NV-198
SEPT 1978

OPERATION MORNING LIGHT

CANADIAN NORTHWEST TERRITORIES/1978

A NON-TECHNICAL SUMMARY OF UNITED STATES PARTICIPATION

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. EY-76-C-08-1183

NOTICE

79-3967

E 1.28:NV-198

United States. Dept. of Energy. Nevada Operations Office.
Operation Morning Light : Northwest Territories, Canada, 1978 : a non-technical summary of U.S. participation. — Las Vegas, Nev . Dept. of Energy, Nevada Operations Office ; Washington : for sale by the Supt. of Docs., U.S. Govt. Print. Off., 1978
20402
vii, 81 p. : ill. (some col.), col. maps ; 28 cm. — (NV ; 198)
Contract no EY-76-C-08-1183.
Issued Sept. 1978.
Item 429-T-4
S/N 061-000-00172-7
pbk. : $3.25
1 Artificial satellites, Russian — Accidents. I. Title.

OCLC 4408413

Available from GPO at $6.00 per copy.

NV-198

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A NON—TECHNICAL SUMMARY OF U.S. PARTICIPATION

SEPTEMBER 1978

Authorized for Publication

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Operation Morning Light

UNITED STATES DEPARTMENT OF ENERGY
NEVADA OPERATIONS OFFICE
LAS VEGAS, NEVADA

CANADIAN-USA TASK FORCE

MORNING LIGHT

NORTHWEST TERRITORIES 1978

When U. S. observers noticed the change in orbit of the Russian satellite Cosmos 954, a series of planning steps began within elements of the U. S. Government to prepare for the possibility of a reentry with subsequent dispersion of radioactive debris over a populated area.

Consequently a computer-generated code name, Morning Light, was assigned to this impending reentry problem to simplify reference for planning purposes among the various departments and agencies of the U. S. Government. When the reentry and debris dispersal actually took place over Canada's Northwest Territories, the search and recovery effort of the Canadian Government proceeded promptly with U. S. cooperation, carrying by mutual agreement the same name for convenience of reference.

FOREWORD

This non-technical summary of the United States participation in Operation Morning Light is directed to interested persons or those who have a need to be generally informed about this example of international cooperation for the protection of the health and safety of the population of North America.It is thus intentionally limited only that information necessary to provide a comprehensive overview.

This document is generously illustrated with photographs and explanatory artwork to sharpen and clarify the many technical, logistical, political and environmental considerations implicit in the conduct of an operation of such size within severe weather and time constraints.

This summary is not intended to be a technical report of the help provided by U. S. specialists to assist the Canadian government's search operation; the U. S. Department of Energy will be issuing a final technical report at a later date. In addition, the Canadian government is expected to be publishing one or more reports on the subject.

ACKNOWLEDGMENT

The United States Department of Energy [illegible] government wishes to acknowledge the professional [illegible] personal consideration of their Canadian [illegible] group of resourceful specialists who [illegible] difficult conditions.

The Morning Light Operation involved [illegible] in a well coordinated operation involving two [illegible] governments and a number of key agencies and organizations [illegible] each of the governments. The personnel of each country worked long, hard, and harmoniously under severe environmental conditions. It was an excellent merging of capabilities to protect the health and safety of the population in the impact area.

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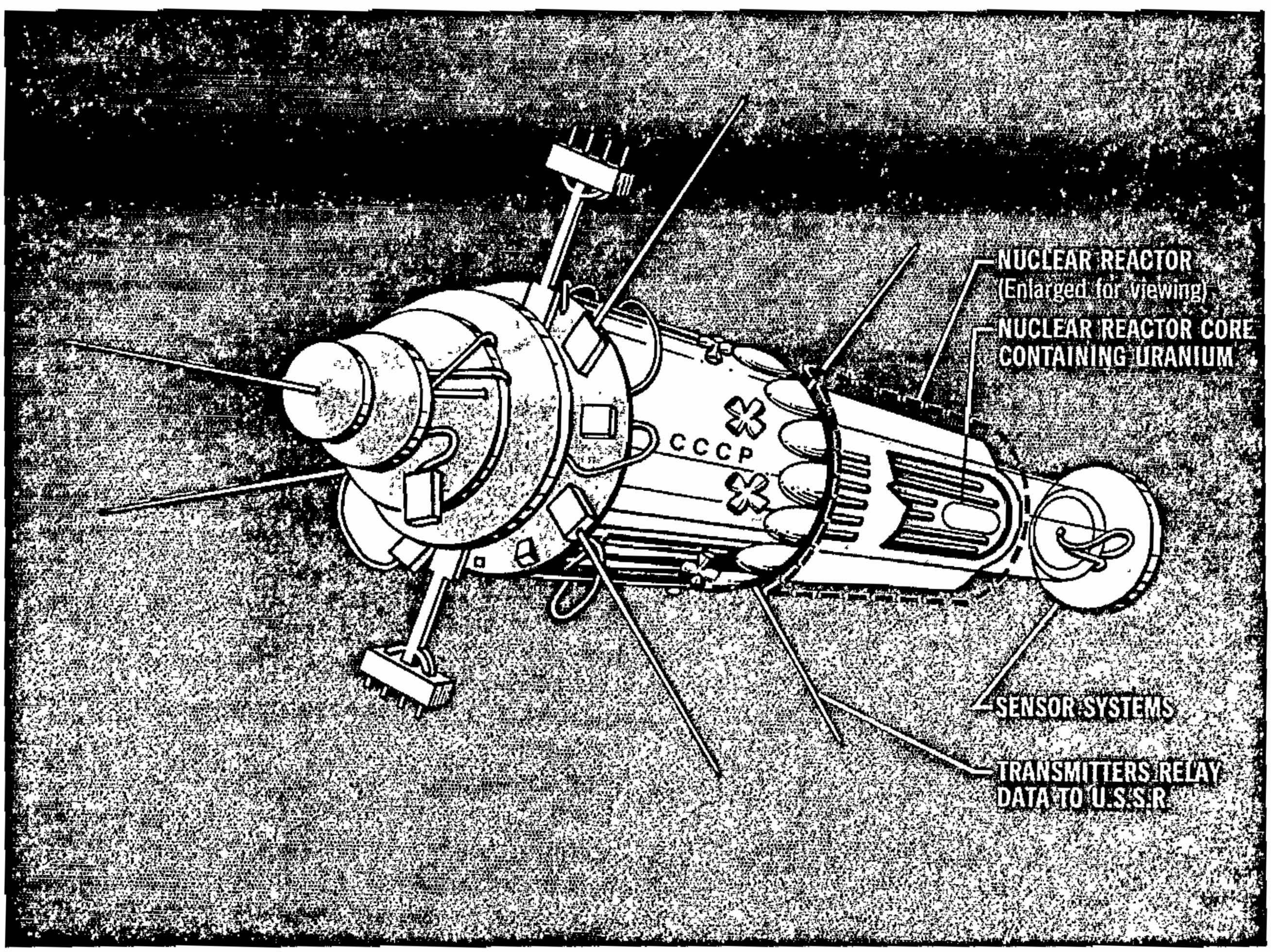
IMPENDING SATELLITE REENTRY

Analysts of the North American Air Defense Command (NORAD) track the 4,600 pieces of machinery now floating in space. There are currently nearly a thousand satellites "out there."

The NORAD specialists at the Space Defense Center in Colorado began tracking Cosmos 954 when it was launched September 18, 1977. Cosmos 954 was in a 150-mile high orbit designed to cover the world's oceans from the Arctic to the Antarctic.

When Cosmos 954 began to slip from its orbit, the Soviets reported that they attempted by radio command to separate the satellite into three sections according to a predesigned fail-safe plan that should have sent the nuclear core into a much higher orbit to park the hazard (hopefully) out in space. The attempt to separate was unsuccessful.

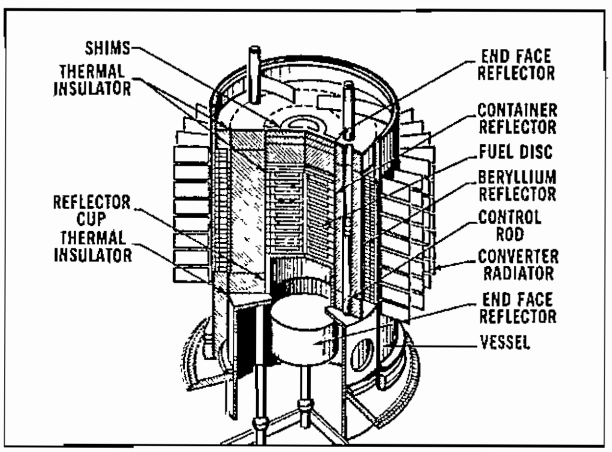
The satellite at that time was horizon stable, that is, a certain portion of the satellite always pointed to the horizon, which was normal for this type of satellite. Such a stable mode implied that it would take some time for the satellite's orbit to fully decay. First estimates of the anticipated reentry date left time for detailed preparation. The actual reentry time occurred months sooner, because the satellite began to tumble.



Artist's conception of one of the Cosmos series satellites.

Cosmos Characteristics

What was the nature of the satellite? Cosmos 954 was a cylindrical spacecraft weighing approximately 4000 kg, that posed a special problem: it had a large nuclear power plant aboard. The Cosmos nuclear package was not an explosive danger, it was thought to be a 100 kilowatt or less reactor estimated to contain on the order of 50 kg of highly enriched uranium 235. However, such reactors employ a fission process which produces radioactive strontium, cesium, iodine, and other radioactive fission products. What the debris from such a reactor might mean if it survived reentry and landed in a densely populated area is one of the concerns growing out of use of such nuclear power packs on satellites.



It is possible that the Cosmos 954 reactor was a development and refinement of this design.

Early Planning

To ascertain the extent of the anticipated problem associated with Cosmos 954 if it should impact in a populated area, the Department of Energy Office of Nuclear Research Applications conducted a risk analysis as soon as it became apparent that the satellite was in trouble. The analysis proved to be very perceptive, including the estimate of the dispersal footprint. The extent of estimated risk depended upon the presumed details of Soviet reactor construction and failsafe systems aboard; unknown at that time because the Soviet Government had not revealed design details. The conclusion: risk to the public could not be eliminated, thus consideration of health and safety must be given priority in decisions regarding Cosmos 954.

The planning and coordination necessary to respond to this unprecedented event involved many U. S. Government organizations and it was referred to the National Security Council. The Council chaired a "working group" to deal with the problem; contributory agencies consisted of: Central Intelligence Agency, Department of Defense, Department of Energy, Department of State, Environmental Protection Agency, Federal Preparedness Agency, and Office of the Attorney General.

The question of public notification was carefully considered by the working group. Because of the uncertainty in determining when or where (in the world) Cosmos 954 would reenter, the assessment made was that there was no preventive or preparatory action that could be taken by the public. The decision was made to ready those U. S. resources which could be used to insure public safety -- *but not to issue a public announcement.* Selected Governments, including Canada, Great Britain, Australia, New Zealand, and Japan, were informed.

The National Security Council directed the Department of Energy to place its nuclear emergency response capabilities into full alert status, to assist in the protection of public health and safety should radioactive debris from Cosmos 954 come to earth in the United States. Response organizations such as the Accident Response Group and the Nuclear Emergency Search Team includes technical experts and equipment necessary for search and recovery.

These emergency response capabilities had been developed to respond to accidents or incidents where the general location of the material is known. They were not designed for large area search. If the point of impact could not be determined within two to five hundred miles, these capabilities probably would not be useful. If local contamination occurred, the Department of Energy had the resources to perform radiological mapping of the contaminated area.

The National Security Council then further directed the Department of Energy to prepare to take operational control of federal emergency response efforts in the United States, and directed the Department of State to coordinate assistance that might be requested by other nations.

Accelerated Planning

Early in January the working group was informed that the satellite orbit had suddenly started to decay more rapidly and that the new projected impact date was January 23. Planning was greatly accelerated in anticipation of a possible impact in the United States.

Department of Energy field units were alerted and told to develop detailed organization, transportation, equipment and personnel plans. The Joint Nuclear Accident Coordination Center was directed to coordinate logistical support between the Department of Defense and the Department of Energy.

A federal emergency response plan was prepared and approved by the National Security Council working group. Responsibilities were assigned to the following federal agencies:

Department of Energy: Overall command responsibility for search and recovery operations associated with Morning Light. The Director of the Emergency Action Coordinating Team was to implement the emergency response.

Department of Defense: To provide the location of the satellite's point of impact and logistical support.

Department of State: Responsible for notification and interaction with foreign governments; to assume operational control should the U. S. decide to provide technical assistance to another nation.

Office of the Attorney General: Provide legal assistance.

Federal Preparedness Agency: Provide the interface between the Department of Energy and State governments.

Environmental Protection Agency: Conduct radiation monitoring of those aspects of concern to the Public Health Service.

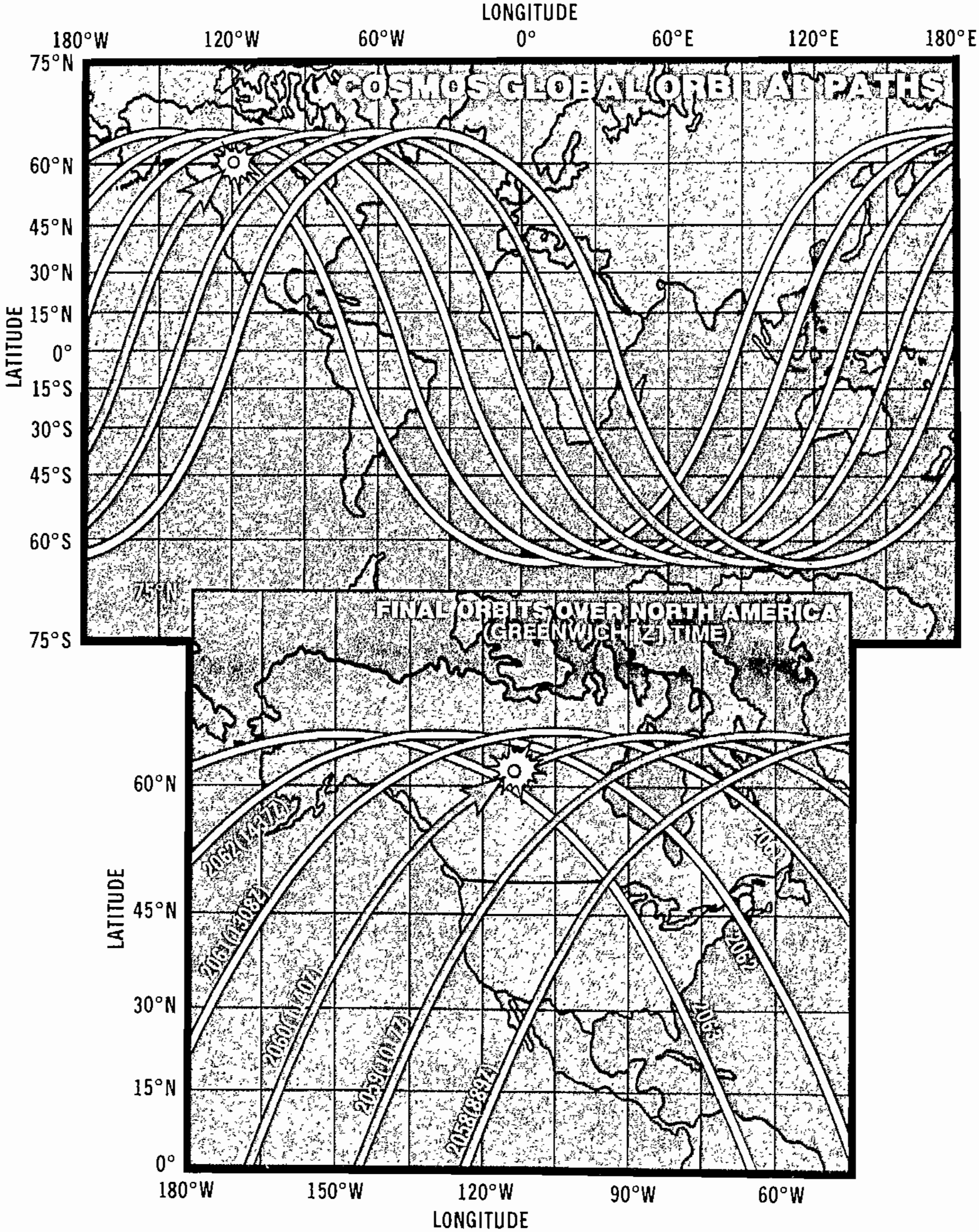
Central Intelligence Agency: Provide both national level intelligence assessment and foreign liaison.

National Security Council: Make the initial public announcement of the situation at the appropriate time.

On January 12, the Assistant to the President for National Security Affairs, Zbigniew Brzezinski, summoned Soviet Ambassador Anatoli Dobrynin to the White House. Brzezinski discussed the serious public hazard if the satellite fell in populated areas and asked the Russians to share any information that would permit steps to be taken to reduce or eliminate the dangers. According to Time Magazine, Dobrynin's answer the next day was "somewhat reassuring" to Brzezinski, "but not fully satisfactory."

Dobrynin and Brzezinski had further discussions by phone and in a meeting on January 17 Dobrynin insisted that the uranium on board could not reach critical mass and explode either on reentry or on impact with the earth.

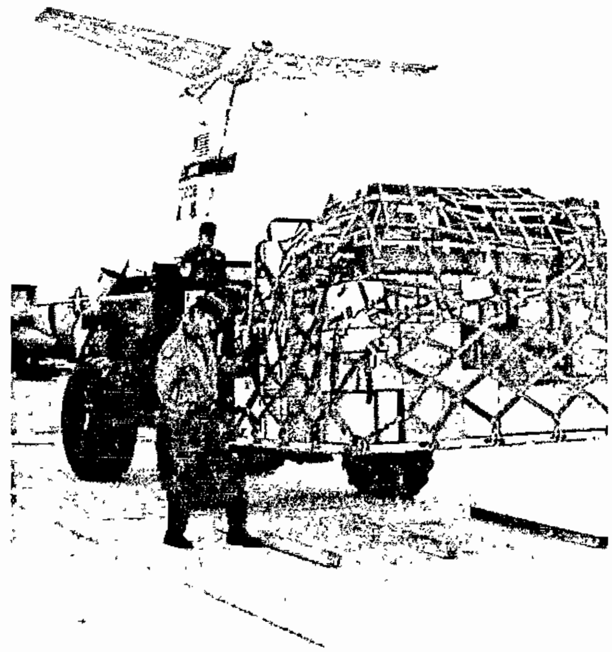
At this time, Cosmos 954 had decayed to an orbit of about 90 minutes, scanning a zone between 65 degrees north to 65 degrees



Orange and red lines show the final complete orbits (2058, 2059) as well as the partial orbit (2060) which terminated in re-entry over Canada. Blue lines show the potential orbits (2061, 2062, 2063) which Cosmos 954 would have followed had it re-entered later.

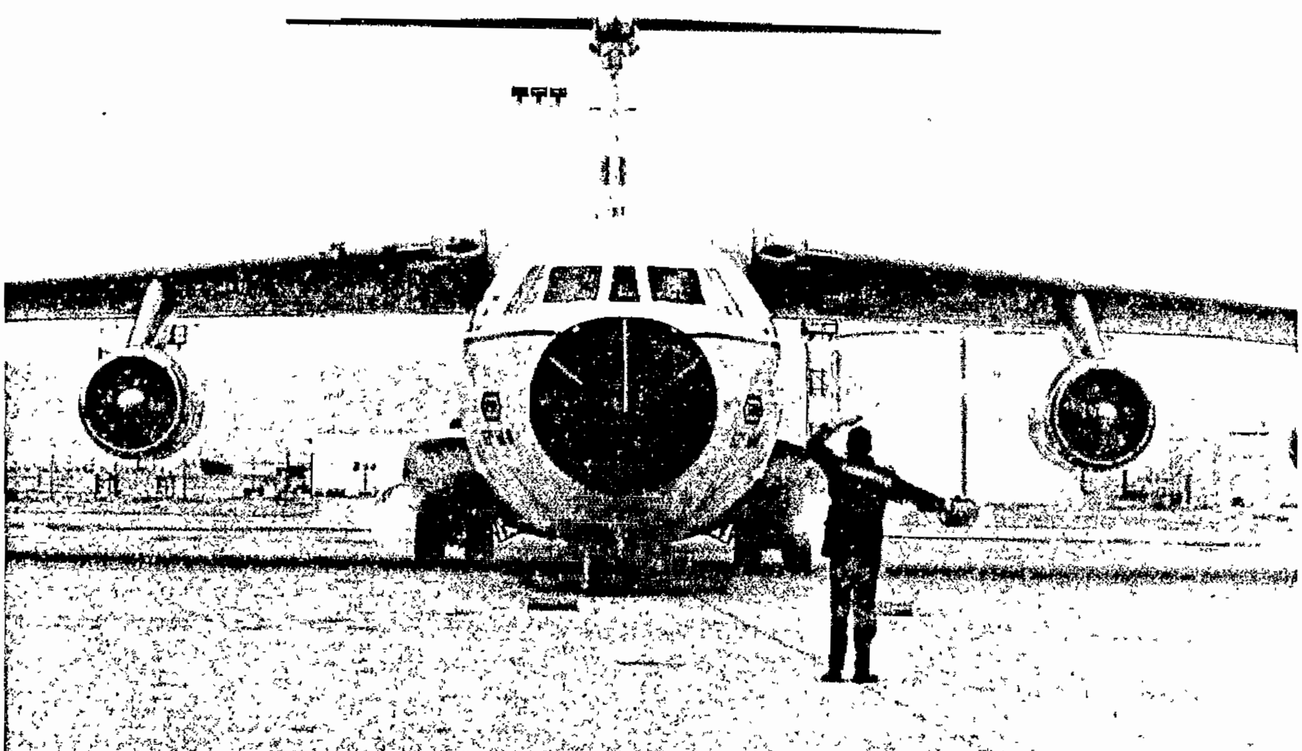
south latitude. The satellite was being continuously tracked by all available U. S. assets until it reentered the earth's atmosphere. Originally it was relatively easy to predict orbit decay, based on prior observation, as long as the satellite remained horizon stable. Later, when the satellite began to tumble, planners were dealing with an uncertain entry window because geometry, mass, and attitude were unknown. This uncertainty of entry window location further precluded the possibility of prior action to protect the health and safety of specific population clusters.

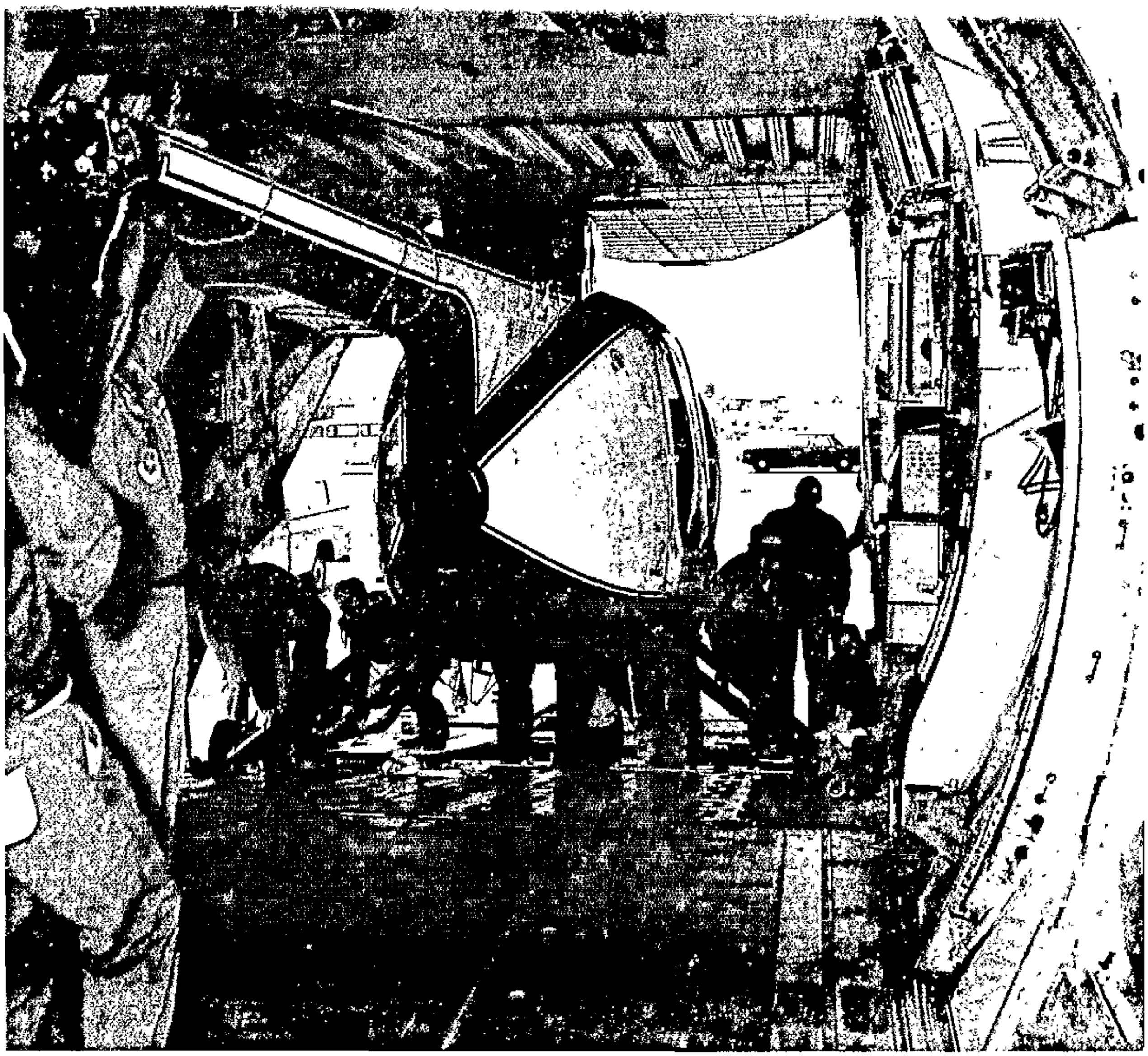
The Department of Energy field units were ready for deployment to a point of impact. As of Sunday night, January 22, all equipment was loaded on Air Force C141 transports at Andrews Air Force Base, Washington, D. C., Travis Air Force Base, Fairfield, California and McCarran International Airport, Las Vegas, Nevada. All personnel were placed on two-hour alert.

