was a Negro; HeLa cells contain type A G6PD. So did those human cell cultures sent to the United States by the Russians. Nelson-Rees' conclusion: the Russian cell lines are really HeLa cells. Each line may have been accidentally contaminated, ironically enough, by HeLa cells that American scientists had sent to Russian investigators long before a formal exchange program ever began.

Having reached what can only be described as embarrassing results—which, Nelson-Rees says, the Russians took with good grace—he and his associates began looking at human tumor cell lines that were being used by American cancer specialists. Many of them, some from the very "best" of laboratories are, in his opinion, HeLa cells. It is a finding that leaves many researchers noticeably uncomfortable and which has caused considerable dismay and uncertainty within the community.

Many cell lines are implicated, as is reported by Nelson-Rees in this issue of *Science* (p. 1093); the situation involving HBT-3, for human breast tumor, cells is illustrative. Robert Bassin and his colleagues at the NCI are studying RNA tumor viruses in various cell lines, among them the HBT-3 line. In addition to their own work, they distribute these cells to other laboratories across the country—to some 15 or 20 laboratories altogether. A few months ago, when Nelson-Rees informed Bassin that he thought HBT-3 cells were really HeLa cells that had not been found out, Bassin rejected the notion. But subsequently, he accepted the possibility that Nelson-Rees could be right. On 15 April, Bassin sent a letter to all the persons to whom he sends HBT-3 cells that said in part:

> Karyological data recently obtained by Dr. Walter Nelson-Rees, using trypsin banding techniques, as well as some of our own studies, are consistent with the possibility of HBT-3 cells being a HeLa contaminant. Although this has not been proven as yet, I feel that there now exists enough evidence to alert all recipients of the HBT-3 cell line to the real possibility of contamination with HeLa cells.
>
> If you have distributed this cell line to other laboratories I would appreciate your sending copies of this letter to the recipients.

Nelson-Rees says he thinks it took Bassin real guts to send a letter like that. Bassin says of the situation, "We're in a bit of a muddle." As his letter indicates, he is not ready to concede that HBT-3 cells are not human breast cells. There is evidence, for example, that HBT-3 cells contain a protein marker that is characteristic of human breast cells. There are other data, he says, that cloud the picture.

The implications of what Nelson-Rees is saying go beyond the true identity of the HBT-3 line or of any of the others whose identity he has challenged thus far. There is the matter of the extent of culture contamination. Many investigators reason that their cultures could not possibly be contaminated because there have never been any HeLa cells anywhere near their laboratories. But if it turns out that HBT-3 cells and others previously thought to be "safe" are really HeLa cells after all—well, that reasoning no longer holds.

Then, there is the matter of whether Nelson-Rees is right and whether the various techniques at hand are sufficient to identify HeLa cells beyond doubt. Bassin summed it up nicely. "If we can't tell one cell from another, we have grave problems." That would seem to be the case.

—BARBARA J. CULLITON

Weather Warfare: Pentagon Concedes 7-Year Vietnam Effort

On 20 March, several high-ranking officials of the Department of Defense (DOD) told members of the Senate Foreign Relations Committee in detail about a $21.6 million 7-year program of cloud-seeding to induce rain over the trails of Laos, North Vietnam, South Vietnam, and Cambodia. There had been persistent allegations that the military was carrying out such operations in Southeast Asia. Their briefing, therefore, constitutes the first public description of weather modification techniques as a weapon of war.* Senator Claiborne Pell (D–R.I.), who asked for the briefing, recently released the text of it, of which excerpts follow.

The use of rainmaking as a weapon of war has long been a subject of controversy among weather scientists and arms control experts. Some of the scientists have objected that military use of weather modification will inhibit international cooperation in the atmospheric sciences. Their work, they add, should be used for humanitarian ends such as increasing the world's food supply. Some arms control experts fear that weather modification indiscriminately hurts noncombatants and enemy troops; they also argue that U.S. use of it in Vietnam could lead to proliferation of this relatively simple weapon to other countries (*Science*, 16 June 1972).

