

Alien Space Ships

One of the research laboratories contracted by the U.S. Army to improve smoke screens for troop movements during World War II was located at the General Electric Company in Schenectady, New York. Irving Langmuir, a Nobel Prize Winner and well-known physical chemist, ran the laboratory. After the war his interests in smoke and clouds were turned toward more peaceful applications, such as the colloidal instability of atmospheric clouds and precipitation processes. Two other scientists whose work was steered in this direction were Dr. Bernard Vonnegut and his laboratory assistant, Vincent Schaefer. The name Vonnegut may sound familiar because Dr. Vonnegut's brother, Kurt, later became well known as a writer, even publishing one science fiction book about all the earth's water being nucleated and turning to ice.

Bernard Vonnegut and Vincent Schaefer began to investigate the Bergeron-Findeisen process in the laboratory. This process, suggested independently by Tor Bergeron of Sweden and Walter Findeisen of Germany in the 1930s, is the basis for the precipitation process in most mid-latitude and polar clouds and many tropical clouds. It is the method by which many clouds convert liquid cloud droplets into precipitation-sized particles that can reach the ground. When a cloud extends upward to temperatures colder than 0°C , ice crystals are nucleated, grow at the expense of supercooled liquid cloud droplets, and fall through the cloud, forming snow or rain on the ground. The number of ice crystals nucleated at the top of the cloud is dependent upon the number of ice nuclei present in the air. These nuclei tend to produce about ten times more ice crystals for every four degrees colder the top of the cloud becomes. This strong dependence of ice crystal concentration on cloud-top temperature creates what is called the "feeder/seed" mechanism, in which, the base of a cloud feeds moisture upward to the middle of the cloud, and the top of a cloud produces ice crystals that seed the lower part of the cloud. Because of the lack of ice crystals in portions of a cloud near 0°C when the seeder mechanism is absent or ineffective, it is believed that many clouds should be naturally deficient in ice crystals. If a method for artificially nucleating ice crystals in a cloud could be found, it might be possible to increase the precipitation efficiency of some clouds.

While Vonnegut searched the tables of characteristic lattice dimensions for chemical compounds which matched those of ice, Schaefer worked on constructing a cold chamber in which he could form a water cloud at temperatures below freezing. This chamber would be used to test various smokes produced from the compounds identified by Vonnegut as potential seeding agents. The test agents would be mixed with a volatile solution of acetone and burned, producing a smoke of particles. This process produces as many as 10^{20} or more particles per gram of agent. The effectiveness of the particles as a seeding agent was expected to be dependent upon the nearness of the lattice dimensions to that of ice and to the number and size distribution of the particles created in the burning process.

Schaefer used a General Electric chest-type freezer as his chamber. By simply blowing into the chest he could generate a supercooled water cloud. When a spotlight was positioned to shine across the chest, he could clearly see the cloud droplets. Ice crystals introduced into the cloud of droplets sparkled in the light like miniature stars. It was easy to distinguish cloud droplets and ice crystals. Ice crystal concentrations could also be measured by placing glass microscope slides on the bottom of the chamber, waiting for the crystals to fall out, and then counting them.

Schaefer was ready for the experiments to begin except for one slight problem. He couldn't cool the ice chest cold enough to reach the desired temperatures requested for the experiments by Dr. Vonnegut. So, he decided to drop the temperature further by placing dry ice (solid carbon dioxide) on the floor of the chamber. Dry ice cools to about -80°C as it sublimates. However, upon introducing the dry ice into the ice chest, Schaefer found that the supercooled water cloud was immediately turned to ice crystals. Even a small amount of dry ice would generate myriads of ice crystals.

The search for artificial seeding agents was immediately suspended and a whole series of laboratory and field experiments were conducted on the use of dry ice to seed clouds. Dry ice was a fabulous cloud-seeding agent. It could be ground into small chunks and dropped through a supercooled cloud, either in the chamber or in the atmosphere, and the cloud was immediately turned from water droplets to ice crystals. One famous picture of the field experiments shows large racetrack patterns made in a stratus cloud layer above the General Electric Laboratory in New York State when ground-up dry ice was dropped into it from a small aircraft. Where the dry ice had been dropped, the cloud turned to ice crystals, precipitation formed, and downdrafts developed. Vonnegut and Schaefer claimed that they could carve the initials of General Electric in cold stratus clouds whenever and wherever they chose.

Probably the most important characteristic of dry ice seeding from that day is its ability to create ice crystals at temperatures, as warm as 0°C . However, the number of ice crystals produced was only about 10^{12} per gram of dry ice and did not increase greatly for colder temperatures. Vonnegut believed that he could create many more ice crystals from a compound he had identified for testing, silver iodide. Vonnegut and Schaefer went back to the laboratory. They found, indeed, that when burned properly silver iodide could produce as many as 10^{16} particles per gram which were effective in nucleating ice crystals at a temperature of -20°C . At colder temperatures even more ice crystals could be nucleated. Because of these characteristics, silver iodide became the agent of choice for most cloud seeding projects all over the world.

The method by which silver iodide was burned to seed clouds took many forms. The original method was simply to dissolve silver iodide in acetone with a few additional additives and burn it in a propane flame. This technique was relatively simple and has been used for ground-based seeding generators for over seventy years. However, carrying and burning flammable materials on an airplane was a little more difficult. Special wing-mounted manifolds were needed to ignite

and burn the fluids on airborne platforms. Extra safety precautions were also needed.

