= Project Stormfury =

Project Stormfury was an attempt to weaken tropical cyclones by flying aircraft into them and seeding with silver iodide . The project was run by the United States Government from 1962 to 1983 .

The hypothesis was that the silver iodide would cause supercooled water in the storm to freeze , disrupting the inner structure of the hurricane . This led to the seeding of several Atlantic hurricanes . However , it was later shown that this hypothesis was incorrect . It was determined most hurricanes do not contain enough supercooled water for cloud seeding to be effective . Additionally , researchers found that unseeded hurricanes often undergo the same structural changes that were expected from seeded hurricanes . This finding called Stormfury 's successes into question , as the changes reported now had a natural explanation .

The last experimental flight was flown in 1971 , due to a lack of candidate storms and a changeover in NOAA 's fleet . More than a decade after the last modification experiment , Project Stormfury was officially canceled . Although a failure in its goal of reducing the destructiveness of hurricanes , Project Stormfury was not without merit . The observational data and storm lifecycle research generated by Stormfury helped improve meteorologists ' ability to forecast the movement and intensity of future hurricanes .

= = Hypothesis = =

Cloud seeding was first attempted by Vincent Schaefer and Irving Langmuir . After witnessing the artificial creation of ice crystals , Langmuir became an enthusiastic proponent of weather modification . Schaefer found that when he dumped crushed dry ice into a cloud , precipitation in the form of snow resulted .

With regard to hurricanes , it was hypothesized that by seeding the area around the eyewall with silver iodide , latent heat would be released . This would promote the formation of a new eyewall . As this new eyewall was larger than the old eyewall , the winds of the tropical cyclone would be weaker due to a reduced pressure gradient . Even a small reduction in the speed of a hurricane 's winds would be beneficial : since the damage potential of a hurricane increased as the square of the wind speed , a slight lowering of wind speed would have a large reduction in destructiveness .

Due to Langmuir 's efforts , and the research of Schaefer at General Electric , the concept of using cloud seeding to weaken hurricanes gathered momentum . Indeed , Schaefer had caused a major snowstorm on December 20 , 1946 by seeding a cloud . This caused GE to drop out for legal reasons . Schaefer and Langmuir assisted the U.S. military as advisors for Project Cirrus , the first large study of cloud physics and weather modification . Its most important goal was to try to weaken hurricanes .

= = Project Cirrus = =

Project Cirrus was the first attempt to modify a hurricane . It was a collaboration of the General Electric Corporation , the US Army Signal Corps , the Office of Naval Research , and the US Air Force . After several preparations , and initial skepticism by government scientists , the first attempt to modify a hurricane began on October 13 , 1947 on a hurricane that was heading west to east and out to sea .

An airplane flew along the rainbands of the hurricane , and dropped nearly 180 pounds (82 kilograms) of crushed dry ice into the clouds . The crew reported " Pronounced modification of the cloud deck seeded " . It is not known if that was due to the seeding . Next , the hurricane changed direction and made landfall near Savannah , Georgia . The public blamed the seeding , and Irving Langmuir claimed that the reversal had been caused by human intervention . Cirrus was canceled , and lawsuits were threatened . Only the fact that a system in 1906 had taken a similar path , as well as evidence showing that the storm had already begun to turn when seeding began , ended the litigation . This disaster set back the cause of seeding hurricanes for eleven years .

= = Between the projects = =

The United States Weather Bureau 's National Hurricane Research Project , founded in 1955 , had as one of its objectives to investigate the scientific validity of hurricane modification methods . To this end , silver iodide dispensers were tested in Hurricane Daisy in August 1958 . The flares were deployed outside of the hurricane eyewall , so this was an equipment test rather than a modification experiment . The equipment malfunctioned in all but one of the flights , and no conclusive data was acquired .

The first seeding experiment since the Cirrus disaster was attempted on September 16 , 1961 , into Hurricane Esther by NHRP and the United States Navy aircraft . Eight cylinders of silver iodide were dropped into Esther 's eyewall , and winds were recorded as weakening by 10 percent . The next day , more seeding flights were made . This time , the silver iodide did not fall into the eyewall , and no reduction in windspeed was observed . These two results were interpreted as making the experiment a " success " .

The seedings into Hurricane Esther led to the establishment of Project Stormfury in 1962 . Project Stormfury was a joint venture of the United States Department of Commerce and the United States Navy .