In any event, the Pentagon's briefing to Pell is far and away the most complete statement DOD has made to date of its role in weather warfare. [Even former DOD Secretary Melvin Laird hedged on the issue (*Science*, 5 April)]. While it furnishes many new details, some other information is still missing. For example, there is only vague discussion of whether agencies other than DOD have engaged or are engaging in weather warfare—yet the Central Intelligence Agency (CIA) is alleged to have started Vietnam cloud-seeding with a rainmaking project over Saigon in 1963. There is some discussion of an ongoing National Security Council review of weather modification policies, but no statement of DOD's position on future military weather modification programs. Finally, the military's claim that they succeeded in inducing from 1 to 7 inches of rain in Southeast Asia is not supported with the kind of data that civilian scientists would need for verifying it. Hence the DOD's claim that weather modification is "a valuable tactical weapon" is not proven.

Most of the presentation was made by Lieutenant Colonel Ed Soyster of the Joint Chiefs of Staff. Other DOD spokesmen were: Dennis J. Doolin, Deputy Assistant Secretary of Defense (East Asia and Pacific Affairs); Major General

* *Weather Modification*, hearings before the subcommittee on Oceans and International Environment, Committee on Foreign Relations, U.S. Senate (Government Printing Office, Washington, D.C., 1974).

Ray Furlong, Deputy Assistant Secretary of Defense (Legislative Affairs).

Soyster began by describing the regular Southeast Asian monsoon seasons. He explained that the southwest monsoon begins with a transitional period from April to June and ends with a similar period in September. During these transitional times, unpaved roads in Southeast Asia can sometimes become impassable due to sudden rains or floods: during the monsoon itself such roads are muddy all the time.

The program was to increase rainfall sufficiently in carefully selected target areas to further soften the road surfaces, cause landslides along roadways, and to wash out river crossings. These events normally . . . occur anyway during the height of the rainy season. By seeding it was intended to extend the period of occurrence beyond the normal rainy season and to supplement the natural rainfall as required to maintain the resultant poor traffic conditions.

He then described some principles of tropical cumulus cloud growth and development, and how, in general, cloud-seeding works. As to the specific technique DOD cloud-seeders used:

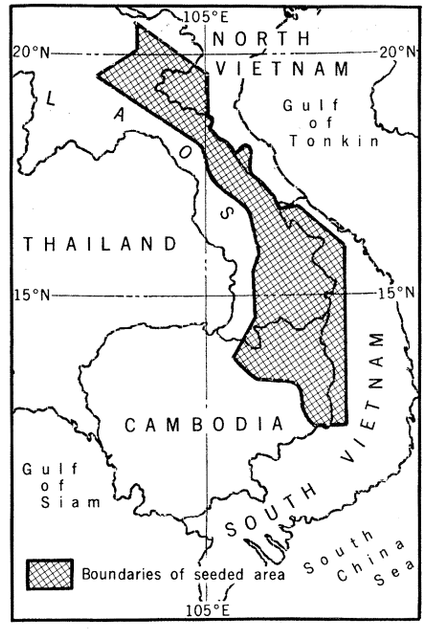
The seeding units used to seed were developed at the Naval Weapons Center, China Lake, Calif. and are not classified. The seeding units and technique are identical to those used in publicized rainmaking projects—for example, Philippines, Okinawa, Texas—and the Stormfury research project.

The seeding units consist of a 40 mm aluminum photoflash-type cartridge case with primer and a candle assembly. The candle assembly includes a plastic container 3 inches long with the seeding material and necessary delayed firing mechanism to ignite the free falling container. The silver iodide or lead iodide is produced as the chemical mixture burns.

The burning time is about 36 seconds for the most commonly used type. The unit drops about 3,000 feet during its functional burn. The units are dropped inside the cloud in the active updrafts at intervals of approximately one-half mile.

The release is normally controlled by the pilot . . . . Two types of aircraft were used—the WC-130 weather reconnaissance aircraft and the RF-4C reconnaissance aircraft. The WC-130 carried pods containing 104 units each on both sides of the aircraft fuselage . . . . The RF-4C carried a total of 104 units in the photo cartridge compartments. Typically, these aircraft could influence an average of 4–5 clouds or groups of clouds per day during the southwest monsoon.

. . . Under nearly perfect conditions, effects last possibly 6 hours maximum. Normally, the effect is about one-half hour. . . . The effects are . . . limited in area, perhaps [to a] 20-mile diameter under ideal conditions and continuous seeding where groups of clouds could be knitted together to form one large storm center. . . .



The above is a composite of DOD maps showing where different cloudseeding missions were flown during the 1966–1972 weather war in Southeast Asia. According to the Pentagon, only selected sections of the above area were seeded during any one rainy season.

Soyster then went into the origins of the classified program.

