Skylab 3: Successes despite troubles

After spending nearly a week getting settled in their new home in the sky, Skylab 3 astronauts Gerald Carr, Edward Gibson and William Pogue have settled down to business—a lot of it.

Flight planners knew in advance that a major milestone of the mission would be its first spacewalk. With a month and a half since the Skylab 2 crew's departure behind them and as long as 84 days in space ahead, the astronauts would have to make repairs, replenish film supplies and install new experiments before the 100-ton space station would really be ready for work. To make things even harder, the liquid cooling system, which Pogue had repaired early in the flight (it malfunctioned during Skylab 2), appeared to be leaking again.

Fortunately, the leak proved to be not in the cooling system, but in the leak detector, and the spacewalk went smoothly, although it kept both Gibson and Pogue outside for an exhausting six and a half hours. With Carr monitoring from within, the two orbiting handymen crawled almost everywhere on the 117-foot station, replacing film in the solar observatory section, fixing a jammed antenna on the spacecraft docking section and installing scientific instruments on the airlock module and the main body of the workshop. The hardest part was repairing the movable antenna, part of a microwave earth-watching device for measuring everything from the heat of cities to changes in vegetation.

Less than a day after the spacewalk, however, another mishap occurred. It posed no danger to the crew—ground controllers in Houston didn't even wake them up to tell them about it—but it has already delayed the mission's scientific plans. One of the three main gyroscopes that helps Skylab reorient itself in space stopped, apparently from a jammed bearing. The gyro was the one in charge of Skylab's x-axis, the main axis of the cylindrical workshop. With only two gyros remaining, it takes more propellant for the space station to make a given change in its position. If a second gyro were to fail, even this early in the mission, the flight could be cut to as little as 20 days, although it could be stretched by sharply limiting the use of the Apollo Telescope Mount, which requires extra maneuvering to aim its eight telescopes.

The first victim of the forced scrimping on propellant was the brilliant comet Kohoutek. Of the dozen Skylab instruments scheduled to study the comet, only one, a light-amplifying camera to photograph Kohoutek's giant hydrogen cloud, was specially built for the purpose. It seems to be working fine, but it didn't get started until Nov. 25, a day late, because it required Skylab to reorient itself a full 90 degrees on its x-axis—with no x-axis gyro.

The problem was also felt by one of Skylab's most valuable groups of instruments, the earth resources experiments package. Work with it was postponed at least twice early this week. Part of the reason was dense cloud cover that obscured much of the terrain in the target area. But officials admitted that they were delaying in part while they searched for ways to do the job with a minimum amount of propellant. On the second day of the delay, the astronauts temporarily filled the EREP camera bay with another instrument, a panoramic camera designed to show the distribution of ultraviolet sources among selected stars, star fields, steller clusters and galaxies.

The sun-watching ATM, however, which in the previous Skylab missions had elated the numerous astronomers responsible for it, seems to be continuing in fine style. Even as the astronauts

were checking it out early this week, the sun seemed to respond as if to an old friend by setting off a series of gigantic flares.

On Nov. 27, another experiment, added late in the planning for the then-already-crowded mission, proved successful when Pogue aimed a camera out through a window and photographed a cluster of glowing lines arcing high over the Pacific Ocean. The glow was from barium ions, released by a high-altitude sounding rocket as a cloud of barium vapor and ionized by ultraviolet radiation from the sun. The ions, attracted to the lines of force of the earth's magnetic field, give geophysicists a way of observing the field lines reaching as high as 22,000 miles above the planet. Skylab's lofty viewpoint, free of most of the distorting atmosphere, gives the astronauts 10 times as good a look at the lines as have observers on the ground. □

The tie that

New techniques enable a closer

which governs the relations of

by Dietrick E. Thomsen

The molecule is the smallest unit of a chemical compound that retains the nature and characteristics of the compound. Since there are many more compounds than elements in nature, most substances are built up out of molecules, and the structure of gross samples is determined by the forces that exist between molecules. These forces are known as van der Waals forces after a Dutch physicist, J. D. van der Waals, who postulated their existence a century ago.

The van der Waals force determines among other things whether a substance is a liquid, solid or gas; it lies at the basis of the structure of liquids and crystals and it determines the solubility of one substance in another. It is thus of the highest importance to physical chemistry.

Lately a new technique, one that uses beams of molecules that collide with each other, is being used in at least three centers of research to study the van der Waals force. The researchers involved are Aron Kuppermann of the California Institute of Technology, Yuan Lee of the University of Chicago's James Franck Institute and Giacinto Scoles of the University of Waterloo in Waterloo, Ontario, Canada.