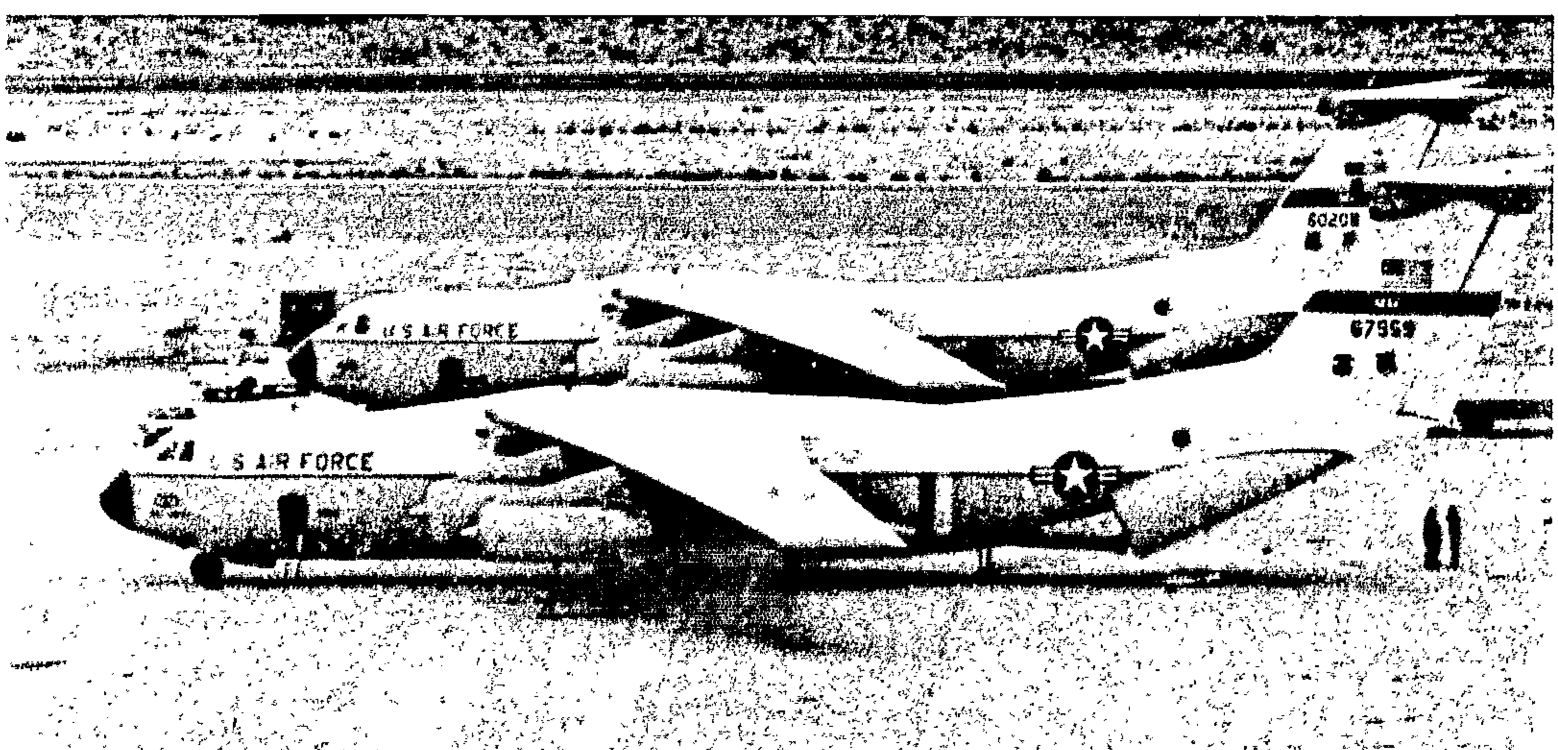


NEST equipment being loaded aboard C141.

Bottom. *C141 arrival in Las Vegas, January 22, 1978.*



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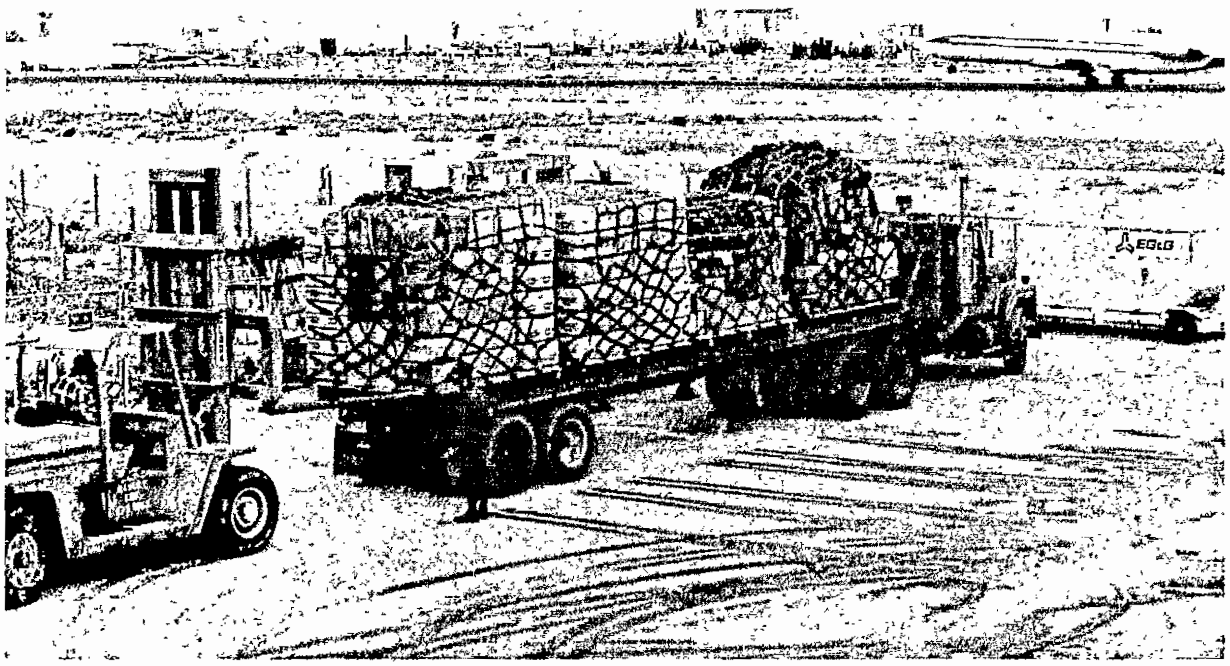
Left. *H-500 Helicopter being loaded aboard C141 cargo carrier.*
Right. *Equipment being prepared for loading on C141 aircraft for deployment from Las Vegas, Nevada (to an as yet undetermined impact location of Cosmos 954). Equipment was packaged in shock resistant containers loaded on standard Air Force freight pallets.*
Bottom. *C141 in loading operation of emergency response equipment at McCarran Airport, Las Vegas.*



Post-Impact Action

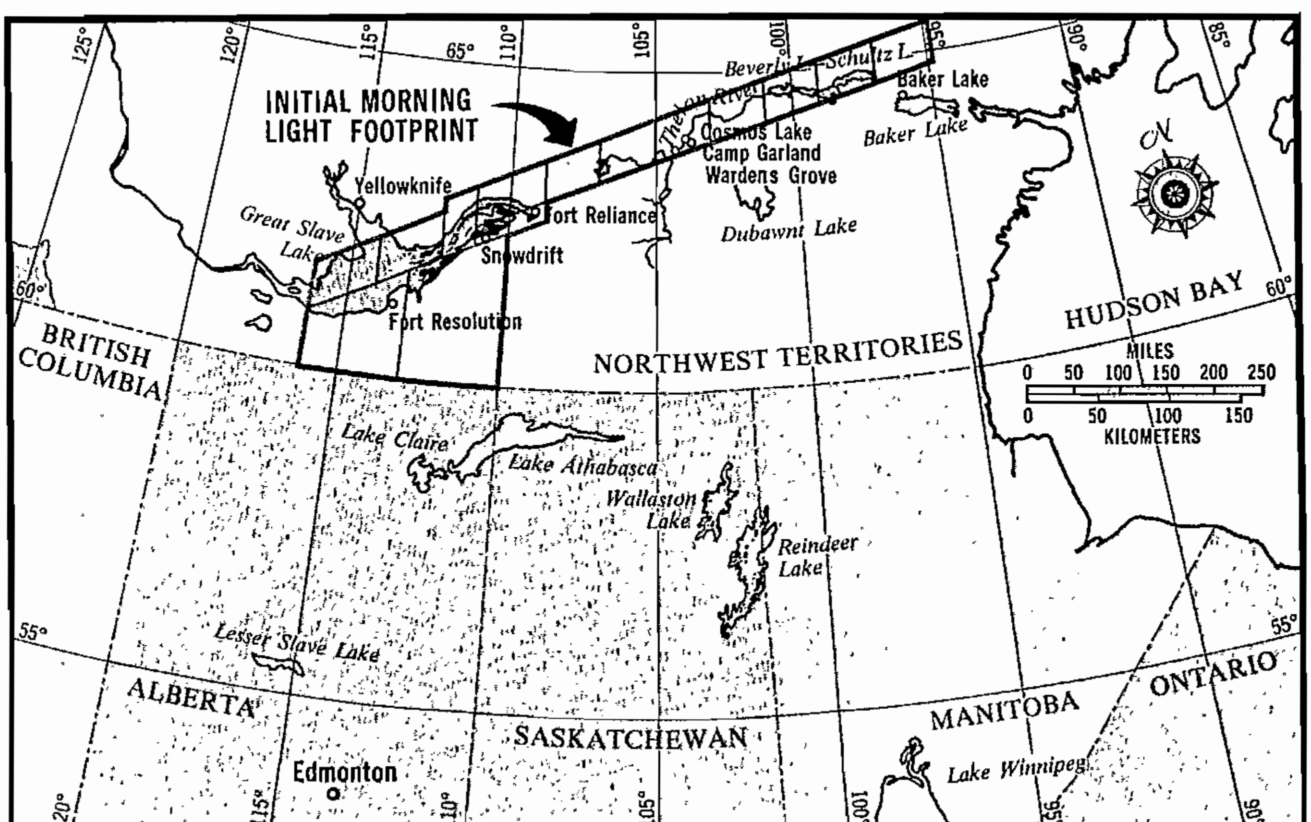
Soviet Cosmos 954 reentered the earth's atmosphere on revolution 2060, at 0653 Eastern Standard Time, north of the Queen Charlotte Islands on Canada's Pacific Coast on January 24, 1978. Following approximately a three-minute burn period during reentry, pieces of the satellite impacted in the Northwest Territories between Great Slave Lake (62 degrees, 30 minutes north, 114 degrees west) and Baker Lake (64 degrees, 30 minutes north, 96 degrees west).

There were eyewitness sightings reported. One of the first was a night janitor in an office building in Yellowknife, the capital of the Northwest Territories on Great Slave Lake, nearly 1,000 miles north of the Montana/Canadian border. At a Royal Canadian Mounted Police detachment in Hay River, 125 miles south of Yellowknife, a Corporal reported a meteor sighting.

From the various sightings, parts of the satellite appeared to have fallen some 115 miles east of Yellowknife.

President Carter contacted Prime Minister Trudeau as soon as the reentry area was confirmed and offered assistance from the United States. Prime Minister Trudeau accepted the President's offer.

The U. S. Department of Energy contacted the Canadian Department of National Defence to ask what assistance Canada might require from the United States. Following discussions it was determined that the United States Air Force would deliver gamma radiation detection equipment and operating personnel to Edmonton. There the equipment would be installed in Canadian aircraft and operated as a part of the Canadian search and recovery effort. During the morning of January 24, other U. S. aircraft also conducted high altitude air sampling flights for radioactive debris over Alberta and Saskatchewan. Results were negative.

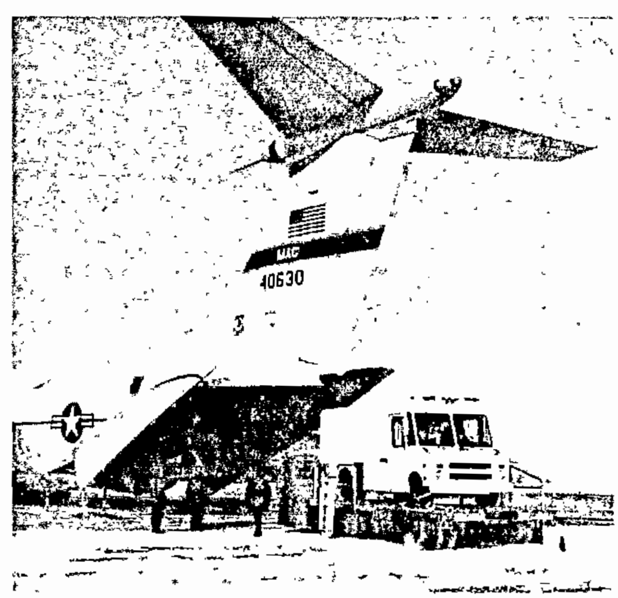


Cosmos reentry footprint as calculated from data obtained on final orbit and from visual observations.

A portion of United States team aboard a C141 enroute to Edmonton.

When it had been determined that the satellite had reentered over Canada, the American response team was placed under the direction of the Manager of the Department of Energy Nevada Operations Office, who had been prepared to serve as On-Scene Commander if the satellite had entered the United States. The American team arrived at the Canadian Forces Base, Edmonton, Canada at 1938 EST on January 24.

The Canadian Forces had aircraft and crews on alert and standing by. They had arranged for technical assistance to help mount the Department of Energy equipment into their aircraft and to help assure equipment and aircraft compatibility. They also provided on-site logistic support.



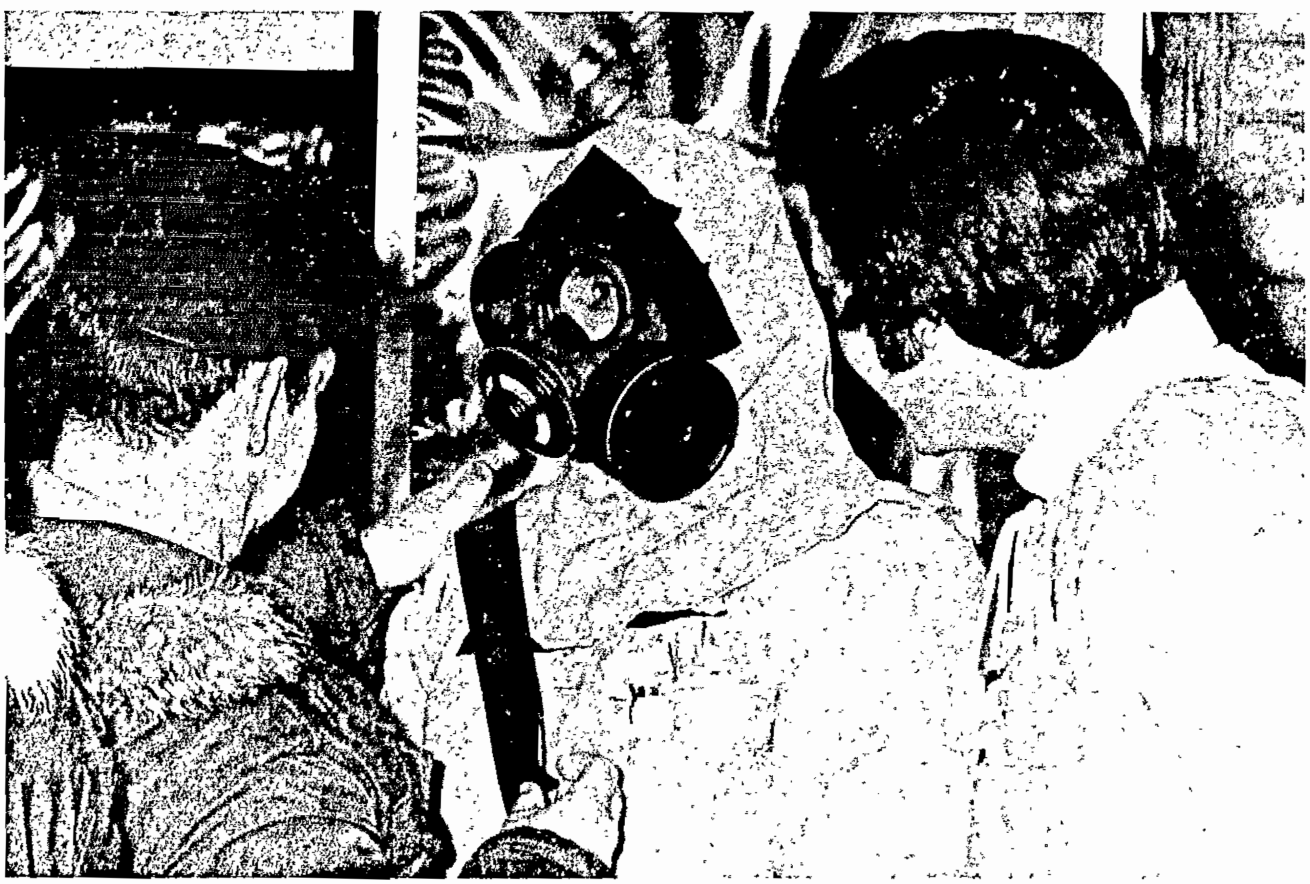
Van containing a computer-based data processing system is unloaded at Edmonton.

The First Days

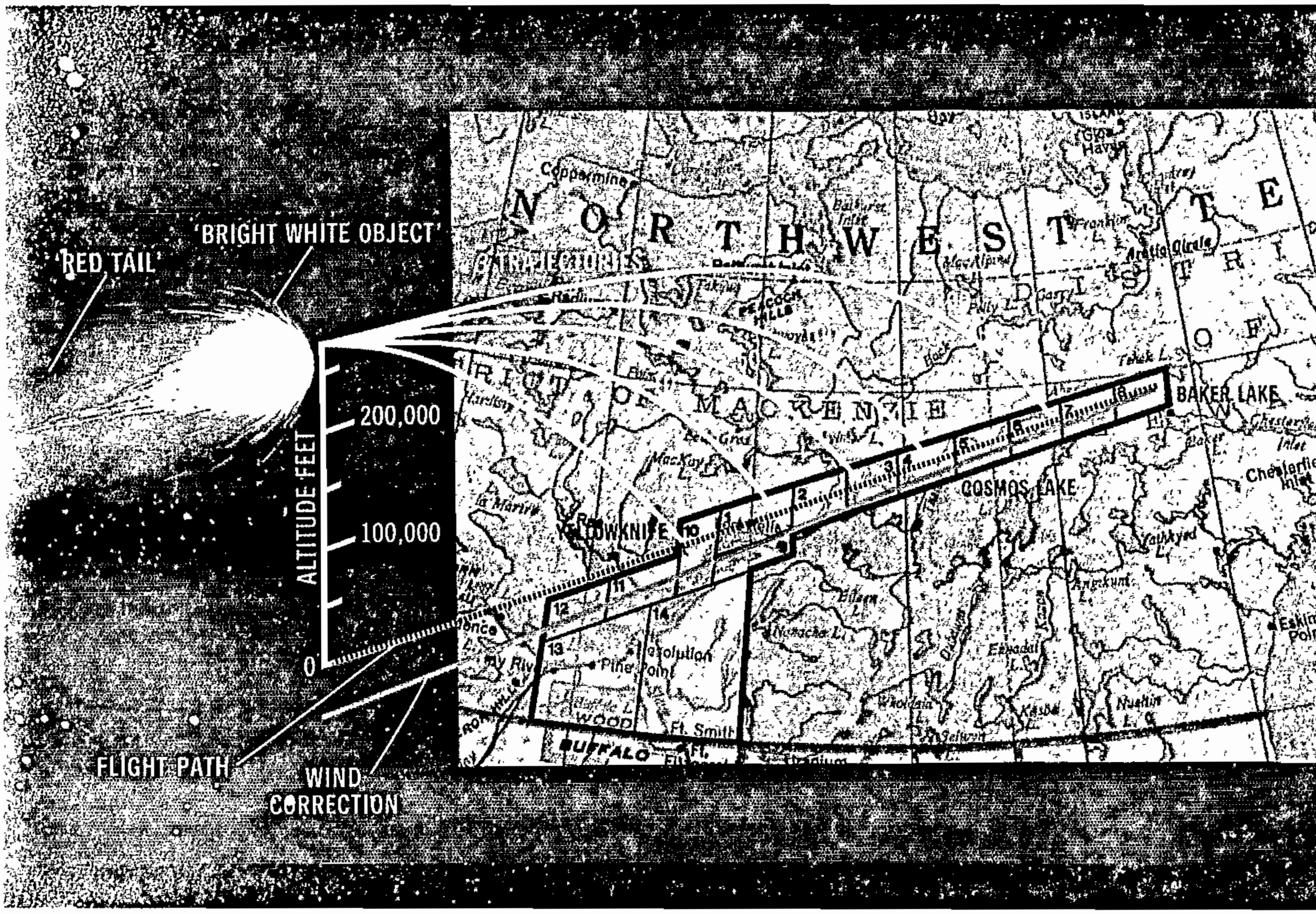
The Canadian Government had alerted the Commander, Canadian Forces Base, Edmonton, on January 23, 1978 of the possibility of impact of Cosmos 954 in the Edmonton Search and Rescue Region. A 22 person Canadian Forces Radiation Monitoring Team had been alerted and placed on two-hour standby.

At 1030 EST, January 24, the Base Commander was directed by Air Command Headquarters to prepare to assume control of a search and recovery operation for Cosmos 954 in the Yellowknife area of the Northwest Territories. The 22-person Radiation Monitoring Team was dispatched aboard a C130 to Yellowknife to conduct radiation surveys in that community. Three other C130 aircraft were readied to launch continuous search activity when U. S. detection equipment and operating personnel arrived.

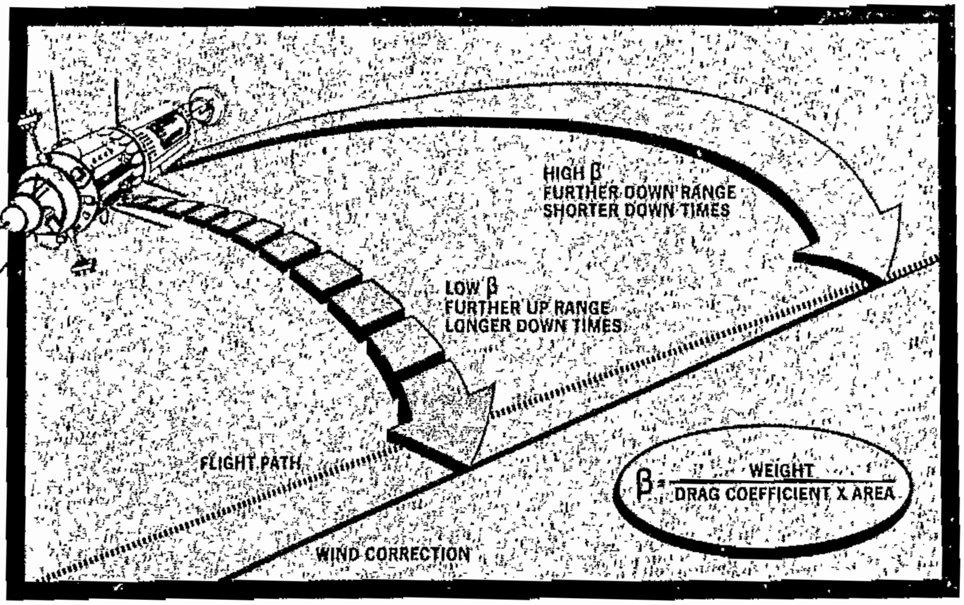
HIGHLIGHTS OF THE OPERATION



Canadian Forces Radiation Monitoring Team members, center, in full protective gear including an air filter breathing apparatus and dosimeter.



As Cosmos 954 reentered the atmosphere, it was observed as a bright, white object in the heavens. Later, as it broke into pieces, several bright objects were observed. As the parts of Cosmos 954 reentered the atmosphere the larger, more massive objects with a high mass to drag ratio (high β) tended to fall further down range than other objects. The smaller objects which had a lower mass to drag ratio (small β) tended to come down at shorter ranges. The local winds also affected the point of impact of the objects as they passed through the atmosphere. The figure shows the best predicted reentry flight path. Using latest available tracking data, eye witness reports and computer predicted impact points, the initial predicted footprint was defined the day of reentry. Subsequently the initially predicted footprint area was adjusted, enlarged, and divided into sectors for search control. The impact location of various classes of objects is noted on the figure.



Right. *Beta (β) is a mathematical measure of the ability of a ballistic object to penetrate the atmosphere while maintaining its momentum. A well streamlined object of high density would tend to have a higher β than a poorly streamlined object of low density. For instance, a cannonball would be a higher β object than a piece of plastic foam the same size and shape.*

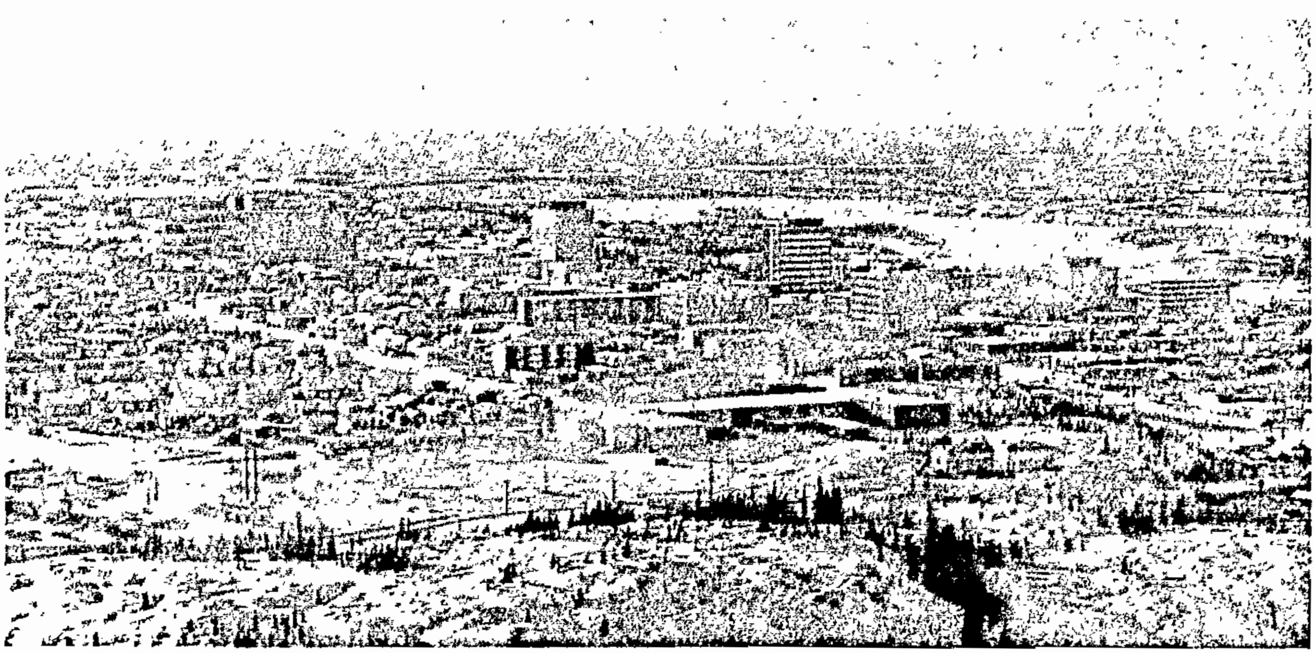
Looking forward in the bay of a Canadian C130 aircraft with United States search and detection equipment mounted in it. The crew members on the left are operating the equipment which consists of a large sodium-iodide scintillation detector array, microwave ranging system for navigation, and digital data acquisition equipment. The equipment is used to correlate location versus gamma ray intensity and to provide periodic gamma ray spectral measurements up to five times per second. This correlation of radiation information in relation to position was the basic data used to establish debris existence, radiation intensity, and its location.

Definition of the initial search zone for Operation Morning Light was accomplished on the evening of January 24. This definition was based on the latest available tracking data, computer predicted impact points, as well as eye witness accounts of Cosmos 954 passing over the Great Slave Lake region. The computer calculations were normalized to the available tracking data. Several U. S. sources supplied computer predicted impact points; there was some scatter in the predicted impact points due to the assumptions made concerning ballistic parameters and elevation of breakup. The eye witness accounts were used as a gross check on the computer predictions.

The U. S. task force arrived at Edmonton aboard two C141 aircraft in the early evening (approximately 1930 EST) of January 24, and personnel immediately began installing the detection equipment in the Canadian C130 aircraft. The first C130 search aircraft was launched at 0315 EST January 25, and completed a straight line search of more than 500 miles along the projected line of Cosmos 954 impact --- Yellowknife to Baker Lake.