In the 1960s the Naval Weapons Research Center in China Lake, California under the direction of Dr. Pierre Saint Amand took up the challenge of developing an alternative to the liquid silver iodide seeding generator. He and his laboratory were closely associated with the development of bombs, flares, and fuses for military use. With only slight alteration he believed silver iodide could be burned in a type of flare and would be much easier and safer to use on aircraft. He and his staff developed two basic kinds of pyrotechnic silver iodide generators. The first type looked like a long railroad flare which could be mounted in a special rack on the wing of an airplane. It was ignited electrically and burned in place in a rack, leaving a line of seeding material in clouds behind an airplane. The second type looked somewhat like a large aluminum shotgun shell and was mounted in a different type of cannister under the wing or belly of an airplane. This flare was also fired electrically but had a small explosive cap in its head which forced the flare out of the shell and ignited it. The flare fell for several thousand feet, burning on the way down. The advantage of this type of flare was that the seeding material was distributed in the shape of a curtain if flares were fired every few seconds. A curtain of nuclei distributed in a two-dimensional curtain shape was more effective in seeding a cloud than a one-dimensional line.

Both types of flares are used in cloud seeding. They were initially used only for military and government projects, later both types were used commercially by many private companies. One top-secret military project for which the flares were used to seed clouds was *Operation Popeye*, an effort to slow the movement of men and supplies southward on the Ho Chi Min Trail during the Vietnam Nam war. Navy pilots seeded clouds over the Ho Chi Min Trail with the intent of creating more rain, which would, in turn, create more mud, and bog down the supply trucks. Pierre Saint Armand not only developed and manufactured the silver iodide flares for this operation, he also produced a training film for the pilots. This ten-minute

film is one of the most humorous technical films ever made. Saint Armand recruited one of his secretaries to instruct the pilots in the techniques of injecting flares into tropical clouds found in North Vietnam. She was obviously a novice at conducting briefings but came across as a ditzy weather girl giving a forecast. She pointed at a cardboard cloud with a silver iodide flare and described how tropical clouds should be penetrated to create the greatest effect. Several suggestive double entendres provided the humor that military pilots tend to appreciate.

Operation Popeye didn't long remain top secret. In the 1970s someone leaked the details of the project to the news media and it appeared on the cover of Time Magazine. The antiwar protestors and liberal environmental advocates started a protest the use of cloud seeding as a weapon of war. The viewpoint expressed was that cloud seeding over the Ho Chi Min Trail was an incredible misuse of technology on a defenseless country. Furthermore, it could become a weapon of mass destruction if allowed to continue. Hurricanes could be intensified and made to hit the enemy's populated coast lines. Floods and droughts could be created starving out whole populations. All kinds of dire scenarios were painted.

I was always puzzled why dropping more rain on the people of Vietnam was considered more serious than dropping bombs. Besides, as a professional rainmaker, I had a healthy skepticism about the efficacy of cloud seeding. I knew that rainmaking activity over the Ho Chi Min Trail was a measure of last resort. There was no clear evidence that it had worked. These were tropical clouds. We weren't even sure that cloud seeding worked on mid-latitude clouds where the ice crystal process was better understood.

Prohibitions against using cloud seeding as a military weapon had already been included in the long-forestalled SALT I treaty, but it had never been signed. All offices in the U.S. military which had been considering weather modification applications for military uses were disbanded not long after I left the Air Force in 1970. The United States wished to show good faith in adhering to the terms of the

treaty, even if it hadn't been signed. Finally, in the Carter administration, the SALT II treaty was signed, with provisions prohibiting the military use of weather modification of any kind.

It wasn't long after Saint Armand had developed silver iodide flares at China Lake, that they were being manufactured commercially. A company in Lafayette, Colorado, began selling them to private cloud seeders and government research projects. Some of the droppable silver iodide flares were used in the Sierra Cooperative Pilot Project (SCPP) that I directed from 1977 to 1982. Because we suspected the supercooled water which might exist in the Sierra Nevada clouds would be at low elevation and warm temperatures, we began to use dry ice more frequently. However, in the early phases of the SCPP we tested seeding methods using both dry ice and droppable silver iodide flares because both agents could reach the lower, warmer parts of the clouds.

Each year at the start of our SCPP field season in October or November we performed seeding trials to make sure all our seeding equipment and procedures were functioning properly. The droppable flares were tested at night when they could be seen burning as they fell from the racks under the low-flying seeder aircraft. However, because we did not want to start grass fires in the dry Fall conditions, we performed these tests over Folsom Reservoir just east of Sacramento, California. Just in case a flare continued to burn longer than we expected, it would fall harmlessly into the water.

To not alarm the residents, we would inform the news media and police of our plans. They, in turn, would typically run special news features in the papers and on TV about the tests over Folsom within sight of most of the population of Sacramento. Several television stations would often send camera crews to the overlook on the dam of Folsom Reservoir where we directed and observed the burning flares falling from our aircraft. We typically instructed the seeder aircraft to fly about 3,000 feet above and parallel to the Folsom Dam and release a flare

every three seconds for a total of ten flares on each of three passes. The tests were very dramatic. When the seeder aircraft flew over, its navigation lights would be lit, so it was easy to spot the plane in the dark. When the flares were ignited, a bright streak of light would begin a few feet below the aircraft, form a slight arc at the top of its path, and then fall straight down toward the water. Occasionally, a flare would not ignite, but in the five years we conducted these tests, none of the flares burned all the way to the water. Sometimes all ten flares would be in various stages of their fall at the same time. It was like fireworks on the fourth of July.

One year, however, a lady who lived near Folsom Reservoir didn't get the word about our tests. She called the police during our operation and her story was reported in the next day's Sacramento Bee. She had reported seeing unusual lights over Folsom Reservoir that night. In fact, she was convinced that Sacramento was being invaded by aliens from outer space. She saw a mother ship which had made several passes over her house. On each pass the mother ship had released ten baby ships. The War of the Worlds had begun!