= = Project BATON = =

The objective of Project BATON was the analysis of the life history of thunderstorms . A Department of Defense research activity supported by the Advanced Research Project Agency , Project BATON sought to expand understanding of storm physics as an aid to weather forecasting , fire prevention , and , possibly , for artificially controlling the weather . Dr. Helmut Weickmann , as an employee of the U.S , Army Signal Research and Development Laboratory , and Dr. Paul McReady of Meteorology Research , Inc . , were joint leaders of the Project BATON team .

During the 1962 July ? August storm season in Flagstaff , Arizona , the scientists , selected " guinea pig " storms , and seeded them with chemicals . Effects were thoroughly analyzed from the ground and from the air with time @-@ lapse motion picture cameras , stereo still cameras , storm radar , lightning detectors , and airborne heat sensors . Among the agents inserted in selected clouds were " condensation nuclei " which temporarily increased the number of water droplets in the cloud , and pulverized dry ice , which turns a portion of the cloud to fine snow crystals that remain aloft . The utilization of these agents facilitated study of a storm 's characteristics .

= = Project STORMFURY begins = =

Robert Simpson became its first director , serving in this capacity until 1965 . There were several guidelines used in selecting which storms to seed . The hurricane had to have a less than 10 percent chance of approaching inhabited land within a day ; it had to be within range of the seeding aircraft ; and it had to be a fairly intense storm with a well @-@ formed eye . The primary effect of these criteria was to make possible seeding targets extremely rare .

No suitable storms formed in the 1962 season . Next year , Stormfury began by conducting experiments on cumulus clouds . From August 17 to 20 of that year , experiments were conducted in 11 clouds , of which six were seeded and five were controls . In five of the six seeded clouds , changes consistent with the working hypothesis were observed .

On August 23 , 1963 , Hurricane Beulah was the site of the next seeding attempt . It had an indistinct eyewall . In addition , mistakes were made , as the seedings of silver iodide were dropped in the wrong places . As a consequence , nothing happened . The next day , another attempt was made , and the seeders hit their targets . The eyewall was observed to fall apart and be replaced by another eyewall with a larger radius . The sustained winds also fell by twenty percent . All in all , the results of the experiments on Beulah were " encouraging but inconclusive . "

In the six years after Beulah , no seedings were conducted for several different reasons . In 1964 ,

measurement and observation equipment was not ready to be used . The year after that , all flights were used for additional experimentation in non @-@ hurricane clouds .

Joanne Simpson became its director beginning in 1965 . While out to sea in August of the 1965 Atlantic hurricane season , Stormfury meteorologists decided that Hurricane Betsy was a good candidate for seeding . However , the storm immediately swung towards land , and on September 1 , the planned flights were canceled . For some reason , the press was not notified that there were no seedings , and several newspapers reported that it had begun . As Betsy passed close to the Bahamas and smashed into southern Florida , the public and Congress thought that seeding was underway and blamed Stormfury . It took two months for Stormfury officials to convince Congress that Betsy was not seeded , and the project was allowed to continue . A second candidate , Hurricane Elena , stayed too far out to sea .

After Betsy , two other hurricanes came close to being seeded . Hurricane Faith was considered a likely candidate , but it stayed out of range of the seeding planes . That same year , recon flights were conducted into Hurricane Inez , but there were no seedings . Both the 1967 and 1968 seasons were inactive . Because of that , there were no suitable seeding targets in either of those two seasons .

Dr. R. Cecil Gentry became the director of Stormfury in 1968 . There were no more near @-@ seedings until 1969 . In the interim , equipment was improved . What once was the primitive method of hand @-@ dumping dry ice was replaced with rocket canisters loaded with silver iodide , and then gun @-@ like devices mounted on the wings of the airplanes that fired silver iodide into the clouds . Observation equipment was improved . Additional reconnaissance data was utilized to modify the working hypothesis . The new theory took cumulus towers outside the eyewall into account . According to the revised theory , by seeding the towers , latent heat would be released . This would trigger the start of new convection , which would then cause a new eyewall . Since the new eyewall was outside the original one , the first eyewall would be choked of energy and fall apart . In addition , since the new eyewall was broader than the old one , the winds would be lower due to a less sharp pressure difference .

Hurricane Debbie in 1969 provided the best opportunity to test the underpinnings of Project Stormfury . In many ways it was the perfect storm for seeding : it did not threaten any land ; it passed within range of seeding aircraft ; and was intense with a distinct eye . On August 18 and again on August 20 , thirteen planes flew out to the storm to monitor and seed it . On the first day , windspeeds fell by 31 % . On the second day , windspeeds fell by 18 % . Both changes were consistent with Stormfury 's working hypothesis . Indeed , the results were so encouraging that " a greatly expanded research program was planned . " Among other conclusions was the need for frequent seeding at close to hourly intervals .

