for later transmission, almost all of the probe's objectives have still been achieved.

In coming years, a new generation of smaller, cheaper, more sophisticated and—their designers hope—more reliable probes (see ) may diminish the need for such ingenious rejigging. But old hands are sceptical. Ed Massey, project manager for the *Voyager* mission, points out that no matter how clever and autonomous a probe is, it can only get itself out of situations it has been programmed to cope with.

There is also the probability of human error. The inquiry held to apportion blame for the SOHO fiasco decided that control of the craft was lost because of a mistake in its software, combined with an error that arose when a confusing computer display was wrongly interpreted. There is, as has been widely observed, no such thing as a fool-proof system. Sooner or later a big enough fool will always come along.

In other words, future space probes are likely to go wrong in new and unexpected ways as well as some of the old familiar ones. When they do, they will no doubt provide opportunities for even more ingenious rescue manoeuvres—as well as the chance for more engineers to distinguish themselves as celestial mechanics.