During the balance of the day, January 25, three C130s equipped with U. S. radiation detection equipment were on search missions in the western portion of the search area. Simultaneously, two CC138 Twin Otter aircraft were deployed from Yellowknife to complete visual searches in the Great Slave Lake area. The Canadian Forces Radiation Monitoring Team at Yellowknife was flown to Fort Reliance to complete ground radiation surveys. At 1000 EST, U. S. aircraft commenced a ~~second air~~ sampling mission ~~over Michigan and northern~~ Ontario (results showed ~~no abnormal radiation~~ levels). At midnight, January 25, a fourth radiation detection system arrived in Edmonton from the Geological Survey of Canada, Department of Energy, Mines and Resources, and was installed and flown in the fourth C130 dedicated to search missions.

The initial goal was to search the entire 15,000 square mile area; with subsequent modifications as more was learned about possible debris distribution patterns from calculations in the U. S. Search priority was given to population centers and traffic corridors.



Yellowknife, capitol city of Northwest Territories and located on the north edge of Slave Lake, north and west of Edmonton -- about 600 miles southwest of Baker Lake, the easternmost tip of the impact footprint.

By late Thursday, January 26, the first ground party with U. S. Nuclear Energy Search Team (NEST) personnel had deployed to Baker Lake. U. S. personnel arrived at Yellowknife two days later. In both locations, they were ready when the first pieces of radioactive debris were found.

Search Direction

The principal U. S. mission in Canada was to assist the Canadian Government in the location of radioactive debris. To this end, NEST enlisted the technical assistance of U. S. personnel knowledgeable in space reactor design and satellite reentry phenomena to define the debris footprint and establish the most likely zones within the footprint for locating satellite fragments.

Sophisticated computer codes were available in the United States for modeling reentry problems. Normally concerned with predicting the impact points of vehicles designed to survive reentry, these same codes could be used to analyze the Cosmos 954 reentry event. However, since Cosmos 954 was not designed to survive reentry, it was essential to continuously renormalize the computer predictions to fit redefined tracking data and debris locations as they became available. This was done by identifying a set of ballistic parameters which produced a calculated flight path that best matched the refined tracking data. It involved extensive communication between Edmonton and the Lawrence Livermore Laboratory Alert Center which coordinated the U. S. based scientific effort.

Baker Lake is located at the far northeast end of the reentry footprint, more than 1,000 miles northeast of Edmonton.

The "Hit" room at Edmonton where all airborne search data relative to the location of radioactive debris was plotted. This "hit" assessment data was used to sharpen the definition of the target area and to assist the Mission Planning Group.

One of the more significant computer calculations assumed an object reentered intact and impacted in the Thelon River area (the site of major debris). It was determined that an object with an effective ballistic coefficient (Beta) of 100 pounds per square foot produced the best flight path match. This flight path, and the ballistic parameter used to generate it, were used as initial conditions for all additional calculations.

A parametric study was performed to determine the sensitivity of the predicted impact point along the flight path surface projection as a function of the ballistic coefficient and the break-up altitude.

A Canadian Forces meteorologist estimated wind conditions along the flight path based on January 23, 1978 meteorology reports from Fort Smith and Primrose Lake (Northwest Territories). The wind was flowing in a southerly direction at the time of reentry. Using this wind data, another parametric study was made to determine the

Every day planning meetings were held. These meetings considered the implications of recent hits and other recovery data and made plans for the next day and for subsequent days' operations. The meeting in the above picture considered health physics aspects of the search.

The first large piece of Cosmos 954 to be recovered and transported to Edmonton is examined by Canadian and U. S. scientists. This non-radioactive object was about the size and shape of an office waste basket.

likely deviation of debris from the best flight path match.

Estimates were also made of the likely depth of penetration of the complete reactor impacting permafrost and frozen dirt. It was estimated that the reactor impact would cause a shallow crater less than 3 feet deep. Orientation of the reactor at time of impact did not appear to be a sensitive parameter. Therefore, if the reactor had reentered and survived impact, it was not expected to be buried beyond detectibility.

A summary status of the reentry calculations, as of February 3, 1978, stated:

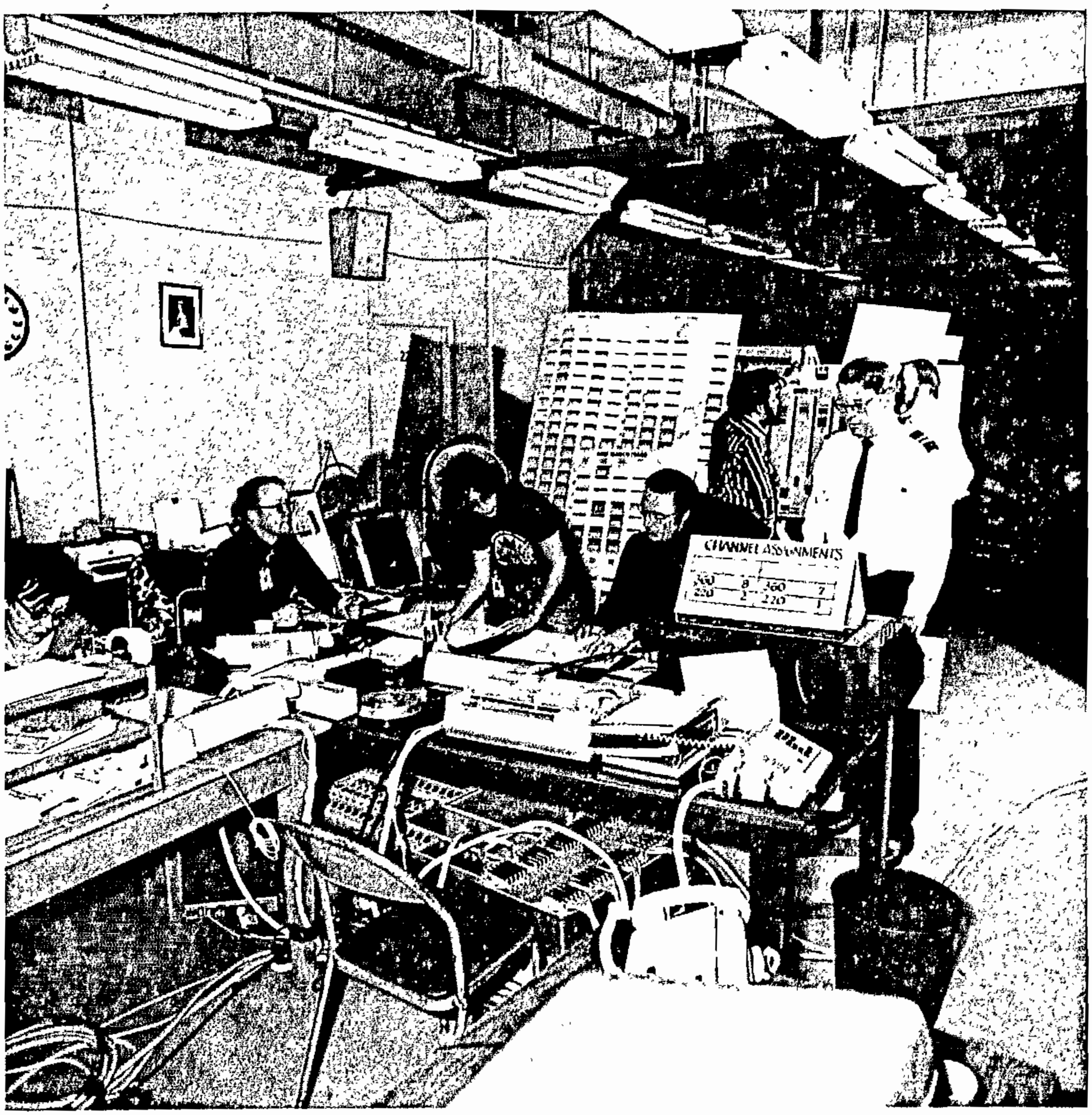
> "Based on all available information, Cosmos 954 did break up during reentry resulting in scattered debris along the flight path east of the Great Slave Lake. The exact position of break up is currently unknown, as well as the details of when and how various components broke off or burned up."

Hit Assessment Group

A "hit" refers to an anomaly in the signature from the radiation detection system. Such a response of the detection instrumentation could mean the aircraft passed over naturally occurring concentrations of radionuclei such as uranium ore outcroppings, man-made concentrations of radioactive materials such as uranium mill tailings, or signals generated by the radioactivity of materials from Cosmos 954. A hit assessment group was established to decide the nature of each hit reported.

A Canadian chaired the Hit Assessment Group at the Edmonton Command Post. It met daily to evaluate and analyze the hit data emanating from all available sources. The information from this group was correlated with the results of supporting reentry studies and fed back to those people doing the studies. It was also given to the Mission Planning Group to help guide its decisions.

MORNING LIGHT



American personnel had an Operations Center at the Canadian Forces Base, Edmonton, Canada where The U. S. personnel and equipment were controlled and scheduled.

OPERATIONS

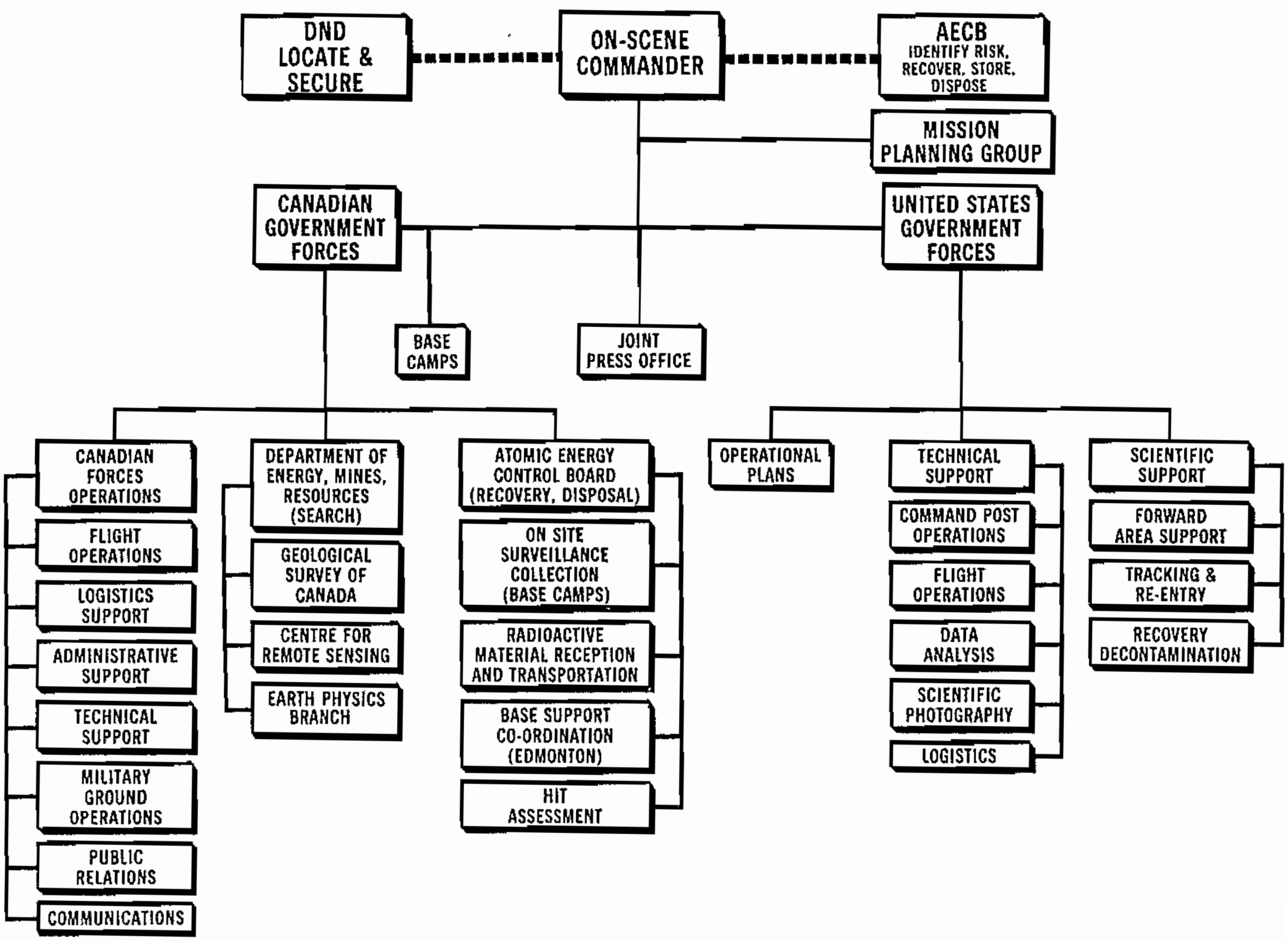
Across the hall the Canadian Command Post scheduled the general logistics and flight support. All scheduling and control was subject to the Mission Planning Group decisions of priorities in the total search and recovery operation.

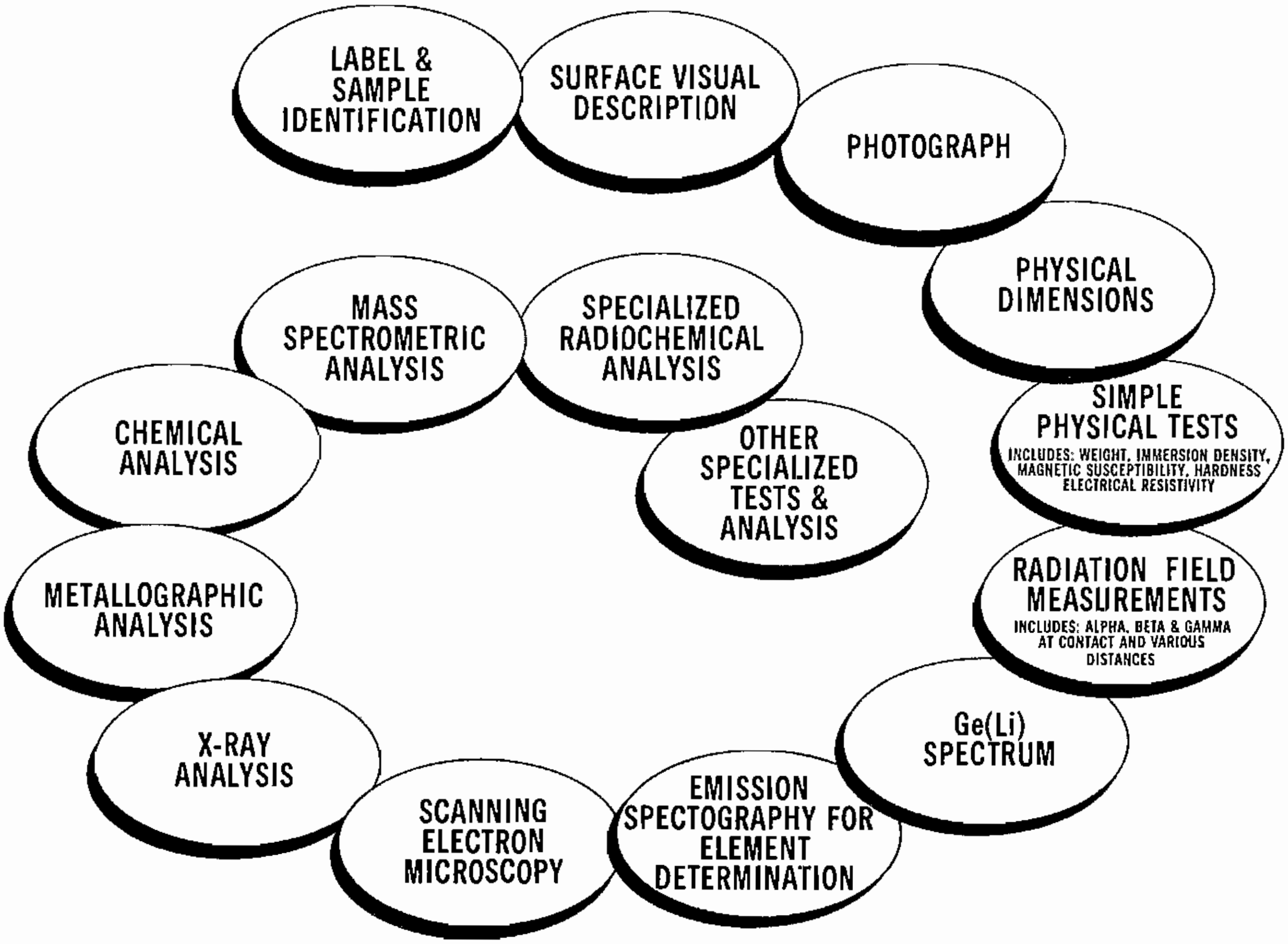
Mission Planning Group

All available information then went to the Mission Planning Group, chaired by the Department of National Defence Operational Commander and attended by all principals. The Mission Planning Group determined, in the short range, the next day's missions for all resources (such as Edmonton, Yellowknife, Baker Lake, Cosmos Lake) and determined long range plans involving operations, personnel requirements, press releases, continual use of specific resources and many other factors. The introduction of the Microwave Ranging System is one example. The establishment of a new base camp is another. Teamwork, bolstered by mutual respect and a critical objective approach was the keynote.

OPERATION MORNING LIGHT

FIELD OPERATIONS ORGANIZATION





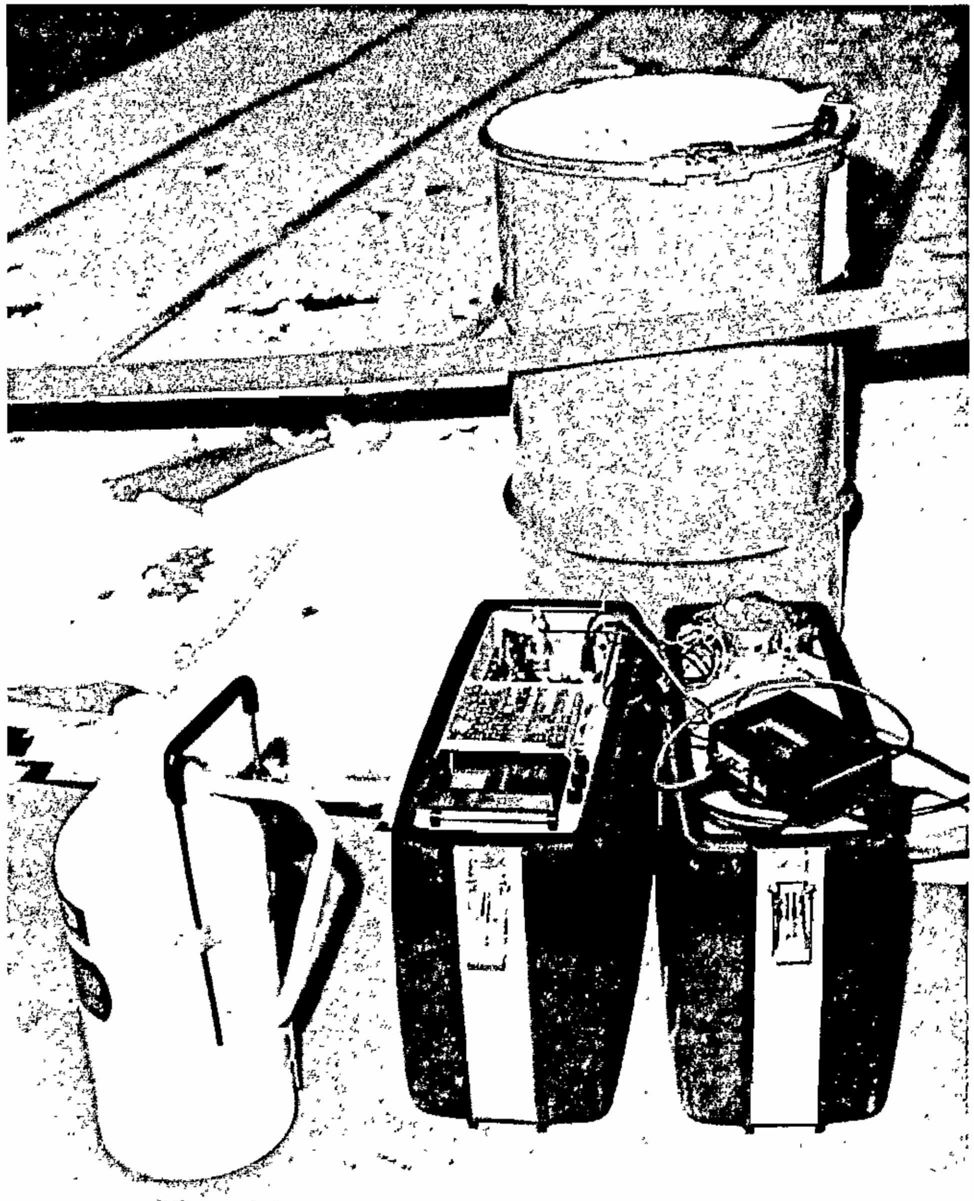
Atomic Energy of Canada Limited Whiteshell Nuclear Research Establishment analyzed characteristics of debris.

Control of Recovered Debris

All debris recovery operations were under the control of the Atomic Energy Control Board and routed from the pickup site to Canadian Forces Base Edmonton by the most expeditious means. Under tightly controlled conditions, materials were examined by the scientific teams from both countries, and data were obtained which provided information on satellite trajectory, breakup, impact, etc., which in turn could lead to the discovery of more debris. The radioactive material was then removed from the Canadian Forces Base Edmonton temporary storage bunker and decontamination site and sent under escort to the Atomic Energy Board of Canada Limited Whiteshell Nuclear Research Establishment for more detailed chemical, metallurgical and spectral analyses. Samples were also sent to the Canadian Department of National Health and Welfare in Ottawa for tests of solubility and effects on human health. The results of this laboratory work will help form the final picture of the satellite's disposition, and its effect on health, safety and the environment.

Scientific Data Assessment

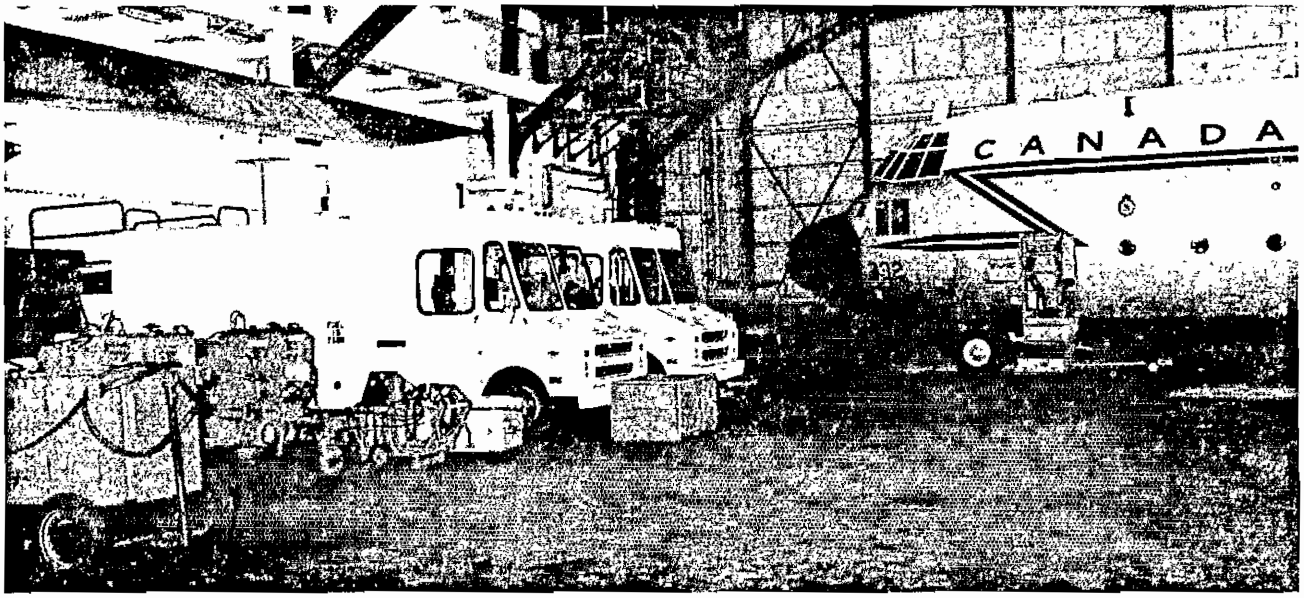
To continually refine the prediction of most likely impact zones, data on all recovered debris were essential. This was initially forthcoming from the field in terms of apparent size, shape, weight, color, structure, radiation intensity and high resolution gamma spectra. The latter measurement was a key one, allowing the



Measurement of gamma spectra using briefcase-packed portable spectrum analyzer and field computer; a system originally designed for and a part of NEST inventory.

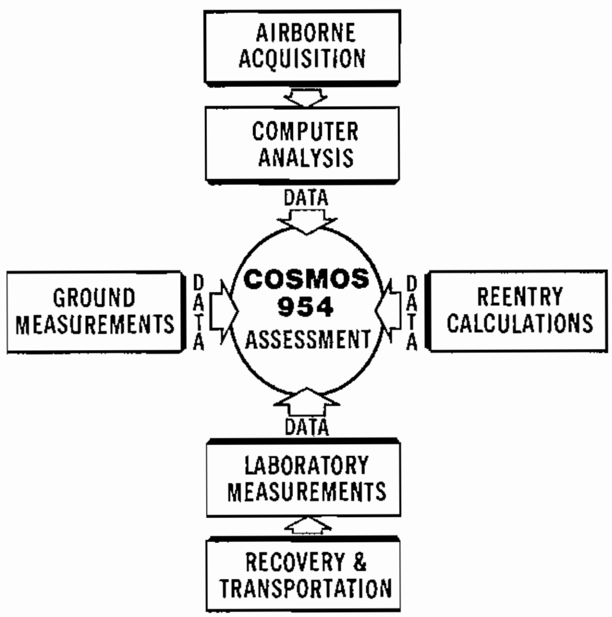
scientists to estimate the material in the debris and its position relative to the reactor's core. It was made with a portable spectrum analyzer and assessed using a "briefcase" field computer, a system originally designed for and part of NEST inventory.

Upon return to Edmonton, the digital magnetic tapes from the airborne radiation detection equipment were analyzed by scientists using the NEST computer vans to determine by spectral analysis whether the source was man-made or natural, and if man-made, whether it was from fission products or activation products. A credibility assessment rating was established for each hit. (Each hour of search flight time by each of the C130s created four hours of computer analysis time, creating a major assessment backlog. As a consequence, on at least one occasion, raw data from the aircraft read-out was prematurely judged.)



NEST Equipment Vans containing computers stood ready in Hangar 5 Edmonton CFB to receive the digital magnetic tape from the airborne radiation detection equipment.