The van der Waals force is of electromagnetic origin. This is in spite of the overall electrical neutrality of a molecule. If a molecule were a static entity and if all of its electrical charges were distributed in a spherically symmetric way, the effects of its negative and positive charges would cancel each other out. But molecules tend not to be spherical, and their charges are continually in motion. This leads to complicated interactions between the charges of one molecule and those of another. What results is a small attractive force, the van der Waals force.

Compared to the other forces that manifest themselves on a microscopic level, the van der Waals force is a lightweight. It represents a binding

binds molecules

study of the van der Waals force,

molecules in substances

energy one-thousandth of the binding energy of the chemical bonds that unite atoms inside molecules and one-billionth of that which holds the atomic nucleus together.

Because the force is so small, molecules must be brought together gently to study it. The crossed-beam apparatus, which Kuppermann pioneered, is designed to do this. It sends two beams of molecules moving at right angles to each other and measures what happens when they collide. The beams are generated by putting samples of the gases desired through a special nozzle that makes the molecules move in the same direction and accelerates them slightly. In one instance cited by Kuppermann hydrogen and oxygen molecules collide with a velocity of 1,000 meters per second (about 2,240 miles per hour). Swift though this may seem, it is the normal speed of molecules moving around at room temperature.

Kuppermann determines the results of the collision with a sensitive mass spectrometer that can be positioned at varying angles to the original molecular beams to identify the molecules that come off and measure their energy. Lee uses a mass spectrometer that he says is similar to Kuppermann's but more sensitive. Scoles uses an infrared detector to measure the energy of the molecules.

"We can determine the distance at which the attraction energy of the molecules toward one another is largest and measure as well the strength of this interaction," says Kuppermann. "This type of instrument makes it possible to predict the properties of gaseous mixtures of molecules, including viscosity, heat conductivity and the ability of one substance to diffuse through another. Moreover, the results enable us to define the sizes of the molecules."

To return to the specific example, the distance between the two atomic nuclei in a hydrogen molecule is 0.742 angstroms; in an oxygen molecule it is 1.207 angstroms. The two molecules' attraction for each other is greatest when they are 3.86 angstroms apart measured from center to center. At that point they are bound by an energy of about 1/140 of an electron-volt.

Recently Kuppermann and his coworkers made the first measurements of van der Waals forces between polyatomic molecules. Earlier work as well as work continuing now dealt extensively with noble gases. Noble gases have the advantage of relative simplicity. Since it is nearly impossible for them to form compounds, their atoms are, so to speak, also their molecules. Lee has done studies of everything from helium-helium to xenon-xenon. Scoles also did such work, he says, in Europe before he came to Canada. Another advantage of noble gases, Lee points out, is the contribution a knowledge of their van der Waals force can make to the construction of rare-gas lasers.

Scoles' Canadian work is centered on water. Ultimately a knowledge of how gaseous water molecules interact with each other will help in understanding the solid and liquid states of water.

If one begins with an understanding of the two-body forces in the gas, one can hope to begin to unravel the three-body and multibody forces characteristic of the liquid and solid states. For noble gases the two body-forces are well known, "a solved problem," Scoles says. For water the two-body force is not yet known. The first step experimentally is to strike water molecules, which are nonspherical, against a spherical molecule. When that interaction is understood one can go on to the water-water interaction. The work is preliminary to a model of the structure of liquid water. "If we can come up with a good definition of the intermolecular forces in water," he says, "we will do a great service to those doing models of liquid water."

Kuppermann is also interested in working with water. He plans to bounce a series of different molecules off water. Learning the precise attraction energies between water and such substances as hydrogen and oxygen can lead to information about their solubility in water. One ultimate aim of this work is to know something about the solubility of oxygen in blood.

One of Lee's interests in polyatomic molecules is a study of the anisotropy of the van der Waals force, how it varies with the orientation and shape of the molecule. He wants to learn about such things as rotational energy transfer, elastic and inelastic collisions and various complexities of the molecules.

"I do believe," says Lee, "that this work will tie up to basic principles." Knowing the potential energy of interaction between argon and argon (which theory could not calculate) one can use quantum mechanics to calculate the forces and accurately predict miscellaneous properties of the substance, such as viscosity, bulk modulus and thermal conductivity.

Both Kuppermann and Lee mention a desire to go on from van der Waals forces to study chemical forces with the crossed-beam technique. To do this Kuppermann proposes to heat the molecules to temperatures on the order of 10,000 degrees C., which represents an energy of a few electron-volts, an energy characteristic of chemical bonds. This is something of a contrast to the van der Waals work where the molecules are often cooled to temperatures as low as 160 degrees below zero C. (liquid-nitrogen temperature), because van der Waals forces are stronger at low temperature.

Whether it is used for the study of van der Waals forces or chemical interactions, the main point, as Kuppermann puts it is that with the crossed-beam technique "one has a powerful tool for the investigation of intermolecular forces." □