The 1970 and 1971 seasons provided no suitable seeding candidates . Despite this , flights were conducted into Hurricane Ginger . Ginger was not a suitable storm for seeding , due to its diffuse , indistinct nature . The seeding had no effect . Ginger was the last seeding done by Project Stormfury .

= = After the seedings = =

Atlantic hurricanes meeting all of the criteria were extremely rare , which made duplication of the " success " reached with Hurricane Debbie extremely difficult . Meanwhile , developments outside of meteorology hindered the cause of hurricane modification .

In the early 1970s , the Navy withdrew from the project . Stormfury began to refocus its efforts on understanding , rather than modifying , tropical cyclones . At the same time , the Project 's aircraft were nearing the end of their operational lifetimes . At the cost of $ 30 million (year unknown) two Lockheed P @-@ 3 's were acquired . Due to the rarity of Atlantic hurricanes meeting the safety requirements , plans were made to move Stormfury to the Pacific and experiment on the large number of typhoons there . This action required many of the same safety requirements as in the Atlantic , but had the advantage of a much higher number of potential subjects .

The plan was to begin again in 1976 , and seed typhoons by flying out of Guam . However , political

issues blocked the plan . The People 's Republic of China announced that it would not be happy if a seeded typhoon changed course and made landfall on its shores , while Japan declared itself willing to put up with difficulties caused by typhoons because that country got more than half of its rainfall from tropical cyclones .

Similar plans to operate Stormfury in the eastern north Pacific or in the Australian region also collapsed .

= = Failure of the working hypothesis = =

Multiple eyewalls had been detected in very strong hurricanes before , including Typhoon Sarah and Hurricane Donna , although the double eyes were usually seen in very intense systems . Double eyewalls were also seen post @-@ seeding in some of the seeded storms . At the time however , the only known times that rapid changes in eyewall diameter , other than during presumably successful seedings , was during rapid changes in intensity . It remained controversial whether the seedings caused the secondary eyewalls or whether it was just a natural cycle . Basically , if eyewall changes similar to those observed in seeded hurricanes were rare in unseeded tropical cyclones , it would provide powerful evidence that Project Stormfury was successful . Conversely , if such changes were common in unseeded systems , it would throw doubt on the very hypothesis and assumptions driving Project Stormfury .

Data and observations began to accumulate that debunked Stormfury 's working hypothesis . Beginning with Hurricanes Anita and David , flights by Hurricane Hunter aircraft encountered events similar to what happened in " successfully " seeded storms . Anita itself had a weak example of a concentric eyewall cycle , and David a more dramatic one . In August 1980 , Hurricane Allen passed through the Atlantic , Caribbean , and Gulf of Mexico . It also underwent changes in the diameter of its eye and developed multiple eyewalls . All this was consistent with the behavior that would have been expected of Allen had it been seeded . Thus , what Stormfury was accomplishing by seeding was also happening on its own .

Other observations in Hurricanes Anita , David , Frederic , and Allen also discovered that tropical cyclones have very little supercooled water and a great deal of ice crystals . The reason that tropical cyclones have little supercooled water is that the updrafts within such a system are too weak to prevent water from either falling as rain or freezing . As cloud seeding needed supercooled water to function , the lack of supercooled water meant that seeding would have no effect .

Those observations called the basis for Project Stormfury into question . In the middle of 1983 , Stormfury was finally canceled after the hypothesis guiding its efforts was invalidated .

= = Legacy = =

In the sense of weakening hurricanes to reduce their destructiveness , Project Stormfury was a complete failure because it did not distinguish between natural phenomena in tropical cyclones and the impact of human intervention . Millions of dollars had been spent trying to do the impossible . In the end , " [Project] STORMFURY had two fatal flaws : it was neither microphysically nor statistically feasible . "

In addition , Stormfury had been a primary generator of funding for the Hurricane Research Division . While the project was operational , the HRD 's budget had been around $ 4 million (1975 USD ; $ 16 million 2008 USD) , with a staff of approximately 100 people . Today , the HRD employs 30 people and has a budget of roughly $ 2 @.@ 6 million each year .

However , Project Stormfury had positive results as well . Knowledge gained during flights proved invaluable in debunking its hypotheses . Other science resulted in a greater understanding of tropical cyclones . In addition , the Lockheed P @-@ 3 's were perfectly suitable for gathering data on tropical cyclones , allowing improved forecasting of these monstrous storms . Those planes are still used by the NOAA today .

Cuban president Fidel Castro has alleged that Project Stormfury was an attempt to weaponize hurricanes .