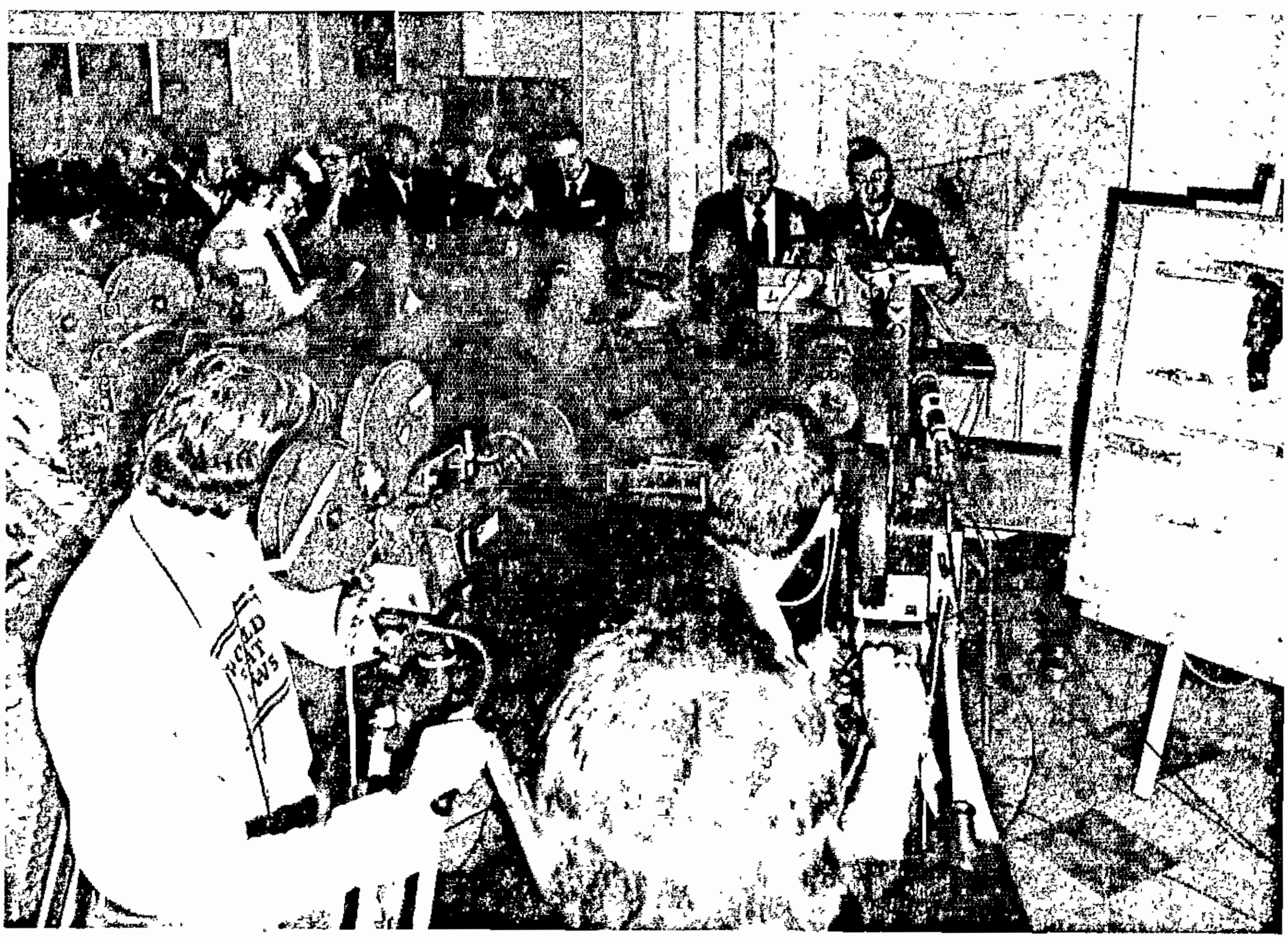
The magnetic tape data output from the airborne detection equipment were analyzed by scientists using the computers in the NEST vans. The analysis considered spectra, intensity-versus-time, and position information. Spectral analysis was used to determine whether the source was man-made or natural, and if man-made, whether it was from fission products or activation products. Intensity-versus-time and position information were the basis of analysis to determine whether it was a point source or a distributed source, the quantity of the radionuclei, and the exact geographic location of the source.



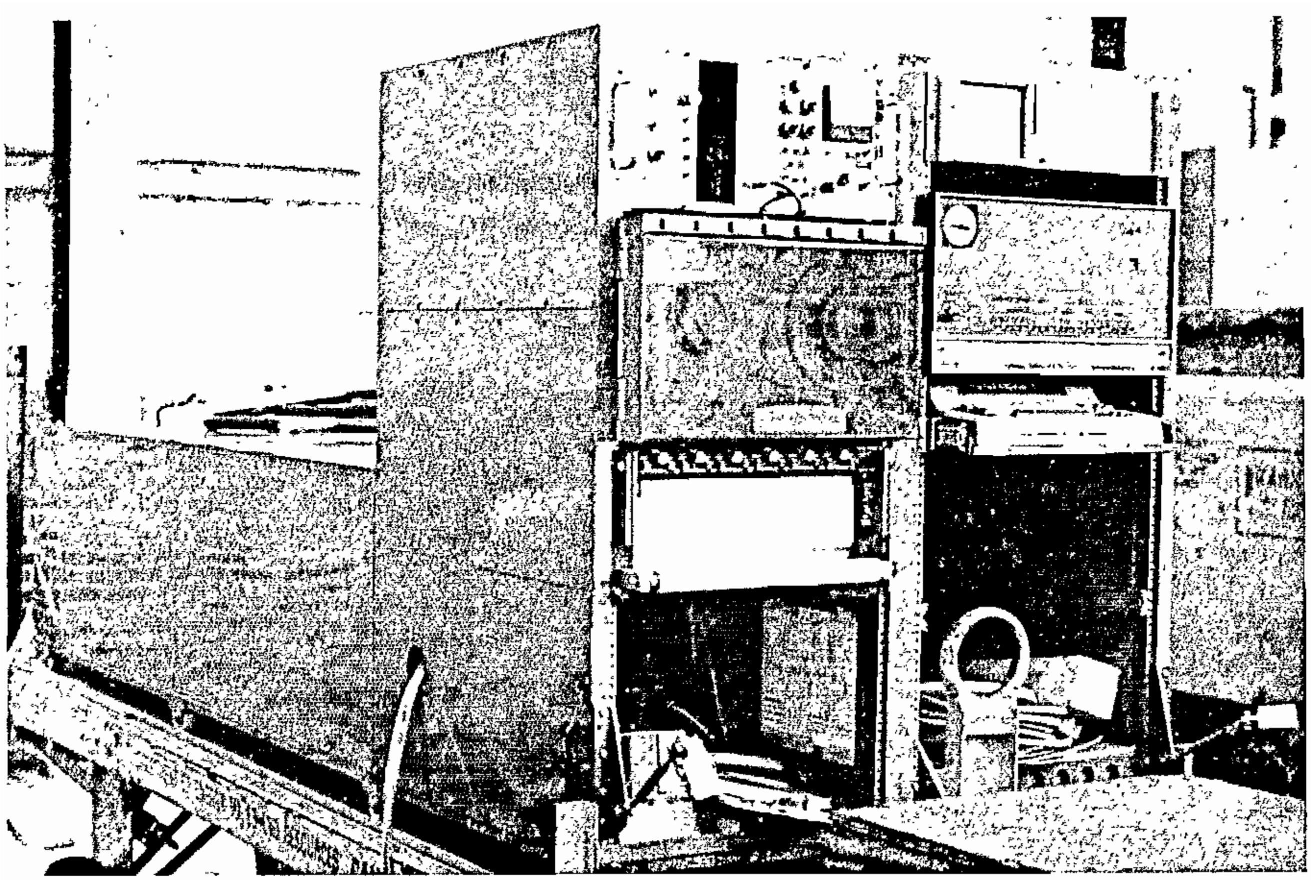
Public Information

Operation Morning Light attracted the interest of news media worldwide. By the end of the first week of operations most of the major news organizations of the free world had reporters covering the story.

Regularly scheduled press conferences were held daily at 10 a.m. from January 26 until February 12 in the press center which was established in the Hangar 5 passenger waiting room (CAF Base Edmonton). A senior scientific advisor and the Canadian Commander each prepared reports for the press conferences, which were each followed by a question and answer period. Scientific and operations personnel were available for interview by individual newsmen upon request on a 24-hour basis for the first two weeks.



The world press was well represented early in the Morning Light operations. A typical daily press conference held in Edmonton opened with statements by both the Canadian and American On-Scene Commanders. The statements were followed by a question-and-answer period where questions were fielded by technical participants.



The Canadian airborne radiation detection system, originally developed for uranium prospecting, waits in hangar for transfer to another aircraft.

The First Airborne Hits

On January 26, the radiation detection system from the Canadian Department of Energy, Mines and Resources was installed in a Hercules aircraft. Up to 12 aircraft (11 Canadian) were now involved in the search: four C130 Hercules, three CC138 Twin Otters, three CC135 Twin Huey helicopters, one CH147 Chinook heavy lift helicopter and one U. S. Department of Energy Convair with infrared equipment. At 2200 EST January 26, the first "hit" (i.e. apparent radiation hot spot) was reported on the Canadian radiation detection system in the McLeod Bay area north of Fort Reliance in the northeast end of Great Slave Lake (position 63 degrees, 54 minutes north, 102 degrees, 34 minutes west).

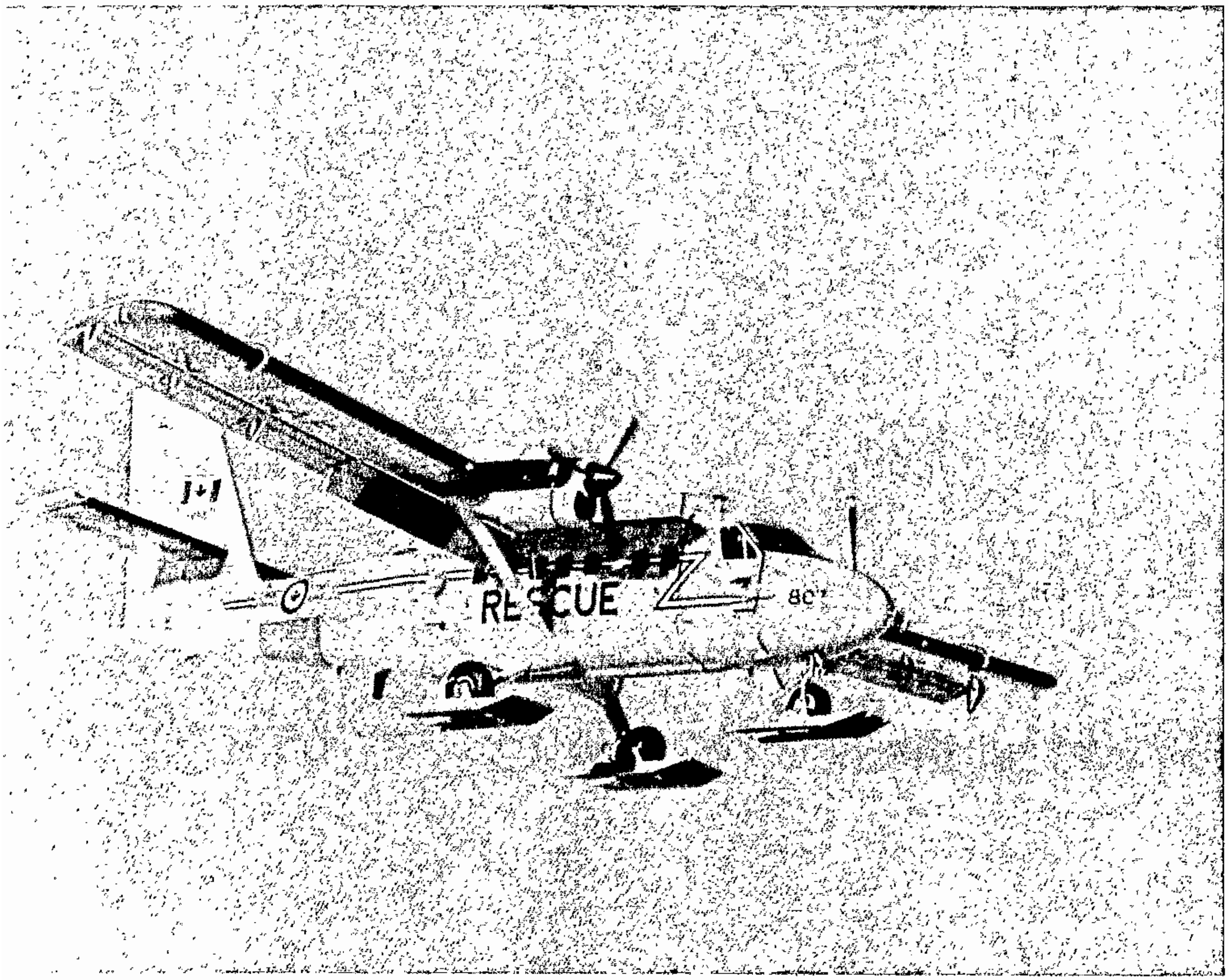
A ten mile grid at one-half mile spacing was immediately established and flown by a second C130 aircraft using U. S. detection equipment. The hit, a possible fragment, was confirmed.

The end of the following day, the U. S. Convair equipped with infrared sensing gear had scanned the entire area.

By early January 28, Northwest Territories officials and The Department of National Defence had, with some confidence, determined and located all civilian persons in the search area. As quickly as possible, each was advised of possible hazards.

During the morning, January 28, three radiation hot spots were detected by search aircraft on McLeod Bay. Two of the hits were later confirmed as satellite debris. By late afternoon, it was reported that two men spending the winter at Wardens Grove some 200 miles northeast of Fort Reliance, has discovered and touched an object on the Thelon River ice 12 miles north of their base camp.

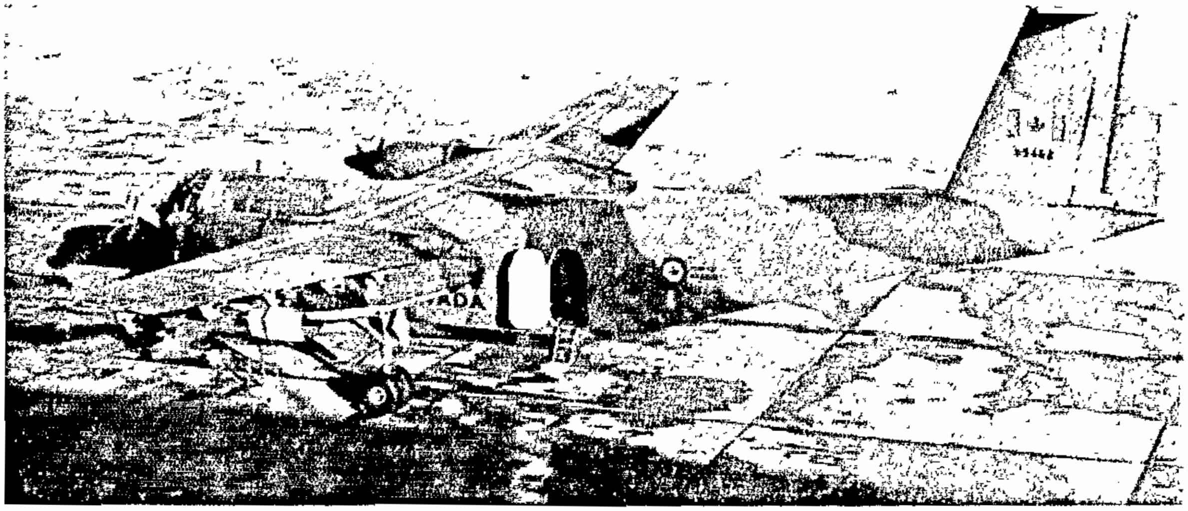
MORNING LIGHT AIRCRAFT



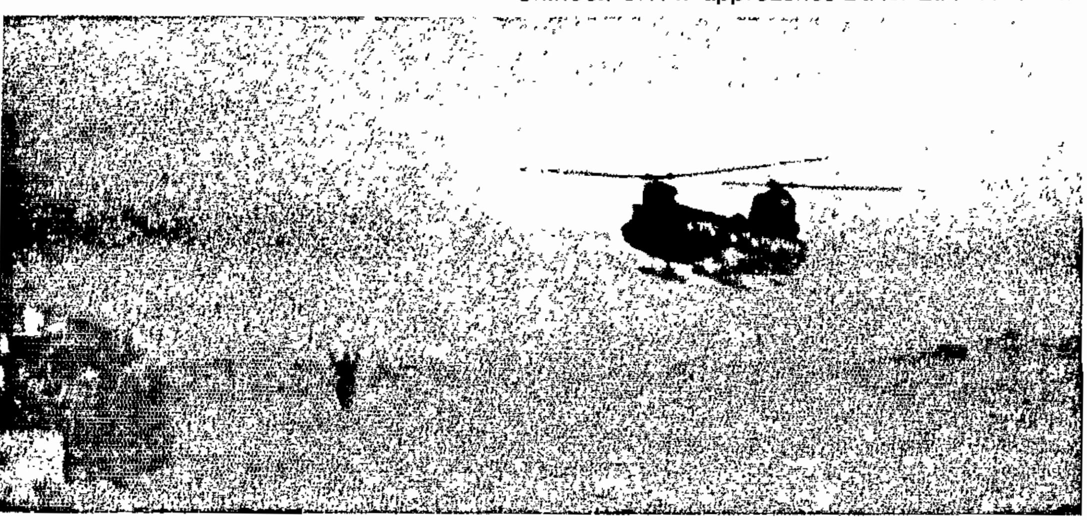
Ski-equipped DeHaviland CC138 Twin Otter

Thirteen different types of aircraft were used in the Morning Light operation. The Canadian C130 aircraft was the workhorse for logistic and radiometric search operations in the far north. Twin Huey CH135, Kiowa CH136, and Chinook CH147 aircraft were the helicopter workhorses. The C130 was ideally suited to carry out the overall airborne radiological search across the 15,000 square mile initial reentry footprint because the large size of the fuselage provided ample working space, the aircraft could carry and load required, and it was capable of great range and endurance. The CC138 Twin Otter proved to be very useful for utility hauling of personnel and equipment between all bases; it was stable, dependable, and could be operated out of unimproved airstrips. The Chinook CH147 had the largest load capacity and range of any of the helicopters in the operation and was used to transport heavy and bulky objects in the forward areas. The Twin Huey CH135 was extensively used for the fine grid radiometric surveys in all forward areas and for the transport of equipment, supplies, and people from the forward areas to the hit locations.

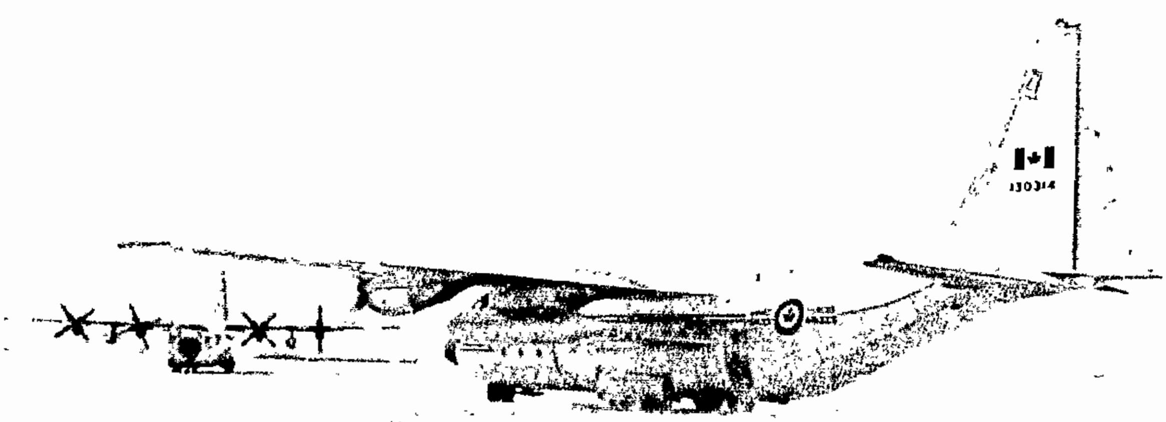
Buffalo CC115 loading at CFB Edmonton.



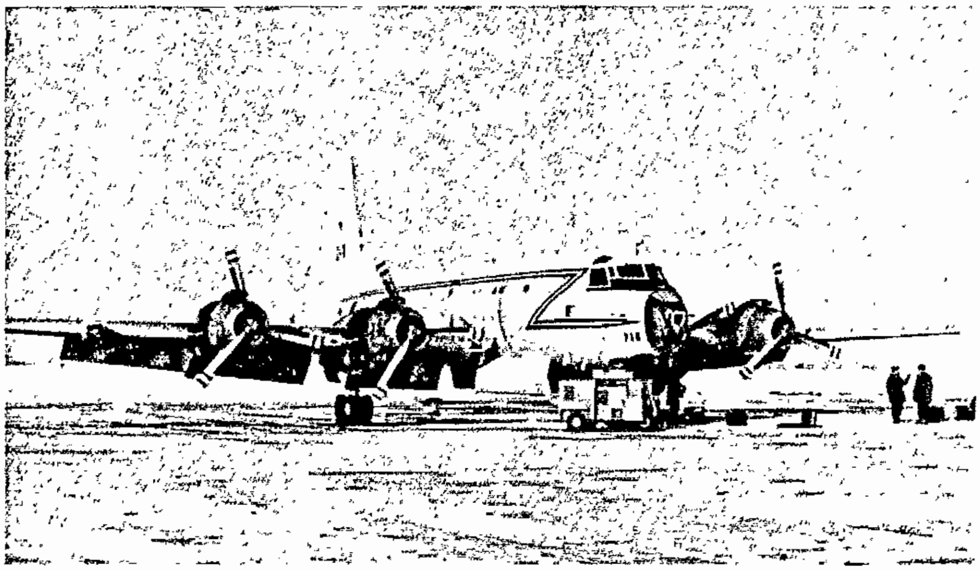
Chinook CH147 approaches Baker Lake Airbase.



The Canadian C130 aircraft taxis out for the next search mission from Edmonton.

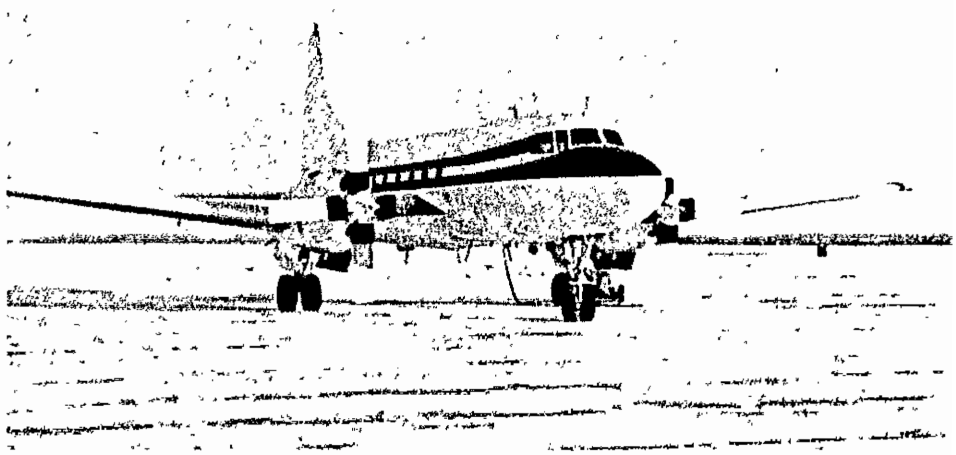


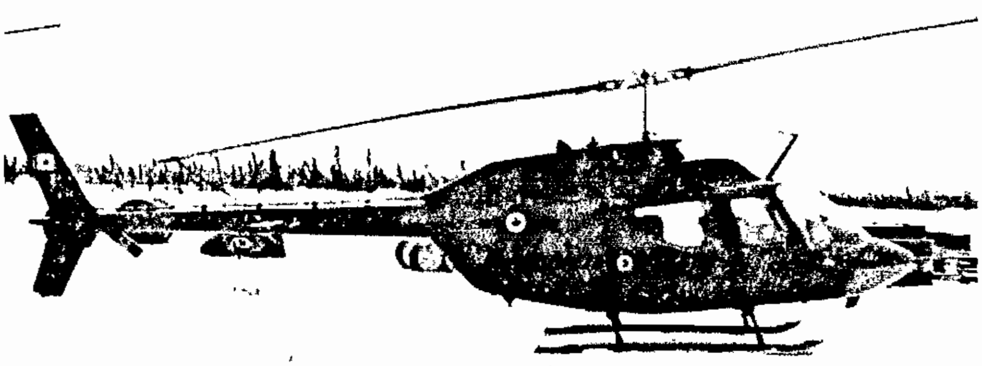
Twin Huey CH135 helicopter operating in a forward area.



Argus C107 antisubmarine aircraft equipped for photography and other forms of remote sensing.

U. S. Convair equipped for aerial photography, thermal infrared scanning, and other types of remote sensing.





The Kiowa CH136 helicopter was used extensively at the Camp Garland forward area.

Canadian C130 Aircraft on ice runway at Cosmos Lake.

AIRCRAFT MISSIONS FLOWN
THROUGH MARCH 25, 1978

CANADIAN

HERCULES C130	162
ARGUS C107	10
TWIN OTTER C138	64
TWIN HUEY CH135	183
CHINOOK CH147	72
REFUELER C137	1
FIGHTER CF5	4
BUFFALO CC115	14
KIOWA CH136	71
TOTAL	581

U.S.A.

C141	9
CONVAIR 580T	5
KC135	8
U-2	5
TOTAL	27

TOTAL FLIGHTS 608

Interior of Convair 580T showing preparation for high altitude thermal scanning mission. Thermal infrared imagery of the Wardens Grove area was obtained as an experiment. (No useful correlation was established between cratering in the ice and temperature distributions.) This platform was also used for photographic missions.

Wardens Grove Camp, Northwest Territories.

CHANCE STILL PLAYS AN IMPORTANT ROLE

The first debris from Cosmos 954 found on the ground was discovered accidently by two men who were traveling by dog sled along a region near the Thelon River called Wardens Grove. These two were part of a party of six men who were carrying out a 15 month trip through the northern wilderness starting in the Yukon and moving across Canada through the Northwest Territory up the McKenzie River to Great Slave Lake. In the spring the party planned to continue on eastward through northern Canada along the Thelon River and to the Coast of Hudson Bay. According to plan, the party was wintering over in the Thelon Game Sanctuary.

Because of the magnitude and duration of the expedition it would be appropriate to call these people explorers or adventurers. To help finance the expedition the members of the group had contracted to perform certain operations and services during their journey. They were retained by the Canadian Government to send out weather reports. In addition, certain wildlife studies were planned for submission to the Canadian Fish and Wildlife Service at the end of the expedition. One of the members of the party, Mike Mobley, was trained as a psychologist and had made arrangements to carry out tests of his colleagues during and after their expedition. The purpose of the tests would be to study the effects of stress and isolation on members of the party.

The party was interested in following in the footsteps of an earlier English explorer of the Thelon River area named John Hornby. John Hornby was an English naturalist who loved the north woods with an abiding passion and he had traveled them by canoe, dog sled and on foot for 20 years before his death in the Thelon River area.

Hornby set out in the winter of 1926-27 to prove that man could live off the land in the area that is now the Thelon Game Sanctuary. He was traveling with two men. The area through which they traveled has recently been described as the coldest spot in the western hemisphere; the chill factor there is often colder than the north pole itself.

John Hornby had planned to live off the land by hunting caribou. The caribou, whose migration cannot be accurately predicted, did not appear in the Thelon area during that winter. Without them, the men were reduced to eating whatever small game and fish they could trap, shoot or net. They starved.