In 1966, the Office of Defense Research and Engineering proposed a concept of using these known weather modification techniques in selected areas of Southeast Asia as a means of inhibiting enemy logistical operations.

During October 1966, a scientifically controlled test of the concept and seeding techniques was conducted in the Laos Panhandle. The test was conducted under the technical supervision and control of personnel from the Naval Ordnance Test Station (now Naval Weapons Center), China Lake, Calif., using in-theater resources. Fifty-six seedings were conducted, and over 85 percent of the clouds tested reacted favorably. On November 9, 1966, the Commander in Chief, Pacific [CINCPAC] reported the test completed and concluded that cloud-seeding to induce additional rain over infiltration routes in Laos could be used as a valuable tactical weapon.

The timing of the Laos tests correlates with one of the few previous DOD statements about its Vietnam weather program, which appears in the *Pentagon Papers* (Beacon Press, Boston, Gravel ed., 1971, pp. 420–424). The *Pentagon Papers* explains that "various separate proposals" for ways of expanding the air war were made by the Joint Chiefs of Staff (JCS) in December 1966 and January 1967. In February 1967, these were incorporated in a single memo JCS sent to then President Lyndon B. Johnson. It said "Laos Operations . . . Authorization required to implement operational phase of weather modification process previously successfully tested and evaluated in area." The JCS evidently also agreed with CINCPAC's evaluation that the weather weapon was feasible, for it added, "Risks/Impact—Normal military operational risks."

During the recent Senate briefing, Soyster explained that the program of cloud-seeding began in March 1967—a date shortly after the *Pentagon Papers* states that the JCS request went to the President. It appears then, that some approval at the Presidential level ordered the program in February or March 1967.

Civilians Said To Be Safe

Soyster also explained why military commanders thought that civilian inhabitants of the seeded regions would not be in danger.

Intelligence analysis of the area indicated that there would be no significant danger to life, health, or sanitation in the target areas. The sparsely populated areas over which seeding was to occur had a population very experienced in coping with the seasonal heavy rainfall conditions. Houses in the area are built on stilts, and about everyone owns a small boat. . . .

The operation was closely monitored and controlled. When reconnaissance indicated that objectives were attained in one area, the limited resources were shifted to other areas. Seeding was not conducted during periods of tropical storms when large amounts of rainfall were falling naturally and accomplishing the military objectives.

Soyster then expressed confidence that the operation had had no undesirable side effects—such as severe storms or drought in neighboring regions. The risk of undesirable side effects is one argument put forth by advocates of a ban on weather warfare.

It is the consensus of the scientific community that the techniques employed could not be used to create large uncontrolled storm systems accidentally or purposely.

Conversely, seeding to the extent conducted in Southeast Asia did not cause drought in neighboring areas. There is simply too much moisture in the air in that part of the world, and operations affected only a small percent of it—probably less than 5 percent. The desired effect was simply to control where that small percentage fell to the ground.

. . . [T]he operational phase began on March 20, 1967, and was conducted each subsequent year during the rainy southwest monsoon; that is the period March through November until July 5, 1972, when we flew the last mission.

The 5 July date of the last mission is 2 weeks after articles began appearing in the scientific and general press alleging that such a war was being or had been conducted.

Soyster displayed on maps (Fig. 1) where the missions were flown.

> . . . [T]hese aircraft . . . operated out of Thailand . . . . The annual cost of the total program was approximately $3.6 million covering operation and maintenance, temporary duty pay, and seeding materials.

According to DOD maps, the first operations in 1966 and 1967 were conducted primarily in the Laos panhandle area. The missions were then expanded to the north to include parts of North Vietnam, and south to include portions of Cambodia and South Vietnam. When President Johnson announced a halt in the bombing of North Vietnam above the 19th parallel in March 1968, weather modification operations above the 19th parallel were also stopped. By 1971, at the height of the program, the missions were being flown in a large portion of northern Cambodia.

Rainmaking and Floods

And, as to allegations that military cloud-seeding was responsible for the devastating floods North Vietnam experienced in 1971, the following exchange took place:

> SENATOR PELL. Was there any relationship between the rainmaking that went on in Southeast Asia and the extraordinarily high floods that occurred at that time in North Vietnam?
>
> MR. DOOLIN. There were not, sir. At the time of the heavy flooding in North Vietnam there were no rainmaking operations conducted. . . . The flooding in North Vietnam, as you will recall, generated widespread civilian suffering and that was never the intention nor the result of this program.

