# Hubble's repair: A second mission needed?

For two years, NASA has planned a single repair mission to correct the Hubble Space Telescope's flawed optics and replace its ailing hardware. In May, an independent task force urged the agency to schedule a second space shuttle visit in case one doesn't suffice. And at a press briefing last week, NASA seemed to agree. While agency scientists said they remained confident it will take but one visit to fix the telescope's major equipment and optics problems, they announced the addition of a back-up mission as part of the blueprint for Hubble's repair.

The first repair mission, now scheduled for December, will cost $630 million. NASA estimates that a second mission, if needed, would fly six months to a year later and cost at least the price of a shuttle flight, about $300 million.

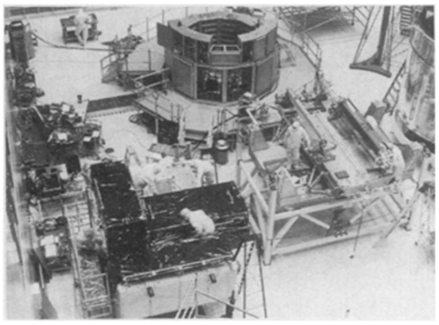
The December mission, which will require a record five spacewalks, has an ambitious list of 11 items to fix or replace. Edward J. Weiler, Hubble program scientist at NASA headquarters, gives only 50-50 odds that the crew could address all 11 items, but says he is virtually certain astronauts can accomplish the key repairs, which involve six tasks.

To compensate for Hubble's flawed primary mirror, which makes faint stars and galaxies appear fuzzier than researchers had hoped, astronauts will apply two fixes. After snaring the telescope with a grappling arm, they will install corrective mirrors for three Hubble instruments — two spectrographs and a camera. The crew will also replace the telescope's Wide-Field/Planetary Camera with a newer, more sensitive version that has a built-in corrective mirror.

But even without the telescope's highly publicized optical problems, other Hubble troubles now require repairs, Weiler notes. The crew must also replace Hubble's solar arrays, which power the craft but vibrate unacceptably due to temperature fluctuations caused when the telescope passes in and out of Earth's shadow. Researchers fear the jittery arrays will eventually snap off.

In addition, NASA wants to replace at least two of Hubble's three failed gyroscopes; if another goes awry, engineers can't point the telescope accurately enough to do scientific observations, Weiler says. Other priority tasks include replacing at least one of two troublesome magnetometers and adding a coprocessor to improve the degraded memory of its onboard computer. Weiler notes that the telescope was designed to undergo maintenance every three years.

Given the complexity of the key repairs, "I wouldn't be surprised if a second mission were necessary," says aerospace engineer Eugene E. Covert of the Massachusetts Institute of Technology. Covert served on the task force that urged NASA to consider a back-up mission.


NASA

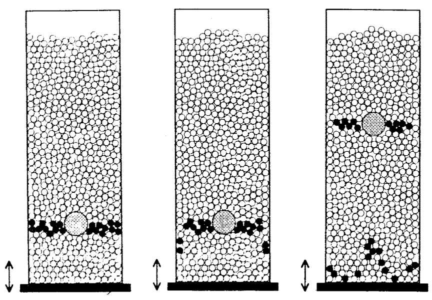
*NASA technicians test instruments astronauts will use to repair Hubble.*

Robert C. Bless, a Hubble researcher at the University of Wisconsin-Madison, feels encouraged by the extensive planning for the December flight. But he expresses concern that in underwater simulations of the space environment, the diving gear worn by the crew allowed them to stay immersed for only four hours, compared with the six-hour spacewalks required for the repair mission. Bless adds that more of Hubble's aging equipment could fail by the time of the rescue flight. Weiler says that by October, after further crew training, NASA should have a better idea if Hubble will need a second mission. *— R. Cowen*

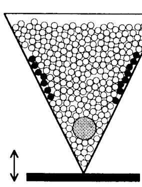
# Great shakes: Why pebbles wind up atop sand

As just about any devotee of the sandbox has observed, vigorously shaking a bucket that holds a dry mixture of pebbles and sand inevitably brings the pebbles to the top. Other mixtures of granular materials show the same segregation effect when shaken. Even if the components differ only in size and not in composition or density, the larger particles usually end up on top.

Now, researchers have obtained experimental evidence that this phenomenon involves more than just the local rearrangement of particles. Vertically vibrating a cylinder packed with glass beads induces a collective stop-and-go motion — resembling a convection cycle — that carries beads upward through the cylinder's middle and downward in a thin layer along its inner surface.


Knight et al./Phys. Rev. Lett.

*Before tapping, a large bead rests in a layer of small colored beads close to the bottom, as shown in this diagram of a cross section of a bead-filled cylinder (top left). After just one or two taps, the colored beads closest to the cylinder wall begin to move downward (top middle). After more taps, both the large bead and the small colored beads near the middle of the cylinder move upward. Beads that started out near the wall reach the bottom, move inward, and begin to rise (top right). In a conical container, the beads tend to move upward along the wall and downward through the middle. This leaves the large bead trapped at the bottom (left).*



Thus, a large glass bead immersed in smaller beads can readily travel upward. But when it reaches the top, it can't join in the much narrower downward flow of beads along the wall. It gets trapped at the top.

James B. Knight, Heinrich M. Jaeger, and Sidney R. Nagel of the University of Chicago describe their experiments in the June 14 Physical Review Letters.

The researchers used a glass cylinder, 35 millimeters in diameter, mounted on a shaker that gave it a vertical shove, or "tap," once per second. Open at the top, the cylinder was filled with spherical, 2-millimeter-wide glass beads, some of which were dyed so that their motion could be observed.

Previous computer simulations had suggested that vibrations would create substantial voids beneath any large particles present. Smaller particles would then slip into these voids during subsequent shakings. These rearrangements would slowly drive the large particles upward (SN: 8/8/92, p.86).

"What we found was completely different," Nagel says.

Nagel and his co-workers attribute the convective motion they observed to friction between the cylinder wall and adjacent glass beads. Earlier computer simulations had failed to take this factor into consideration.

The researchers also designed and tested a container with slanting sides that reversed the direction of the beads' motion (see diagram). In this conical container, a large bead descends to the bottom and stays there.

Many questions remain unanswered, including what effect a cylinder's width may have on the motion of the beads. Sadly, packagers of mixed nuts don't have enough information yet to select a tin of just the right shape to keep their product thoroughly mixed. *— I. Peterson*