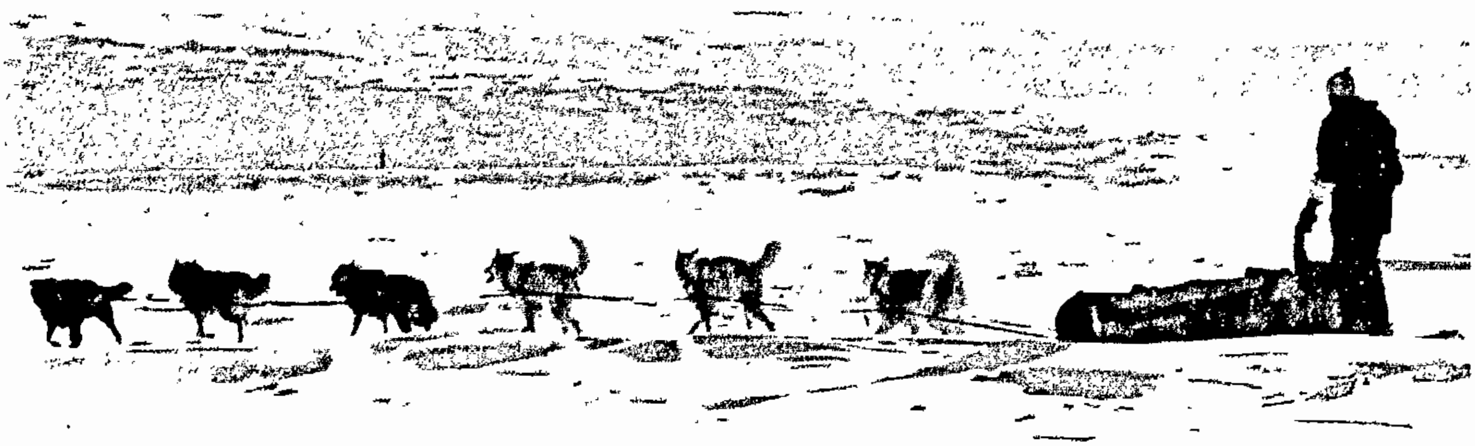
The diary of one of the Hornby party gives a precise and moving account of the sufferings of the group. It was this remarkable document which originally inspired and motivated the six explorers.

John Mordhorst and Mike Mobley had made a two-day dog sled expedition that included a visit to the site of the cabins occupied by the Hornby party. As they crossed the frozen river bed of the Thelon River to return to their own camp, they came across an odd looking metal object which they stopped to examine. When they reached their camp they learned from other members of the party of radio news about the fall of a Russian satellite carrying a nuclear reactor. The group became convinced that there was a good chance they had discovered a chunk of the fallen Russian satellite and that John Mordhorst and Mike Mobley might have been contaminated. They radioed this information to Yellowknife via the radio transmitter which they had been using for their daily weather broadcast. The Canadian Armed Forces sent a plane and a helicopter to their site. The aircraft brought the six men out for observation, leaving paratroopers to guard the camp and feed the dogs.

Mordhorst and Mobley were subsequently sent to Edmonton for extensive tests of the possibility that they were contaminated by nuclear debris. The tests were negative.

Explorers and the Role of Chance . . .

John Mordhorst and Mike Mobley were making a local expedition from their winter camp in the Wardens Grove area when they sighted a strange object in the ice of the Thelon River.



The object which they sighted turned out to be a large piece of Cosmos 954. Because of its shape it appeared from a distance to be the antlers of a moose or caribou.

John Mordhorst (left) and Mike Mobley were brought by air, by way of Baker Lake, to Edmonton for extensive tests; no radiation contamination was found.

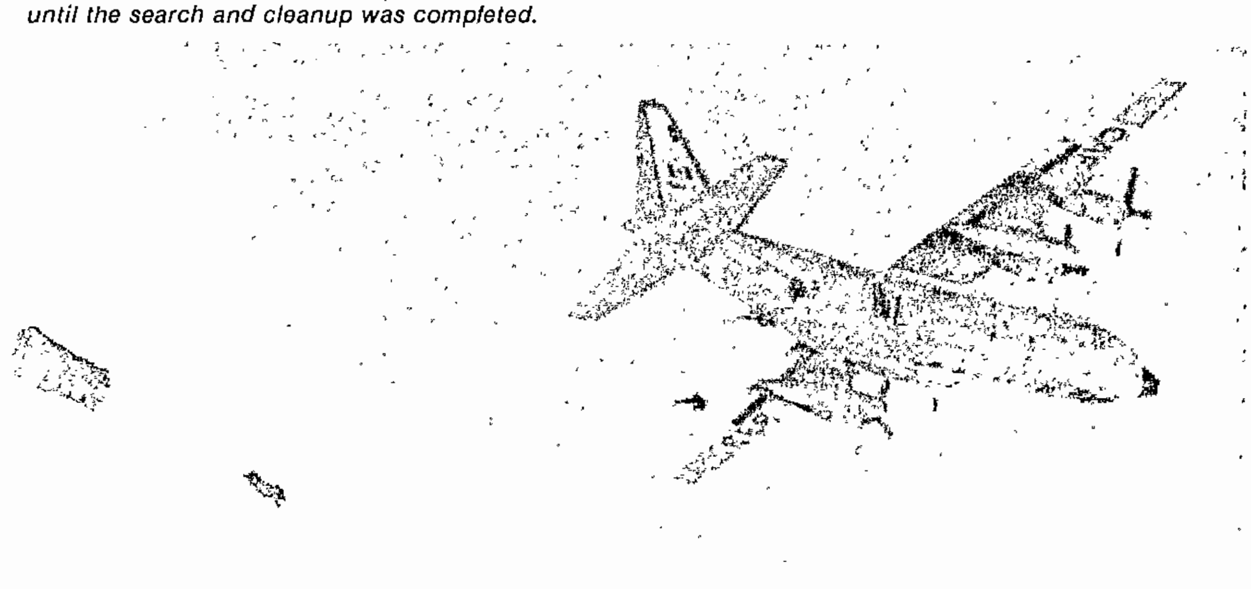
Left. *Mike Mobley (left) and John Mordhorst are shown explaining to officials in Edmonton the circumstances associated with their discovery of the "antlers" in the Thelon River.*

Securing Wardens Grove

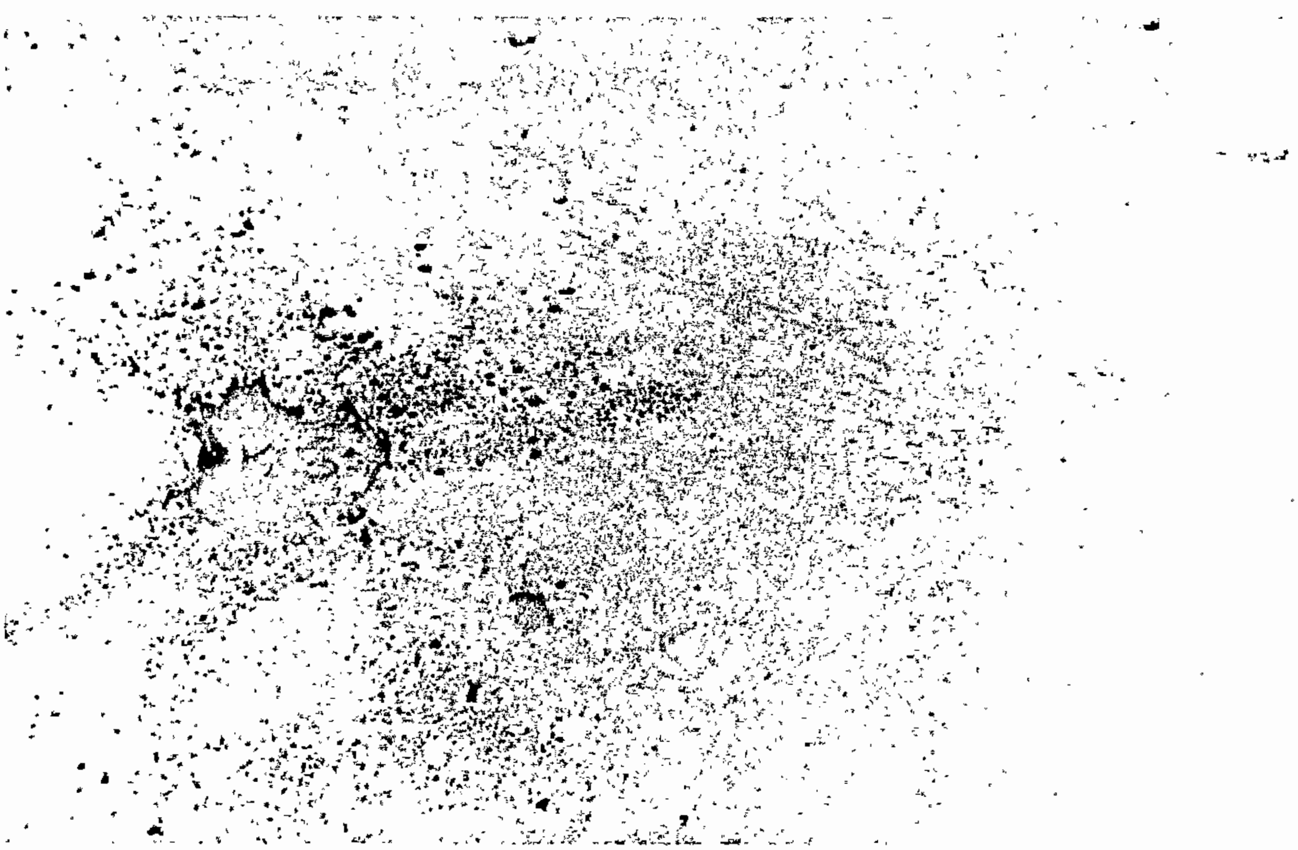
Because of other apparent hits in the Wardens Grove area, the existence of a (then) usable airstrip, and information that four "press" charter aircraft were departing Yellowknife for Wardens Grove, it was decided to secure the area for public safety. With approval of the Royal Canadian Mounted Police and the Solicitor General's Office, four military parachutists were dropped near Wardens Grove prior to dawn, January 30, 1978. The airstrip was secured and charter operators were reminded of the Notice to Airmen (issued January 26, 1978) prohibiting flight in the search area without military command post approval.

The Baker Lake Team was deployed to the site of the debris on January 29 to carry out helicopter reconnaissance. Simultaneously, a CC138 carrying a physician (radiation specialist) proceeded from Yellowknife to Wardens Grove to evacuate the six residents. Four who had not gone near the radioactive source were flown to Yellowknife. The other two, including the one who had touched the object, were helicoptered to Baker Lake, transferred to a waiting C130, and flown to Edmonton. Following hospitalization and testing in the Cross Cancer Institute, they were released and became guests — and future employees as guides — of the Department of National Defence.

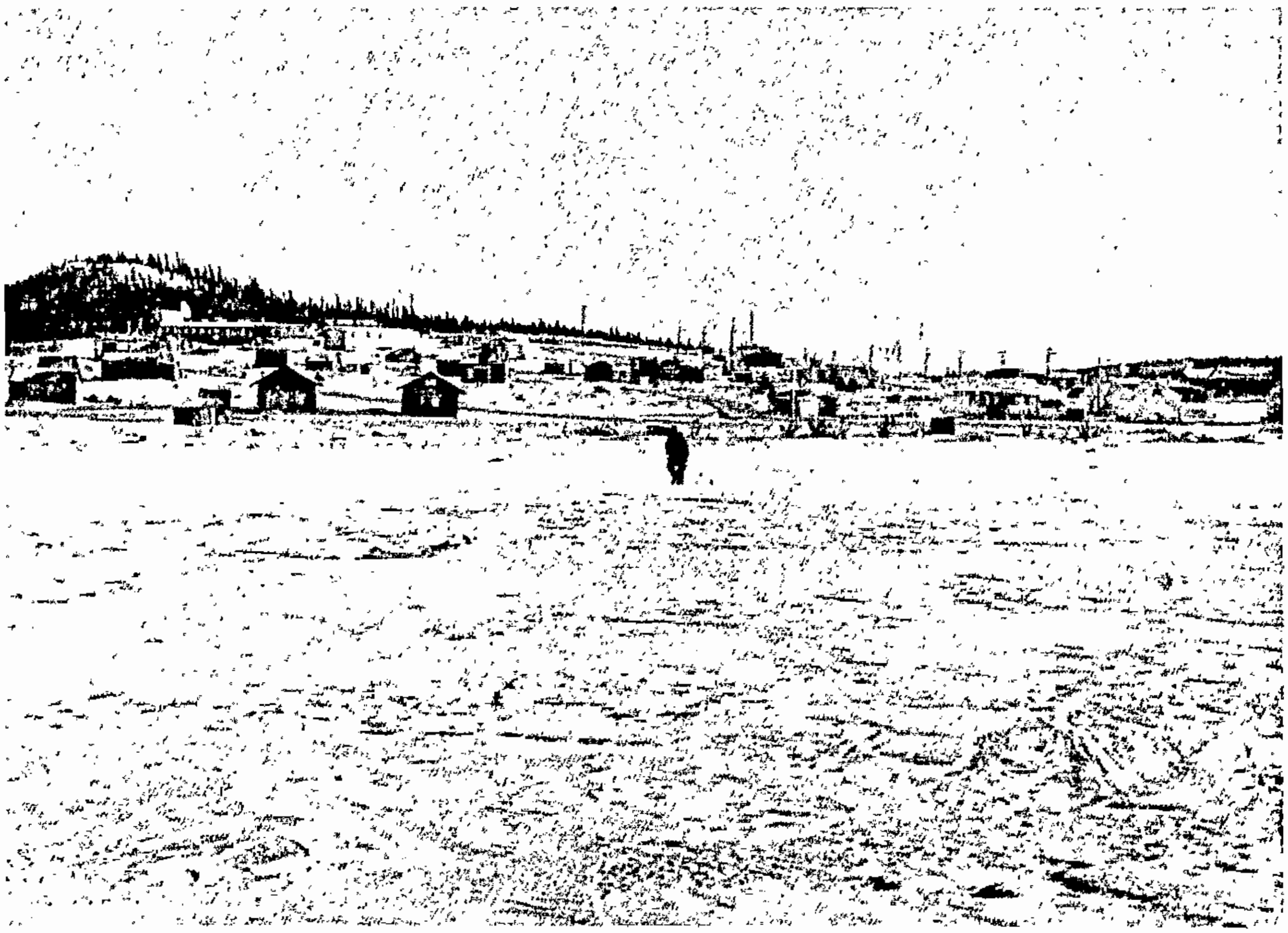
Below. *Parachutists were dropped into the Wardens Grove area from a C130 aircraft to secure the area from random public access until the search and cleanup was completed.*



Left. *This photograph of the "antler shaped" satellite debris discovered by the two young explorers in the Thelon River area became a symbol of the Morning Light operation because of its worldwide publication and distribution.*



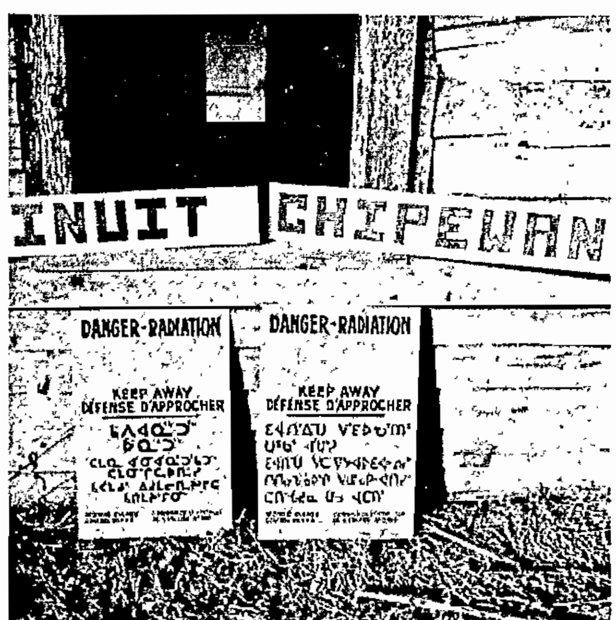
Aerial view of the crater on the Thelon River near Wardens Grove where the adventurers accidently discovered the "antler shaped" satellite debris. The volume of the crater and the great number of melt holes surrounding it indicate that a pyrophoric substance was present in the debris.



The village of Snowdrift on the south edge of the eastern end of Great Slave Lake. The Snowdrift area was the site of some fine particulates. This area is near the western extremity of the predicted footprint.

The satellite reentered over an area of very low population density outside of established communities. Canadian authorities traveled to all known remote residents, such as the trapper's cabin shown here, to inform the people about the satellite debris.

Above. *Canadian military personnel briefed local residents concerning the extent of the danger from the satellite debris and what should be done if a person encountered such debris.* **Below.** *Notices were also posted.*



End of the First Week

By January 29, the entire search area had been nominally covered at least once by C130 aircraft.

On January 30, two CP107 Argus aircraft (one equipped for aerial photography) were added to the search. Royal Canadian Mounted Police had established security guards near Fort Reliance hit areas and at Wardens Grove. Department of National Defence assistance and support was maintained. Canadian Forces Radiation Monitoring personnel from the Yellowknife team completed a radiation survey in the community of Snowdrift, Northwest Territories. This community was revisited on January 31, by the Commander, Northern Region Headquarters, to explain that little or

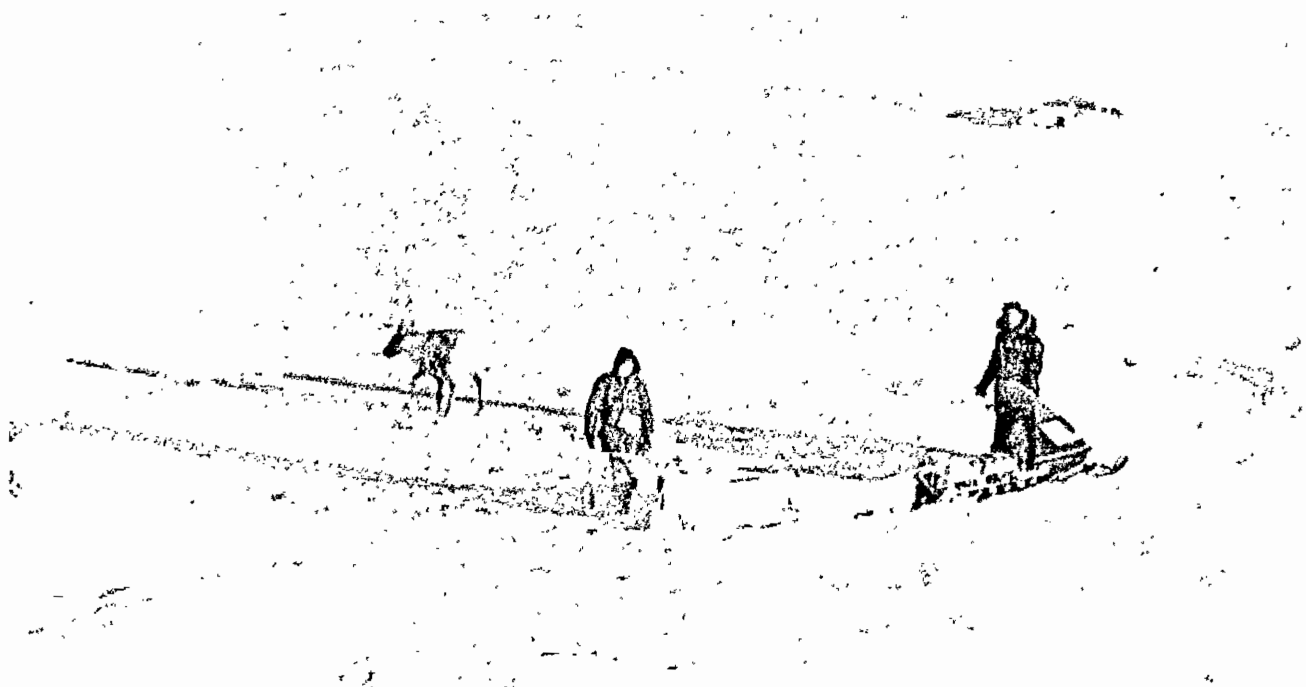
The population of the Northwest Territories of Canada, although sparsely distributed, is significant in numbers and species of wildlife...

In the exposed tundra the ptarmigan depends on camouflage as a survival technique, exchanging mottled brown plumage for white when winter comes.

Moose range throughout the forested portions of Canada, often seeking the shelter of conifer stands when snows become deep. In the winter the animal feeds primarily on the brushy twigs of hardwood trees and shrubs.

Moving caribou make a clicking sound caused by tendons rubbing against foot bones. Noted for their migrations, caribou depend on a mixture of lichens as a food source, supplemented by moss and shrubs. Many natives still depend upon the caribou as a source for food, clothing, and other necessities.

Wild herds of musk oxen are found today only in arctic America and Greenland. The pungent odor which gives the animal its name is released from glands located in front of the eyes.



Native population hunting parties move over great areas for weeks at a time; every effort was made to contact such hunting parties to tell them about the satellite debris.

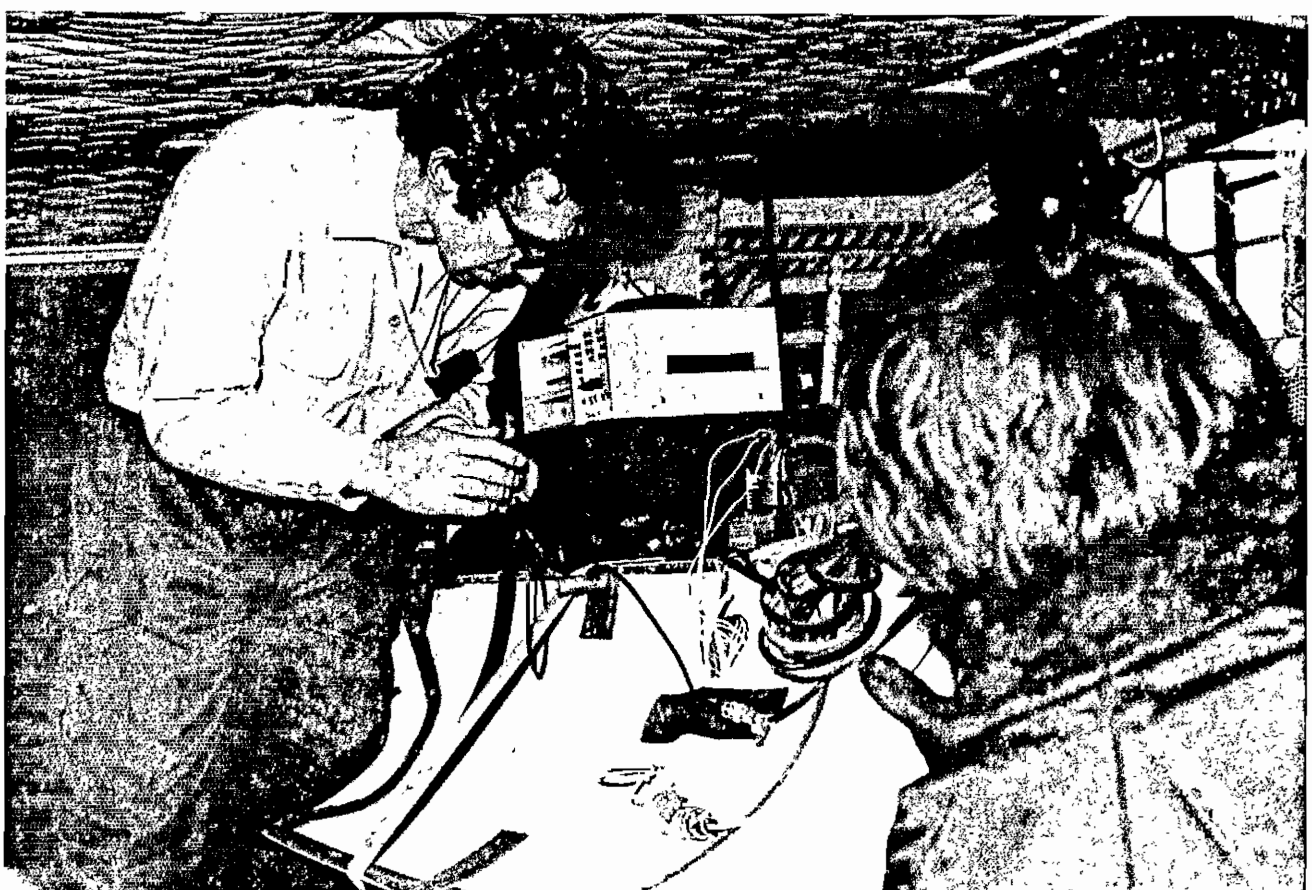
no ecological effects were expected. (This topic had also been addressed in a press release from Edmonton on January 30)

By early January 31, many sources of man-made radiation in the western reaches of the search area were isolated by helicopter-borne ground parties, and retrieval action was started by Atomic Energy Control Board personnel who had joined the teams on January 27.

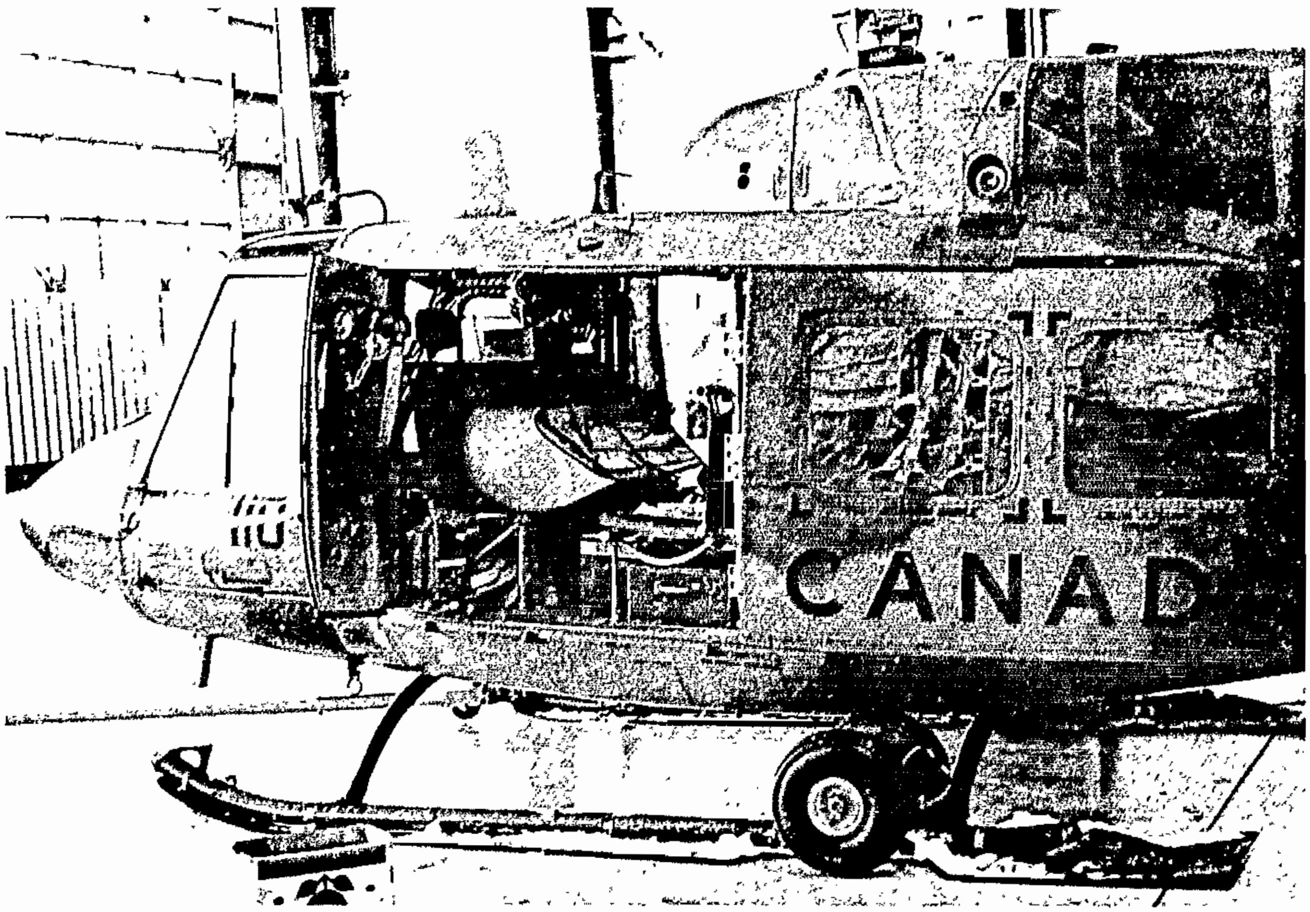
The search was now concentrated in the McLeod Bay and Fort Reliance areas with a total of 15 aircraft (14 Canadian) involved. The airborne measuring systems, three from the U. S. and one from the Canadian Department of Energy, Mines and Resources, were all in use.