As to the effectiveness of the cloud seeding, Soyster stated the following:

> The results of the project cannot be precisely quantified. This is due to the lack of sufficient ground stations to report. . . .
>
> Subjectively, it is believed that this rainfall was heavier than that which would have fallen normally and that it did contribute to slowing the flow of supplies into South Vietnam along the Ho Chi Minh trail.

Methods used to determine whether the seeding units affected the clouds or whether roads had been muddied included: aircraft "crews' judgment"; "visual or photographic reconnaissance"; and "intelligence information." In addition, remote sensors located along the trails monitored ground troop movements. There is no explanation of how rainfall was measured.

Table 1. Southeast Asia cloud-seeding efforts. The data were supplied by the Department of Defense.

Year	Sorties flown	Units expended
1967	591	6,570
1968	734	7,420
1969	528	9,457
1970	277	8,312
1971	333	11,288
1972	139	4,362
Totals	2,602	47,409

Soyster's presentation provided no data on how much rain falls normally or how much rain fell from unseeded control clouds—information which many civilian weather scientists consider crucial to judging success or failure in rainmaking. This kind of information appears nowhere in the briefing transcript. Instead, the argument that the program was effective was made on the basis that enemy movements seemed to decrease during periods of active cloud-seeding. For 1971, Soyster claimed:

> . . . [A]t the beginning of April remote sensors were detecting over 9,000 enemy logistic movers per week in eastern Laos. By the end of June this number was less than 900.
>
> Two of the most significant weekly drops in detected traffic movement occurred during June. One of these weeks was June 2 to 9 during which a typhoon was increasing rainfall and the second was during June 16 to 23 when we were most active with seeding activities during the month.

Soyster noted that 1391 units were dropped over eastern Laos during June and 1275 of these were judged by the crews to be successful.

> . . . which is to say that they had a positive effect on the cloud and either increased rainfall rate or caused cloud growth or development.

To substantiate the effectiveness claimed for the cloud-seeding, DOD submitted two isoline charts of the Laos region for June 1971. One chart showed "total rainfall" with variations from 2 to 28 inches. The other claimed to show "induced rainfall" with variations from 1 to 7 inches.

These claims of success were made by Soyster, who is part of the JCS which had advocated the rainmaking in the first place. Pell then asked Doolin, who is in the Office of the Secretary of Defense, for his opinion of the program's effectiveness. Doolin agreed to Pell's characterization of the program: "an elephant labored and a mouse came forth," and also said:

> When you look at those isolines, and the amount of rainfall that was in these given areas anyway, and what was added to it possibly by these extra seedings, it looks to me like when you are getting 21 inches in a given area, and we add 2 inches, if I was on the bottom, I do not think I would know the difference between 21 and 23.

Who knew about the program? Why was it kept so secret? Even Doolin confessed that although he had been a deputy assistant secretary of defense with responsibility for that part of the world for 5 years, he first learned of it by reading a column by Jack Anderson in 1971, Soyster said:

> Because the program was considered sensitive, reporting procedures were instituted to limit knowledge of the program. . . .
>
> The crews performed weather reconnaissance and made normal factual weather reports through regular unclassified worldwide weather channels. . . . In addition to these reports, special reports to provide information to higher headquarters and to allow evaluation of the project were transmitted through special communications channels. . . .
>
> Periodic reports were prepared by the Joint Staff and submitted through the chairman, Joint Chiefs of Staff, to the Secretary of Defense. In order to conduct the operation approximately 1400 personnel had to be given access to project information over a 6-year period.

DOD also submitted its "best estimate" of who among nonmilitary officials knew about the program. It included the White House, the Secretary of State and limited supporting staff, including the Under Secretary for Political Affairs, the Director of the CIA and limited supporting staff, and the chairmen of the House and Senate appropriations and armed services committees. The Thai government was not informed and the Laotian government was only told that a general interdiction campaign was being waged. No one at the Arms Control and Disarmament Agency was informed.

Pell, at the close of the briefing, also inquired about a related, long-standing rumor that someone dropped emulsifiers, the substances used by oil drillers to make mud retain its slipperiness, on the Ho Chi Minh Trail.

> SENATOR PELL. So it may have been attempted, but it was not under the Defense Department's jurisdiction[?]
>
> GENERAL FURLONG. No. sir, . . . we did not want to do it.

—DEBORAH SHAPLEY