Debris recovered by ground crews in the McLeod Bay area was taken to Yellowknife for preliminary analysis while scrapings from the debris on the Thelon River were taken directly to Edmonton in special containers.

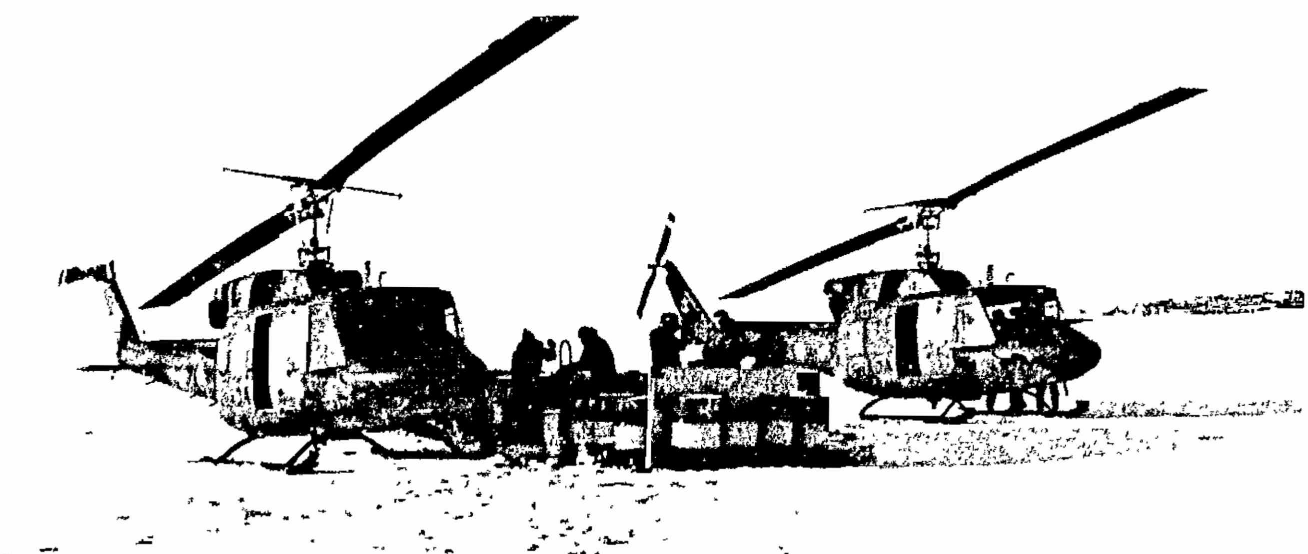
Throughout this period, and continuing until February 4, C130 radiation-detection missions continued 24 hours daily. The Argus and Convair aircraft provided electronic/infrared/photo coverage, and teams at both Yellowknife and Baker Lake carried out daylight search and recovery missions to the Fort Reliance and Wardens Grove areas. Scientific analysis and data processing also continued 24 hours daily. Logistic support flights were completed as required, supporting both teams, and establishing fuel caches north of Fort Reliance and Wardens Grove to support helicopter missions. (The fuel was delivered by using a low altitude parachute extraction system.)



U.S. scientists at Yellowknife adapting a NEST radiation detector pod for mounting on a Canadian helicopter.



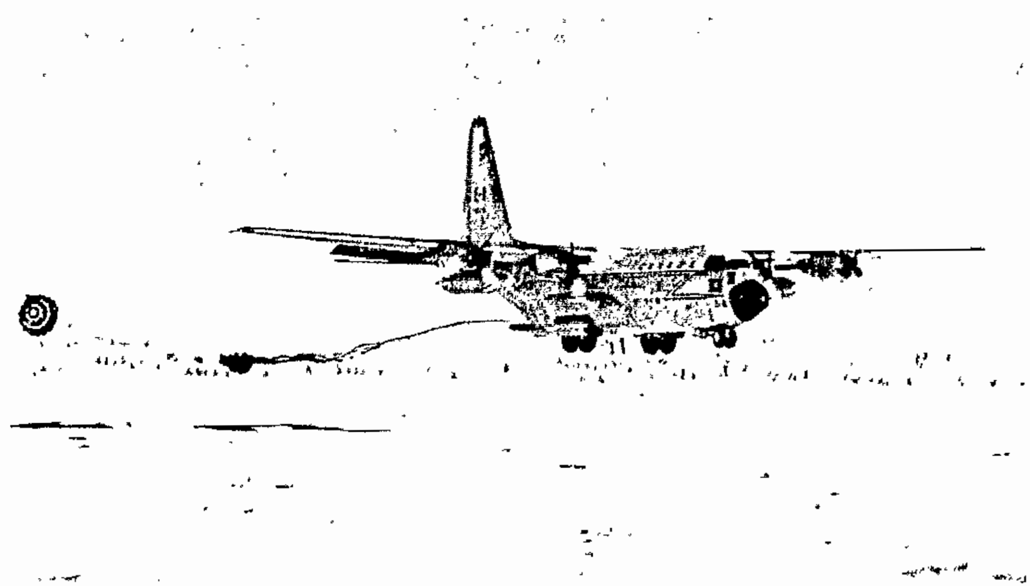
NEST radiation detection equipment mounted in cargo/passenger compartment of a Canadian CH135 Twin Huey helicopter. The radiation detection equipment is packaged in a pod to be suspended on the external air frame of a transporting helicopter. Because of the extreme low temperature involved in the Morning Light operation, the pod and its associated electronic equipment were both mounted within the aircraft to protect the equipment from the extreme temperatures and rates of change of temperatures.



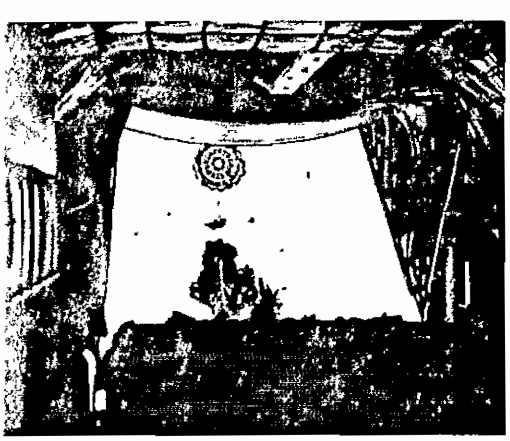
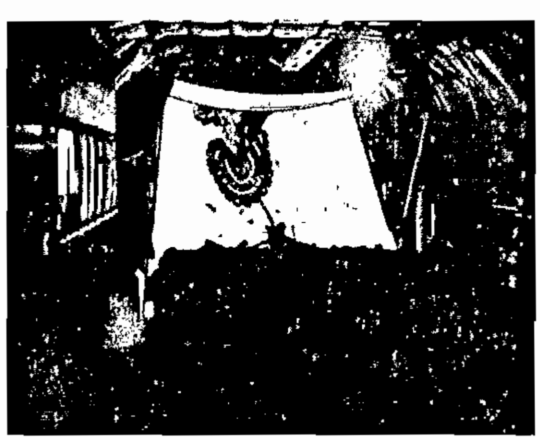
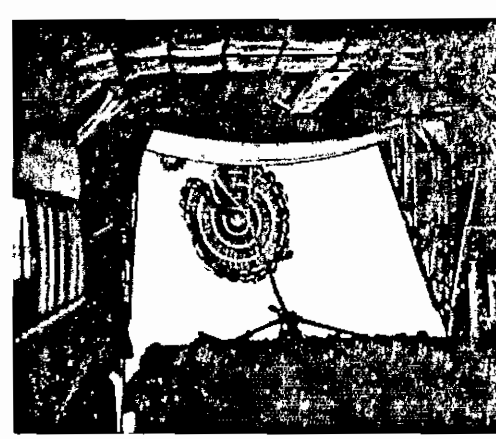
Helicopters refueling in the field at Fort Reliance from drums of fuel dropped by the Low Altitude Parachute Extraction System (see next page).

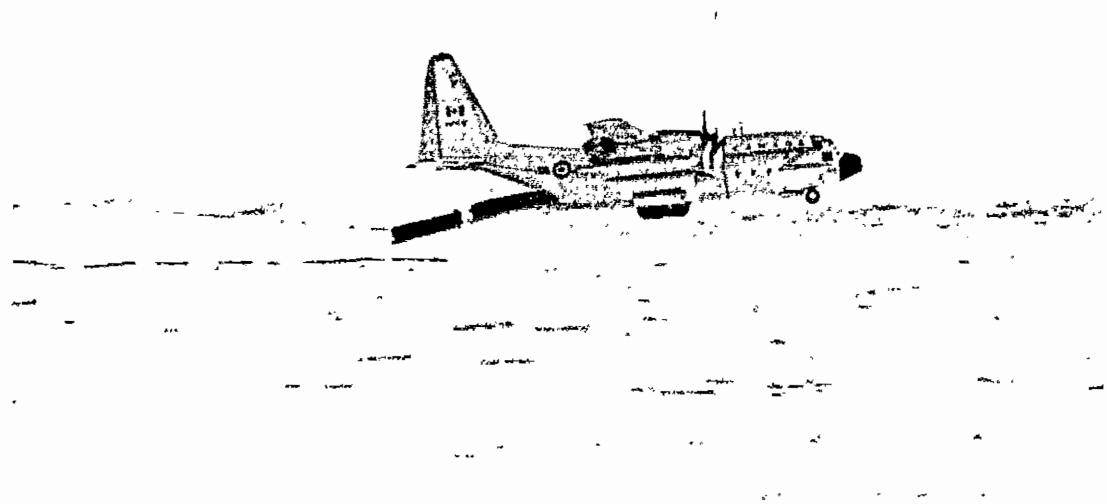
LOW ALTITUDE PARACHUTE EXTRACTION SYSTEM

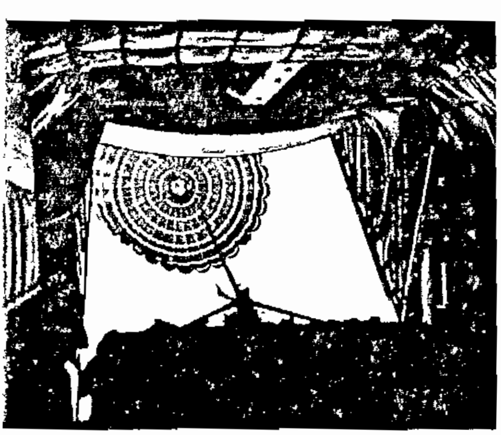
Canadian Forces used every means necessary to supply the search effort...

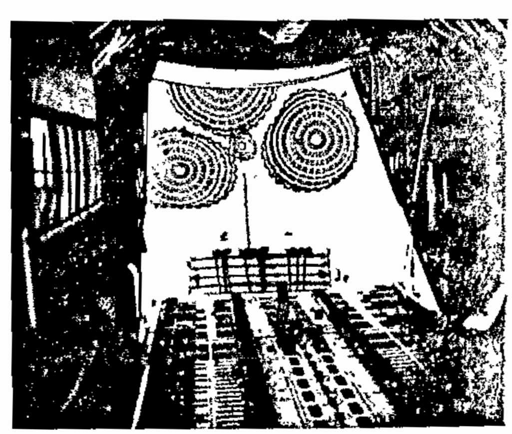


The Low Altitude Parachute Extraction System (LAPES) was an important technique for delivering supplies of fuel and equipment to remote locations. This technique allows the delivery of packages which may weigh several tons (for example, bulldozers) to locations where no airstrip or a minimum airstrip is available. The technique involves the extraction of packages from the C130 aircraft by parachute as the aircraft flies slowly just above the ground. The picture of the plane shows the extraction technique in operation; the sequence of photographs from inside an unloading C130 shows the removal taking place.







Microwave Ranging System transponder unit being placed under a landmark by an international team. The distance limitations of the units meant constant movement of the transponders was necessary as the search moved along the footprint.

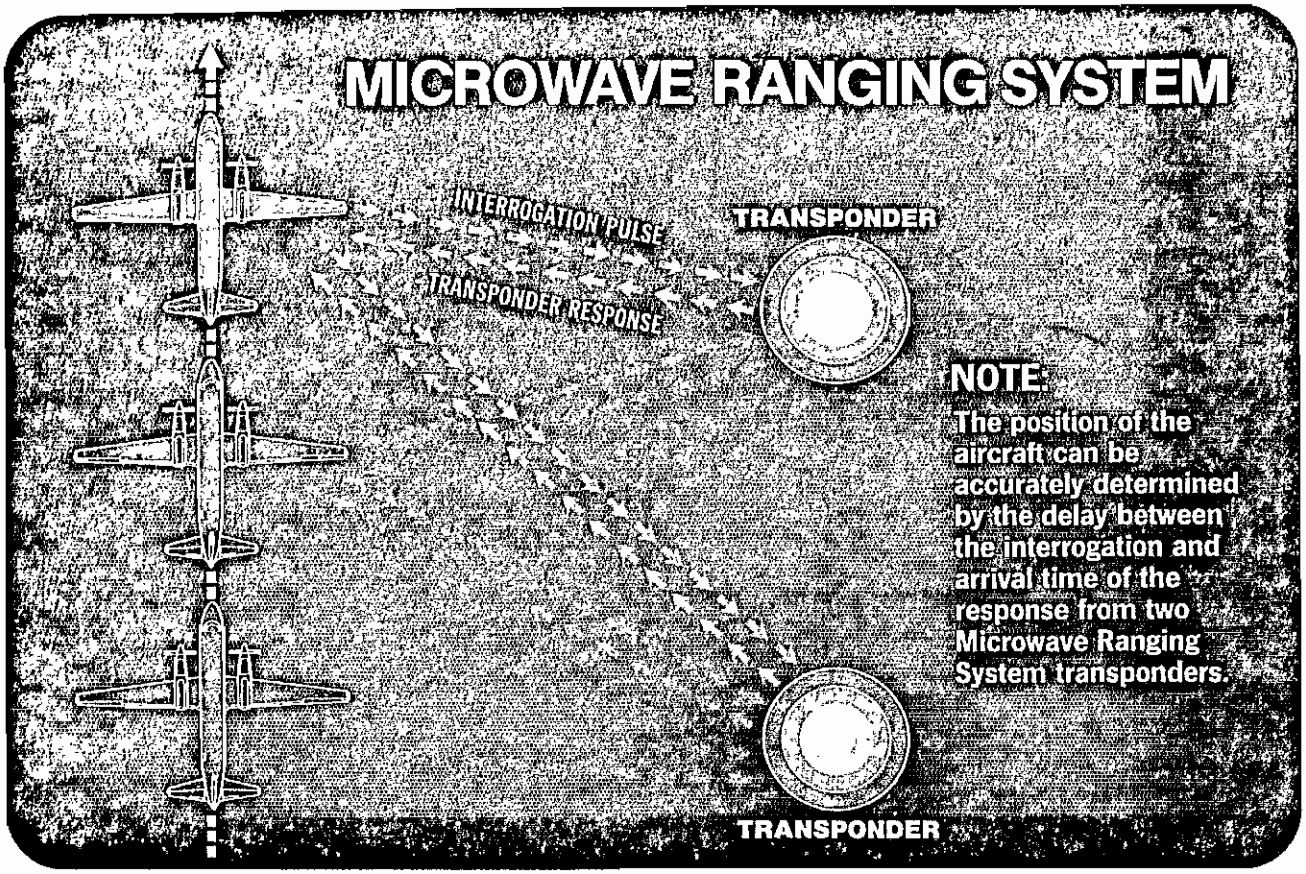
Navigational Problems

Early in the operations it was often impossible to relocate a hit at its reported location. This was due to intrinsic errors in navigation methods that consisted of visual means, inertial navigation systems and the Omega systems. Two basic problems were identified: the pilot needed steering information to accurately maintain the close-spaced parallel search grid and the position of the aircraft needed to be recorded on the same time base as sensor data to permit accurate hit location.

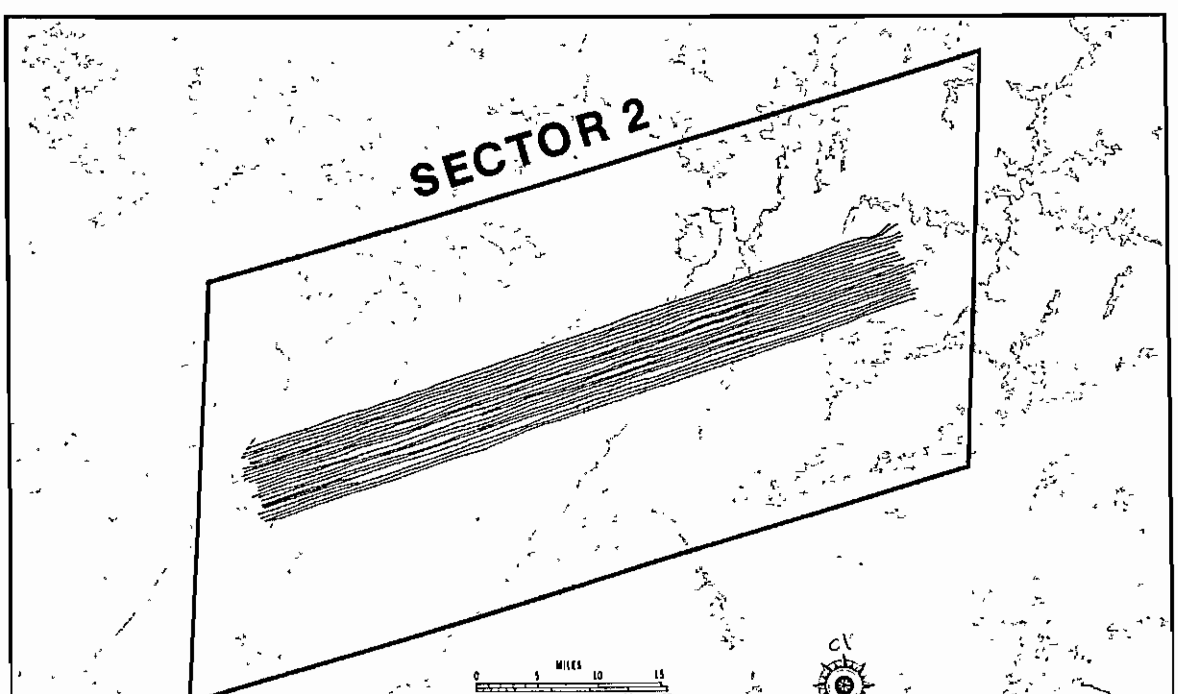
Because of the problems, a search technique was developed using a formation of three C130 aircraft equipped with sensors, flying at 750 feet spacing, providing total ground coverage by the radiation detectors. This formation technique proved successful for finding many probable hits, both by assuring overlapping of the scanned terrain and by looking for coincident hits occurring in different aircraft. This new search technique still did not provide precise positioning.

Microwave Ranging System for Navigation Accuracy

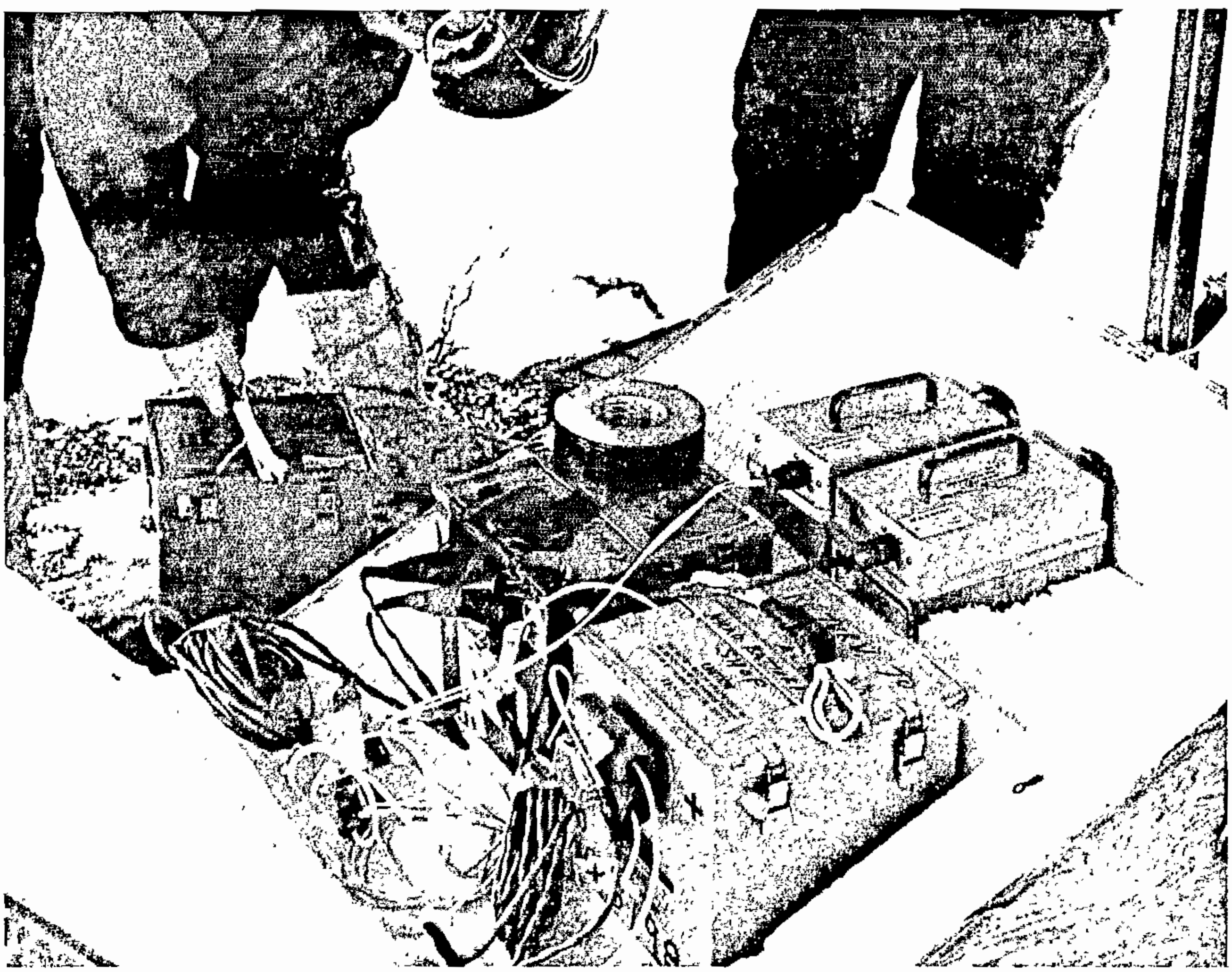
At the end of the first week of operation, the navigation problem was resolved. A Microwave Ranging System was installed in a C130 late February 1, flight tested on February 2, and was operationally employed starting February 4. The results were exceptional, and C130 aircraft with the Microwave Ranging System continued to complete a "refined search" throughout the entire search area. The Microwave Ranging System required positioning of ground transmitters by Twin Huey helicopters at precise locations, and periodic battery replacement. Nonetheless, because of this exceptional accuracy the system became an essential element in establishing the credibility of the complete radiation survey.



The above drawing illustrates the Microwave Ranging System principle. The map below shows the results obtainable. It should be noted that the Microwave Ranging System had limited range and it was necessary to move the transponders as the search moved from sector to sector. The parallel lines were flown on 1500 foot spacings.



An insulated package containing the Microwave Ranging System transponding unit being installed atop a hill in one of the survey sectors. To operate properly, the transponders must have a clear line of sight between the unit and the aircraft.



Two independent Microwave Ranging System transponders were placed at each transponder station. Because of the low temperature, battery lifetime during use was approximately two days.

The First Major Hits

Early on the morning of February 1, 1978, a CC138 transporting the Yellowknife team to hit areas visually observed an object at 62 degrees, 53 minutes north, 109 degrees 50 minutes west. Helicopters were landed with the specialist team and a large tube approximately 35 centimeters in diameter by 50 centimeters in length by 3 millimeters thick, and other smaller debris was recovered. Charring, structure and chemical composition subsequently proved this object to be part of the satellite. It was not radioactive.

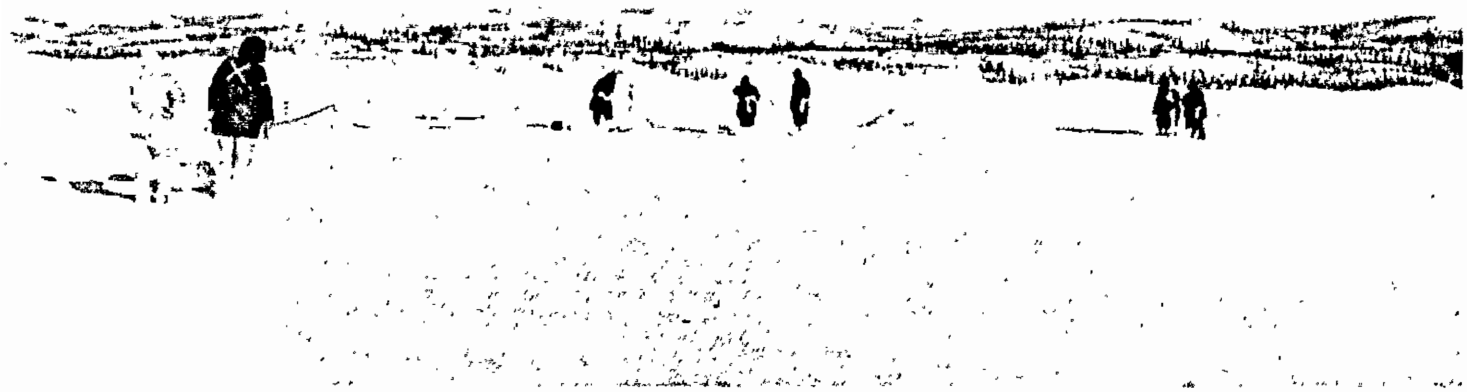
The team then proceeded to a hit site some miles away and located and secured a piece of debris that was quite radioactive --- measuring 200 R/h* near contact. This intensity level necessitated special handling, and a massive lead container constructed by the Cross Cancer Institute was flown to the site. As with all such debris, its recovery and control was under the direction of the Canadian Atomic Energy Control Board.

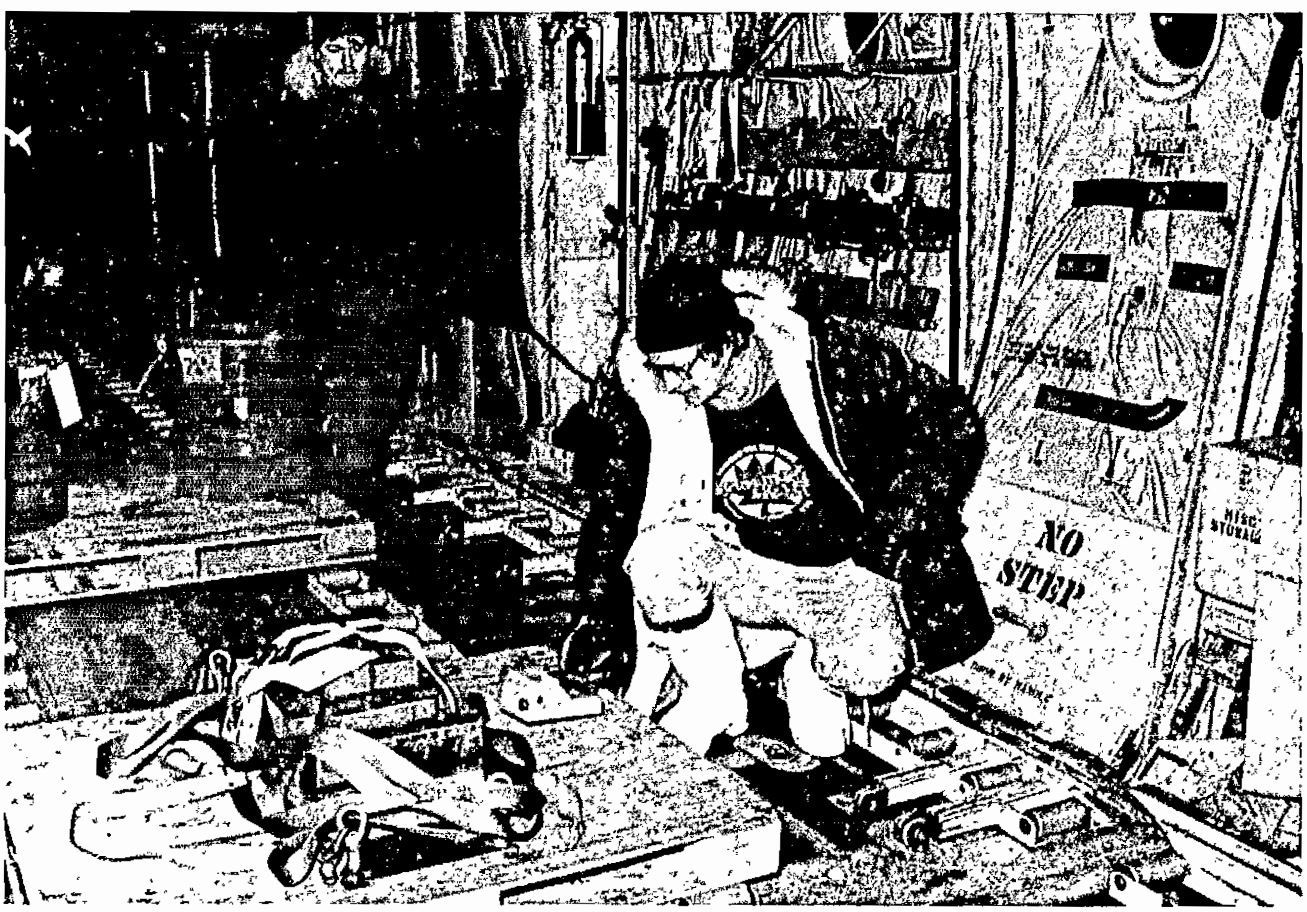
Various parts of the "waste paper basket" shaped object were recovered and fitted together. Most parts were metallic, but some were fiber-filled plastic.

*roentgens per hour, handheld survey instruments.

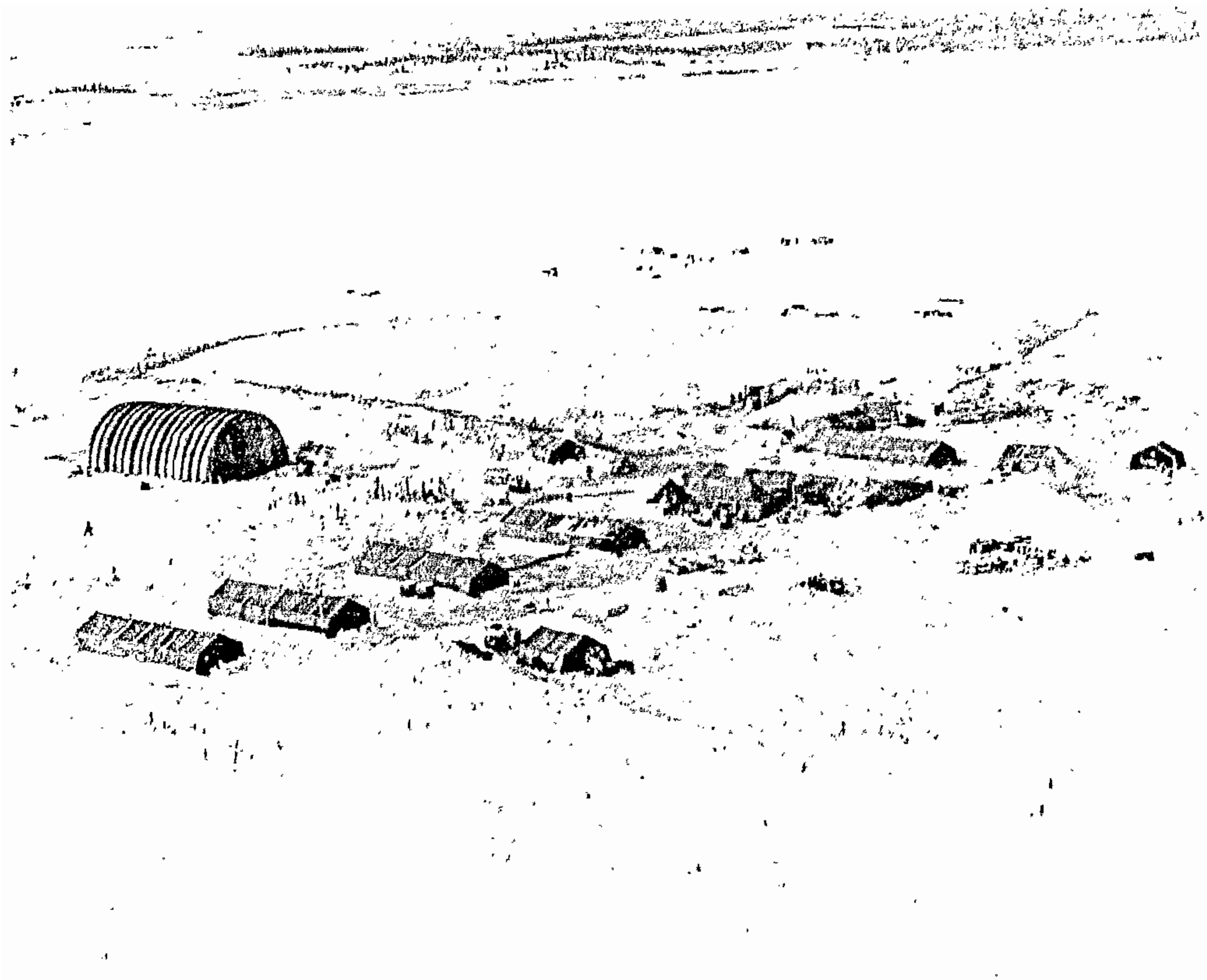
The first major item detected visually from aircraft, that was verified and recovered, was a large tube about the size of a tall office waste basket. The object was located at 62 degrees 53 minutes north, 109 degrees 50 minutes west. It was not radioactive and it was not part of the satellite's reactor.

One of the early major hits was that of an object located in the Yellowknife search area which gave a radiation reading of 200 R/hour near contact. (Rough field measurement using handheld survey instrument.) The recovery operation necessitated special handling. In the photograph the three workers in the center are recovering the object.

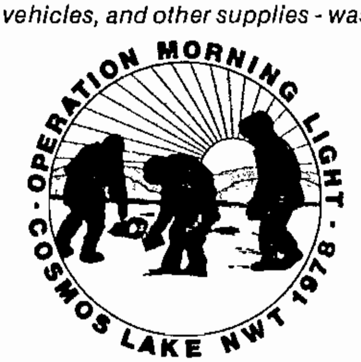




200 Roentgen-per-hour debris from Cosmos 954 (shielded by lead bars) loaded on a pallet aboard a C130 aircraft for transport to Edmonton. An Atomic Energy Control Board representative is using a hand-held measuring instrument to check the amount of gamma radiation escaping from the lead-shielded debris. Other less radioactive debris is contained in the green drums in the background. Aircraft used to transport radioactive materials were not subsequently used in airborne radiometric surveys.



Camp Garland (named after the Canadian on-scene commander for Morning Light) was established as a complete facility to accommodate up to 100 personnel. An air strip, complete with radio navigation aids, was constructed on the surface of the lake ice. Everything - fuel, food, vehicles, and other supplies - was brought in by air.



Camp Garland

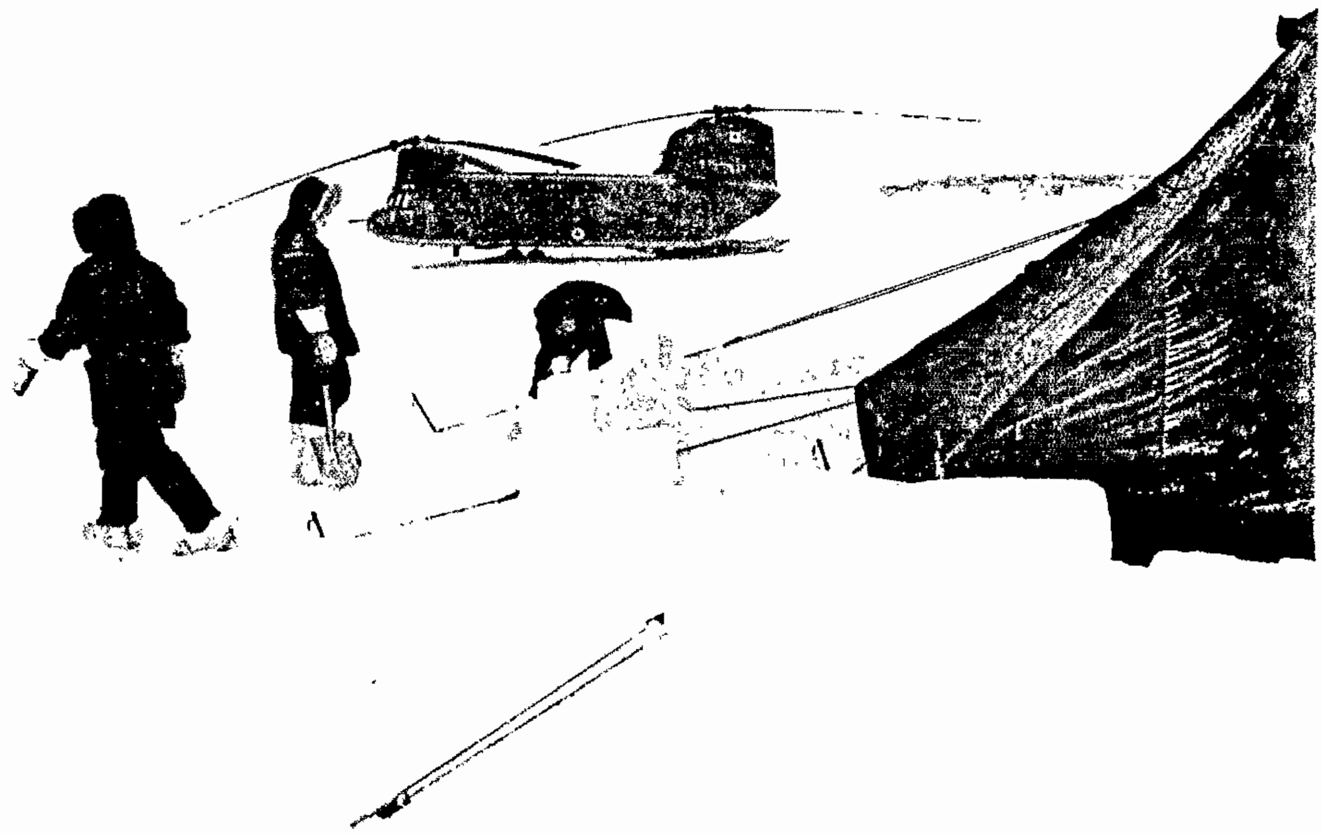
On January 26, a Radiation Monitoring Team, with U. S. personnel attached, was flown to Baker Lake. This provided access to the eastern portion of the original search area. However, the daily deployment of this team to the Thelon River debris site by helicopter, with C130 aircraft providing navigation, communications and safety escort, provided unacceptable. Less than two hours on-site time was available to the team because of the requirement for daylight transit to and from Baker Lake.

Because of the number of apparent hits at this point and its central location in the entire search area, the Mission Planning Group decided, during the weekend of February 4-5 to establish Camp Garland as a base at a site near the debris the explorers found. The new base camp was initially designed to house 21 scientific team members and 32 support personnel (including two twin Huey helicopter crews and maintenance personnel). It subsequently was expanded to support almost 100 persons.

Left. *An integrated capability to do airborne radiometric search, and ground search and recovery, was maintained at Camp Garland which was built at the Cosmos Lake site. The photograph shows a daily planning meeting of U.S. and Canadian radiation experts and Canadian military personnel.*

Inside the survival tent on the Thelon River. The Canadian Forces aircraft all carried arctic survival equipment and supplies, and the Canadian Forces provided arctic survival training to both U. S. and Canadian civilian personnel.

The stress of the arctic temperatures threatened party members when their Chinook CH147 helicopter would not restart February 3; the effective chill factor was minus 100° Centigrade and personnel were forced to resort to survival techniques. Here they are building a snowblock windbreak around their survival tent.



Camp Garland had an ice air strip on a lake and was primarily made up of tents built to the Department of National Defence standards. The lake was designated "Cosmos Lake" by the first Morning Light inhabitants --- the Baker Lake Team who camped overnight in the area February 3, when their C147 helicopter developed engine problems due to the extreme cold. (All survived in good health and spirits in spite of a *chill factor of -100° C* equivalent.)

Hit Verification Sequence

The search technique covered a very large area in the extreme of near arctic winter with the mission continuing throughout foreshortened days and long nights.

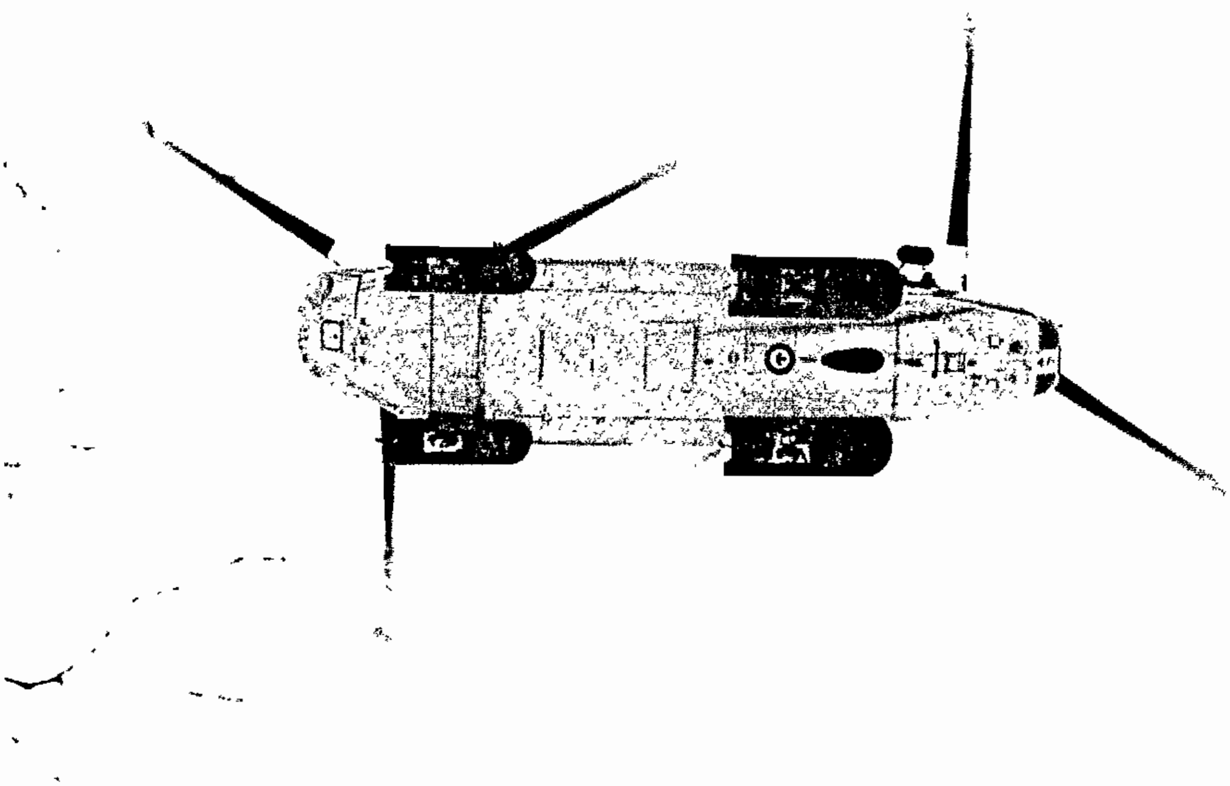
As a first step the huge C130 aircraft, operating out of Edmonton, combed the 15,000 square mile footprint to pick up radiation signals from each piece of satellite debris where it had fallen to the frozen earth.

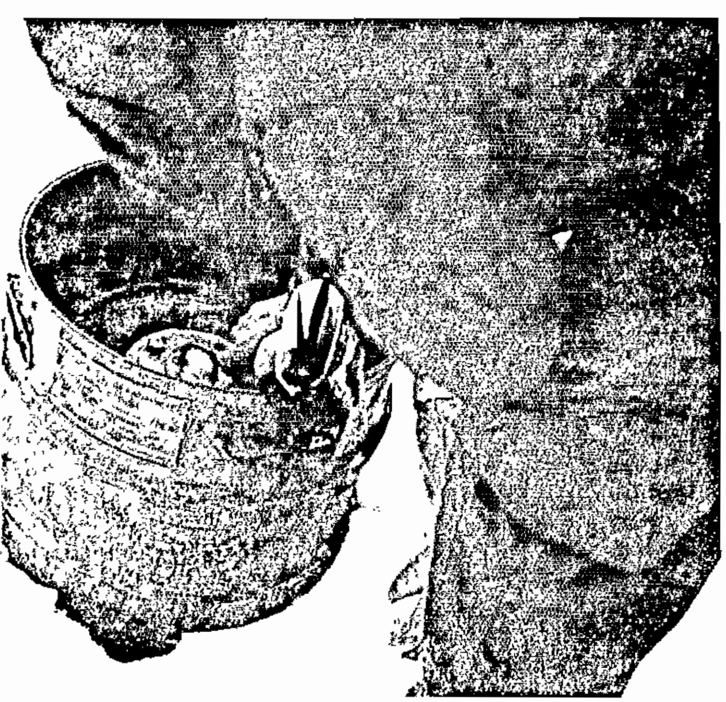
Each hot spot noted in the broad search was then verified from a lower flying helicopter equipped with a detector. This

After a hit was located by means of a radiometric survey using the large C130 aircraft, the locations were verified by a helicopter close-in survey and marked by dropping colored banners. A second helicopter transported a recovery team to the marked location with appropriate tools, containers, and hand-held radiation detectors.

helicopter flew in as close as possible and dropped a bright colored streamer to mark the location. The helicopters did not have the range of the C130s and consequently were operated out of local advance field locations, such as Yellowknife, Baker Lake, and Camp Garland.

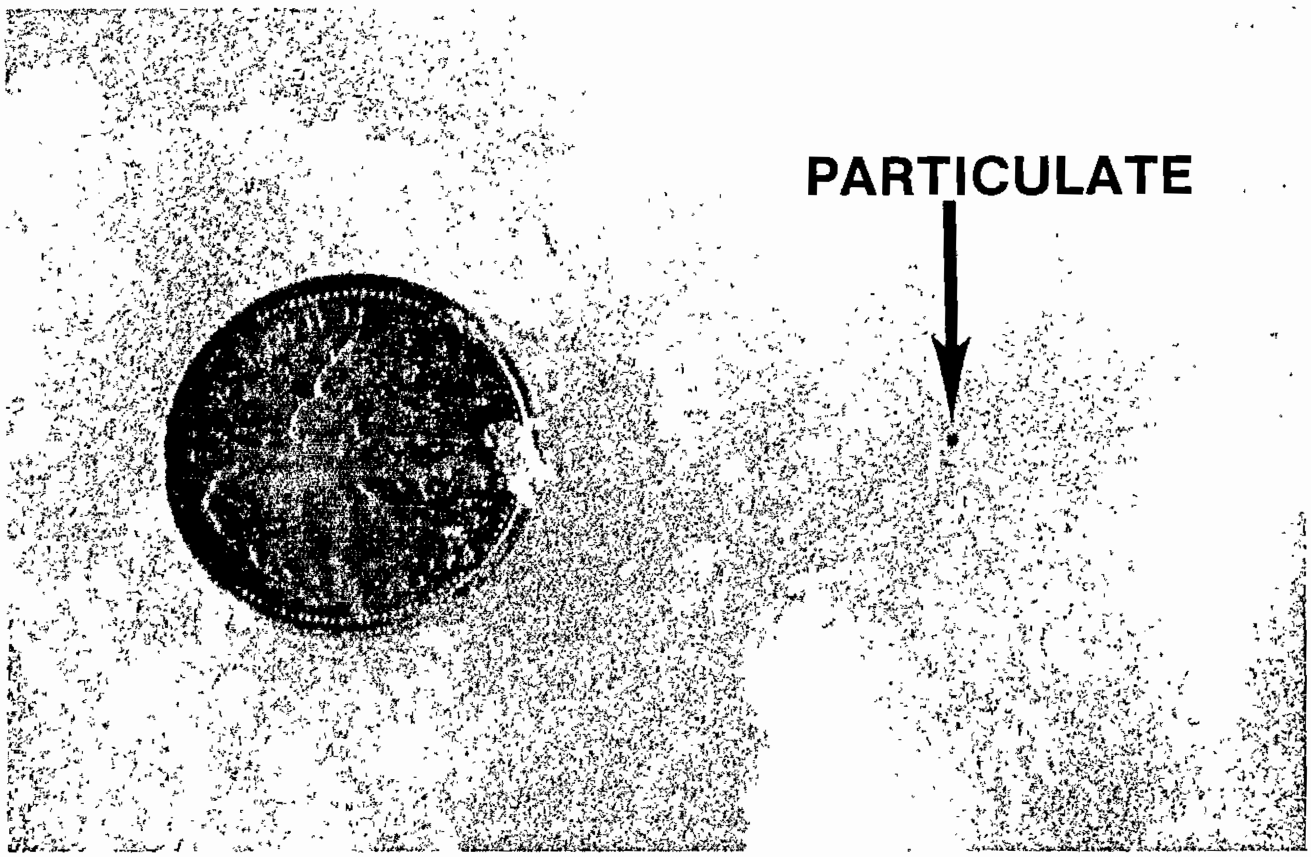
Finally a second helicopter flew to the banner location to discharge a 3-mar recovery team. The recovery team wa responsible for bringing back each piece o debris to the local field operations camp from there it was forwarded to Edmonton.





Above. *The containers when loaded with recovered debris were loaded aboard aircraft.*

Left. *The recovery team manipulated the radioactive object into suitable containers. In cases where the object was highly radioactive the containers were made of protective shielding materials to permit safe transport.*



One important category of debris consisted of fine particulate matter which probably originated from the reactor core. Some of these particles were highly radioactive and proved to contain both uranium 235 and fission products resulting from the operation of the nuclear reactor. Samples of this type of debris were collected by scraping or shoveling snow into garbage cans. The particle in the photograph (arrow) is shown next to a Canadian one cent coin for size comparison.

Reactor Core Disposition

By late February, it became clear that a widely dispersed shower of small radioactive particles had come down on and south of the Great Slave Lake. Initial field spectral analysis showed the predominant source of radiation was from fission products in these specks. Data from the Whiteshell Nuclear Research Establishment showed the presence of uranium. All built-up areas, camps and roads in the region were again surveyed for radiation on foot as well as from helicopters. All detected particulates were removed if they gave more than 100 μR/h* at 1 meter (this being the acceptable dose level established by the Atomic Energy Control Board). Within built-up communities and around camps all particles detected were removed, regardless of size.

The question remained - how much of the reactor core was on the ground? To estimate this, two plans were put into effect.

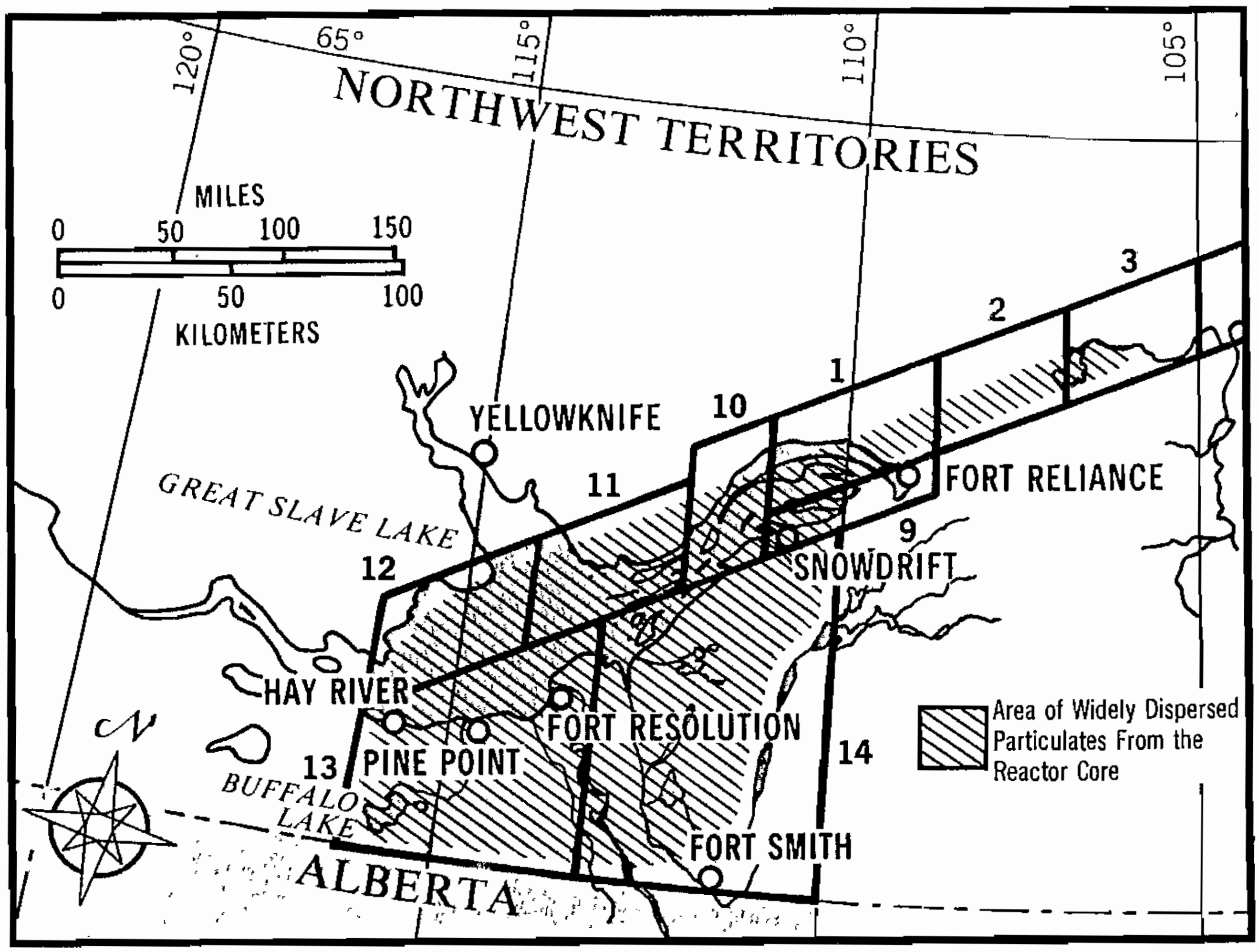
Particulate Measurement Plans

Two kinds of data were needed to provide bases for independent estimates of the total amount of particulate on the ground: The first plan involved having ground crews collect sufficient particles at more than a dozen sites on and south of the Great Slave Lake. Activity, size and density measurements of these, determined at the Whiteshell Nuclear Research Establishment, were combined with information on the particle distribution at each site.

*microroentgens per hour

Right. *After transportation to the Edmonton temporary storage site, samples of the snow were melted to allow collection of the particles. The procedure consisted of melting the snow and allowing the water to pass through a suitable filter to capture the radioactive particles for further study. Because of the possibility of ingestion of radioactive products, these operations were carried out under strict health physics operational procedures.*

Below. *Radioactive particles on the surface of a filter in the Edmonton temporary storage site. These types of particles were later subjected to more detailed radiological study at the Canadian Whiteshell Nuclear Research Establishment.*



The grid of parallel lines represents the 20,000 aquare mile area of the contamination caused by the small particle dispersion. (Subsequently particles have been found south and southeast of sectors 13 & 14.)

The second plan used an aerial survey with helicopter-transported gamma detectors to estimate the radioactive activity distribution in the region (curies per square kilometer). Flight paths were flown over the Great Slave Lake and Buffalo Lake.

Two Twin Huey helicopters were used to define the area of low level contamination caused by the small particle dispersion at the western end of the search area. Approximate boundaries were established on the north, east, and south sides. The northern boundary follows the track of the satellite trajectory; the eastern boundary runs from Snowdrift to a point approximately 30 miles north of Fort Smith; the southern boundary is an east-west line to a western boundary which helicopters were still attempting to establish as late as February 24. At that time a Radiation Monitoring Team was conducting a survey in the area of Fort Resolution and nearby hunting camps.

As of February 24, one month after satellite reentry, Canadian military flying time totalled approximately 1830 hours.(By April 17, about 5200 hours.)

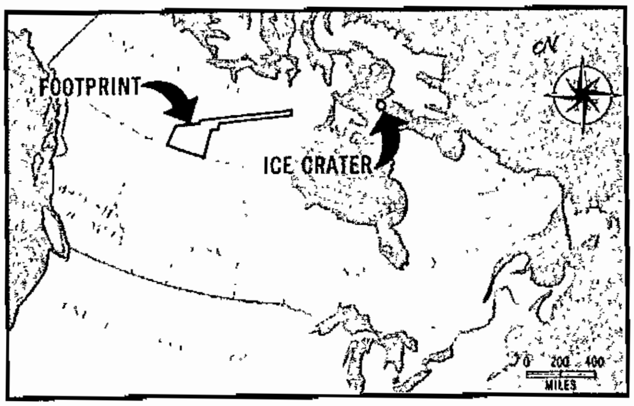
At the beginning of March the Atomic Energy Control Board, Health and Welfare Canada and Environment Canada authorities reported their opinion that people living in the area where the satellite debris fell should not be concerned about changing their lifestyle and recreation activities.

Canadian Forces and Atomic Energy Control Board personnel were actively involved in the recovery of small, detectable particles in the townsites of Snowdrift, Pine Point and Fort Resolution. Because of their small size, these particles lost momentum quickly and, under the influence of a northerly wind, drifted over a wide area in a random fashion. They have been found as far west as Hay River and south of Buffalo Lake. Measurements have shown the particles will not have added significantly to the natural background radiation. Nevertheless, to avoid possible health risks from contamination and ingestion of particles in water melted from snow, it was agreed that cleanup activities would be conducted in the townsites.

Uranium and thorium-bearing rocks are found in this part of Canada, and the natural background radiation may locally be much higher than the figures given. However, in general, the natural radiation background on land in the area may be 7 to 10 μR/h, and the search instruments are sensitive enough to detect an increase of about 2 μR/h at this level. The background over lakes is about half that on land.

Particles have not been distributed in a dense pattern but are scattered randomly and quite far apart. For example, in Fort Resolution six particles were found roughly 200 feet apart. Thus, cleanup in towns or wherever crowds of people were expected to congregate was feasible.

Fort Reliance, one of the first communities checked, was found to be outside the area of particle distribution.



Chunks of ice forced upward by natural processes involving groundwater seepage and subsequent freezing created an area of broken ice at Cape Dorset which was originally suspected to be caused by impacting debris from Cosmos 954.

Cape Dorset Ice Crater

On March 10, 1800 EST, the Royal Canadian Mounted Police at Cape Dorset notified Edmonton that a 30 year old Inuit had discovered a large hole in the ice of an unnamed lake 25 miles northwest of Cape Dorset. The police advised local residents to avoid the area.

On March 11, a combined team of Canadian Forces, Atomic Energy Control Board and U. S. personnel were flown by Hercules to Frobisher Bay. A Royal Canadian Mounted Police Twin Otter flew them to Cape Dorset and they then were taken out to the lake by skimobile. On arrival they discovered a large number of chunks of ice on the frozen lake surface, the largest being about 18 x 10 x 2 feet. The lake ice thickness was approximately 5 feet and the lake was estimated to be 15 feet deep. No radiation was detected.

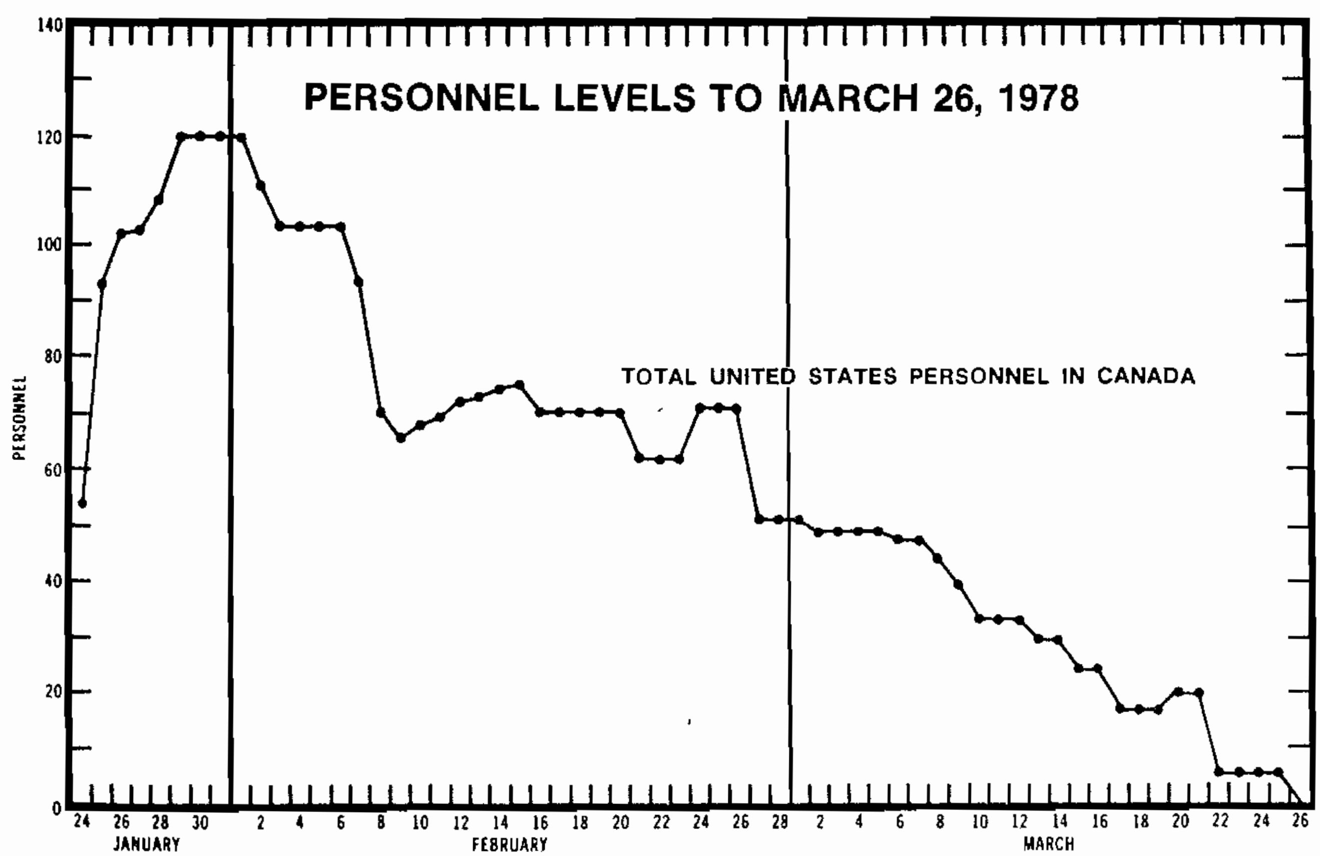
An explanation for the ice formation was required as the site was directly on an extended trajectory of Cosmos 954. (It was approximately 500 miles northeast of the most eastern extremity of the calculated footprint; about 1300 miles north of Montreal in the Quebec Province of eastern Canada.) The site was examined by an ice expert from the Canadian National Research Council and judged to be the result of a combination of natural phenomena, having no relation to the impact of any sort of an object with the ice cover.

A survey of the site revealed a convex ice feature running about 50 yards along the shore and 5 yards back from it. The top of this ice feature was approximately 6 feet above the level of the lake ice. The ice in the feature was about 4 feet thick and was underlain by about 18 inches of water.

Experienced ice observers gave the following explanation of the ice formation on the lake: The site is characterized by groundwater seepage at the surface near the shore. In early winter this area is covered with snow. The groundwater seeps up through the snow and eventually freezes. This results in the formation of a granular snow ice shell that effectively caps the area of groundwater seepage. Ice growth under the cap continues at a slow rate which would result in the formation of clear columnar-grained ice. Between the continuing flow of groundwater, and freezing, pressure could be built up under the ice. At some point this pressure, combined perhaps with a sharp drop in air temperature, would be sufficient to fracture the ice cap. The fracture of the cap would result in a sudden release of water which would wash the ice fragments out onto the surface of the lake. The coefficient of friction for ice on ice when lubricated with water is extremely low; so the ice fragments or blocks could be carried some distance.

U. S. Team Phase-Out

When the operations first began the manpower demands for experienced health physics personnel were extremely heavy. Members of the Canadian Nuclear Accident Support Team (NAST) were deployed at Edmonton and at all field locations. Their duties in the field were to monitor for radioactivity at debris pick up, assist with its handling and packaging, escort the material during transport, store it and perform decontamination checks and procedures on



personnel, aircraft and equipment. At Edmonton, NAST controlled field manning, performed radiation monitoring on all personnel departing and returning on flights and performed transport and storage bunker duties at Edmonton.

Personnel from the United States Department of Energy Nuclear Emergency Search Team assisted both by operating aerial measuring equipment and in the ground recovery operations. As the Canadians increased their resources by training in the field, the U. S. personnel were phased out.

Radiation detection resources designed for uranium prospecting were pressed into service. The U. S. team assisted in the conversion of specialized software designed for detection of fission and activation products so data could be run on Canadian computer equipment. Additional survey equipment was leased and installed in helicopters to replace U. S. equipment. This conversion was completed by March 20.

At the peak of operations during the first two weeks, 120 U. S. personnel were operating in Canada. In addition, a number of stateside personnel performed back-up roles. At the conclusion of the gross search operation, personnel not required for continuing operations were sent home. The U. S. staff was further reduced as Canadian personnel were identified to take over search planning, scientific photography, search operation, health physics, computer support, and other functions.

On March 8, a C141 aircraft returned search and computer equipment to Andrews AFB. On March 22, a C141 aircraft returned all remaining U. S. equipment to Las Vegas.

Post-Participation Analysis And Documentation

U. S. participants have agreed to publish reports and establish an archive of historical data concerning their participation in the Morning Light Operation.

Information which is still undergoing technical analysis will probably not be placed in the archives until final conclusions are reached and final reporting has been completed.

Many early planning and operations documents are already available. Certain photographic coverage is also presently available. Some of the archives may possibly involve classified information and the archives will then have a split repository, one unclassified, and a separate area for the classified portions.

The reports and records in the archives will contain a wide variety of data, some that is still undergoing analysis, and will at a minimum include:

- The Canadian Whiteshell Nuclear Research Establishment debris analysis data sheets:

  1. chemical analysis
  2. metallurgical analysis
  3. gamma-spectra analysis
  4. gamma and gamma plus beta count rate data
  5. photographs.

- Operation Morning Light field analysis data:

  1. hit locations, dates, and detection system
  2. portable gamma spectra analysis
  3. gamma and gamma plus beta count data
  4. impact site photographs
  5. daily situation reports.

- Aerospace Corporation's analysis results:

  1. tracking data analysis (Aerospace has been tasked as custodian for the raw data stored on magnetic tape)
  2. reentry trajectory analysis
  3. aerodynamic heating analysis.

An excellent example of international cooperation is demonstrated by this operations meeting of Canadian Forces On-Scene Commander Colonel David F. Garland (right), the Senior U. S. Government Representative, Mahlon E. Gates (center), and his Deputy, Troy E. Wade (left).

• Sandia Laboratories' analysis results:

1. reentry trajectory analysis
2. ballistic coefficients for satellite fragments
3. aerodynamic heating analysis.

• Lawrence Livermore Laboratory's analysis results:

1. reentry trajectory analysis
2. reentry trajectory display plots
3. computer generated movie of reentry sequence
4. visual sighting reports
5. metallurgical experiments to identify Cosmos 954 reactor fuel
6. literature survey of Soviet space reactor technology
7. reactor design systematics analysis for Cosmos 954 fuel
8. Atmospheric Release Advisory Capability predictions of fuel particulate distribution
9. preliminary reactor fission product - inventory estimates.

• Whiteshell Nuclear Research Establishment fuel particle analysis (approximately 370 particles):

1. size and weight
2. gamma spectra analysis
3. gamma and gamma plus beta count rate data.

• High altitude balloon sampling data:

1. gamma spectra analysis
2. gamma and gamma plus beta count rate.

• Background radiation survey results (for particulate estimates).

•Photographs of impact sites.

SEPTEMBER 18
Cosmos 954 launched by Soviet Union.
NORAD begins tracking Cosmos 954.

				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

MID-DECEMBER
Cosmos 954 out of control.
U. S. scientists speculate re-entry March or April.

				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

JANUARY 12-17
Dobrynin communicates with Brzezinski about Cosmos 954.
NORAD computes possible impact in North America.
National Security Council alerts other U. S. agencies, DOE responsibility assigned.
NEST teams alerted.

JANUARY 20
DOE requests C-141 transport.

JANUARY 22-23
C-141's and NEST team members on two-hour alert at Andrews, Travis AFB, and McCarran Airport.

1	2	3	4	5		7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

JANUARY 24
Tracking and visual observation show the **Cosmos 954 re-entered over Canada.**
President Carter calls Prime Minister Trudeau - Canada requests U. S. assistance.
Canadian 22 man Nuclear Accident Support Team deployed to Yellowknife.
CFB Edmonton activated to carry out Operation Morning Light with U. S. support.
U. S. "U-2" and KC-135 high altitude flights over Canada.
Two U. S. C-141's loaded with technical personnel and detection gear travel from Las Vegas and Andrews AFB to Edmonton, arriving approximately 1930 EST.
Reentry footprint calculations in progress.

JANUARY 25
First Canadian C130 launched on search mission at 0315 EST hours with U. S. detection equipment on board.
First Canadian detection system arrives CFB Edmonton.
NAST Radiation Monitoring Team goes to Fort Reliance.

JANUARY 26-27
NAST and U. S. personnel deployed to Baker Lake.
C-130 search mission continues - first hit reported; no confirmed satellite debris.

JANUARY 27
Canadian/U. S. search/recovery team deployed to Yellowknife.
AECB personnel arrive at Edmonton.

JANUARY 28
Satellite debris found i
Thelon River by members of NWT expedition wintering at Wardens Grove.
Three radiation hot spc detected from aircraft over McLeod Bay.

JANUARY 29
Baker Lake team deployed to Thelon Riv site and confirm presence of radioactiv satellite debris.

JANUARY 30
Snowdrift community surveyed by NAST.

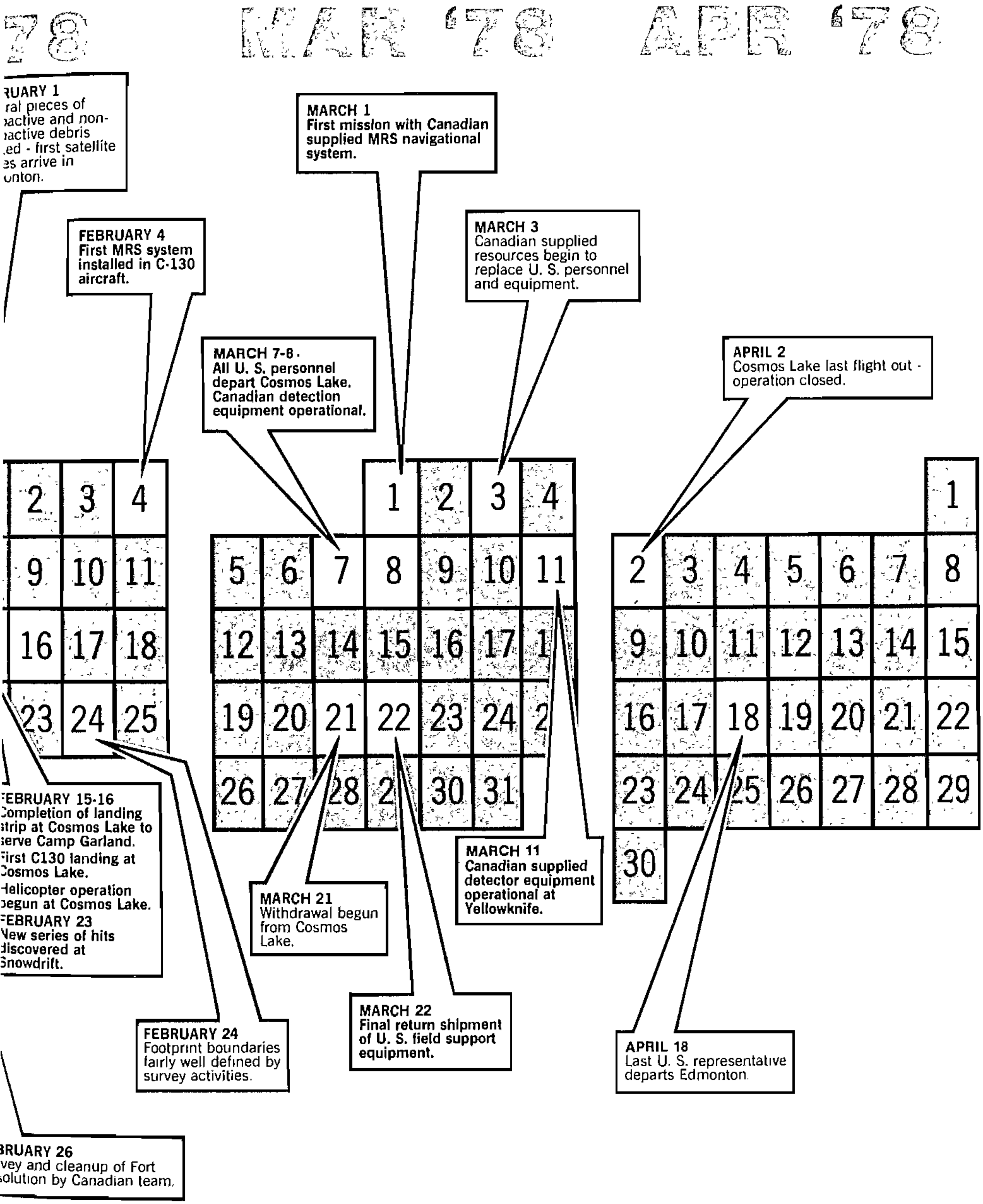
JANUARY 31
Sources of man-made radiation isolated at western end of footpri
Retrieval of debris beg by Yellowknife team.

FEBRUARY 6
Baker Lake operation closed.

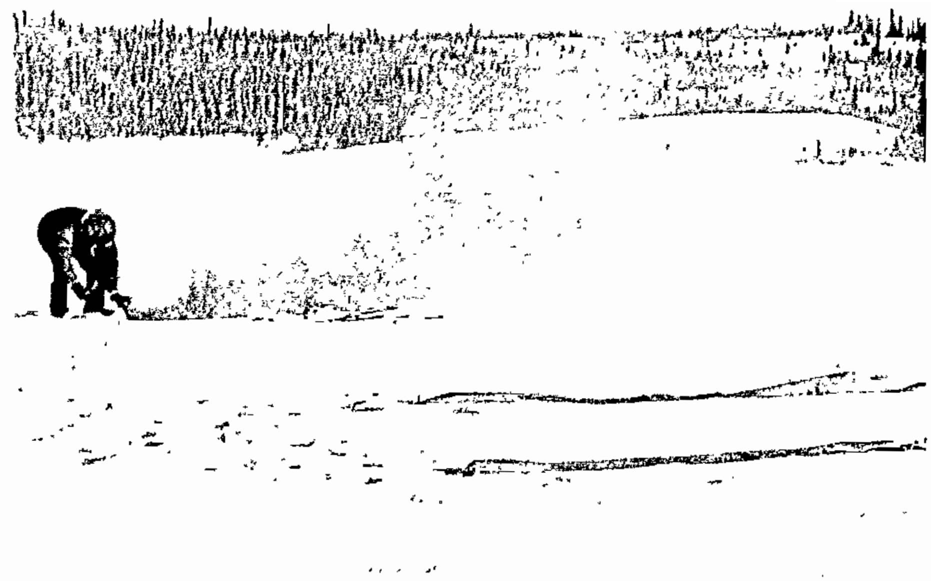
FEBRUARY 7
Debris located b means of helicop with U. S. detect equipment.

5	6
12	13
19	20
26	27

APPROXIMATI



SEQUENCE OF EVENTS



RESULTS

Operation Morning Light was conducted for the purpose of evaluating the hazard and recovering the debris resulting from the reentry, break-up, and impact of the Russian Cosmos 954 nuclear powered satellite. The operation was an international one involving the cooperation of Canadian and U. S. personnel at many levels. Airborne and ground field operations were conducted over a large area of the interior of Canada during the winter and early spring of 1978.

There is no practical way of discussing the results of the Morning Light Operation in terms of the contribution of the U. S. participants separate from that of the Canadian hosts. The extent of Canadian participation both in numbers of manpower and gross logistics far outweighed the U. S. involvement; the Canadian effort is thoroughly described in their interim report and will be the subject of other reporting. Not only was the U. S. effort of smaller numbers, it was also of shorter duration. The U. S. personnel began withdrawing from forward bases early in March and the U. S. contingency was essentially out of Operation Morning Light by mid-March.

However, the previous specialized experience of the U. S. team with nuclear radiation search and measurement over large areas was a key Morning Light resource; the operation could not have been completed as expeditiously without it. Personnel, techniques, and equipment which made up the U. S. contribution to Operation Morning Light were for the most part available as a result of programs carried out since 1954 by the U. S. Department of Energy for the purpose of providing a nuclear emergency response capability. Some of the elements which make up this capability are airborne radiometric search, ground borne search and recovery, and field and laboratory data processing.

Preparations for a speedy search and recovery operation had been initiated through various agencies of the U. S. Government early in December 1977 with the realization that Cosmos 954 contained radioactive materials and was going to reenter the earth's atmosphere with a possibility of endangering public health and safety. During this phase sophisticated computational efforts were employed to best predict the location and time of reentry and evaluations of potential hazards were made as a basis for plans for appropriate response.

Following the reentry, break-up, and impact of the Cosmos 954 satellite in Canada, a large team of American personnel were deployed by air to Edmonton, Canada to assist the Canadian Government in the evaluation of radiation hazard, location of debris, and recovery of debris.

Field operations in Canada consisted for the most part of large scale airborne radiation surveys; local area helicopter radiation surveys; ground borne search and recovery operations; data analysis and interpretation; and airborne logistical support involving both fixed-wing and helicopter aircraft.

Most of the activities outlined above were carried out with joint participation by U. S. and Canadian personnel. However, on-site airborne logistical support was exclusively a Canadian activity. This support involved the transport of all required personnel, equipment, fuel, and supplies used throughout the search region. Bases were established as needed at various remote locations to allow the on-site existence of all required personnel under arctic conditions. A system of fuel depots, landing strips, etc. was established as necessary to allow operation of all required personnel and equipment.

The large area airborne radiometric searches were used to determine the location of radioactive parts of the satellite within the 500 mile long "footprint" where parts of the satellite fell. These surveys were carried out using Canadian Forces type C130 aircraft and Canadian flight crews. The U. S. team supplied the majority of the on-board scientific personnel and equipment in the early phases of these surveys. Helicopter borne radiation searches of a more local nature employed Canadian helicopters equipped with U. S. radiation measuring equipment operated by U. S. team members. U. S. personnel also carried out extensive computer processing of the data produced by the airborne search operation during that period.

The findings and results produced by conducting Operation Morning Light can be summarized in four categories:

1. Reentry and break-up
2. Recovery of debris
3. Radiation remaining in the environment
4. Preliminary conclusions

Reentry and Break-up

Based on beta estimates of each piece of debris and their individual impact locations, computer calculations of fragment trajectories indicated two characteristics of the separation:

- A number of "beryllium cylinders" evidently separated from the reactor at an altitude of 37 to 34 nautical miles; a larger group of smaller "beryllium rods" separated from the reactor next over an altitude span from 34 to 30 nautical miles altitude.

- The actual reactor core probably began to disintegrate at about 37 nautical miles altitude (approximately 100 nautical miles west of the Great Slave Lake, Northwest Territories) and continued disintegration - piece by piece - down to an altitude of about 30 nautical miles (over the west end of the Great Slave Lake). Reactor disintegration occurred over a range of approximately 270 nautical miles or about 70 seconds.

The recovered debris does not allow either the core mass or dimensions to be established with any degree of certainty. To date, there has been no evidence that large pieces of the reactor core survived reentry.

Recovery of Debris

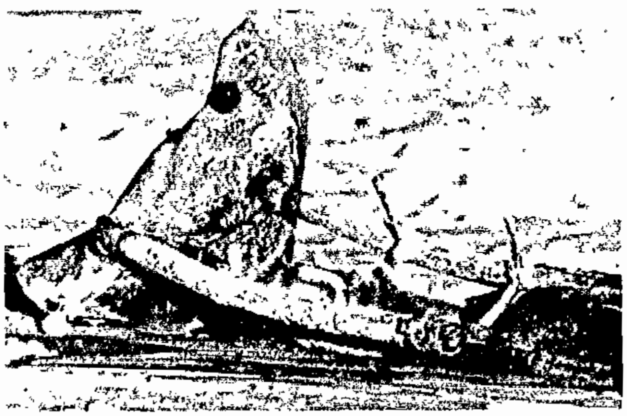
There are four general areas where debris has been located: Two areas about 20 miles northwest and northeast of Fort Reliance, one in the Thelon River area, and one near Snowdrift, a small Inuit community 55 miles southwest of Fort Reliance.

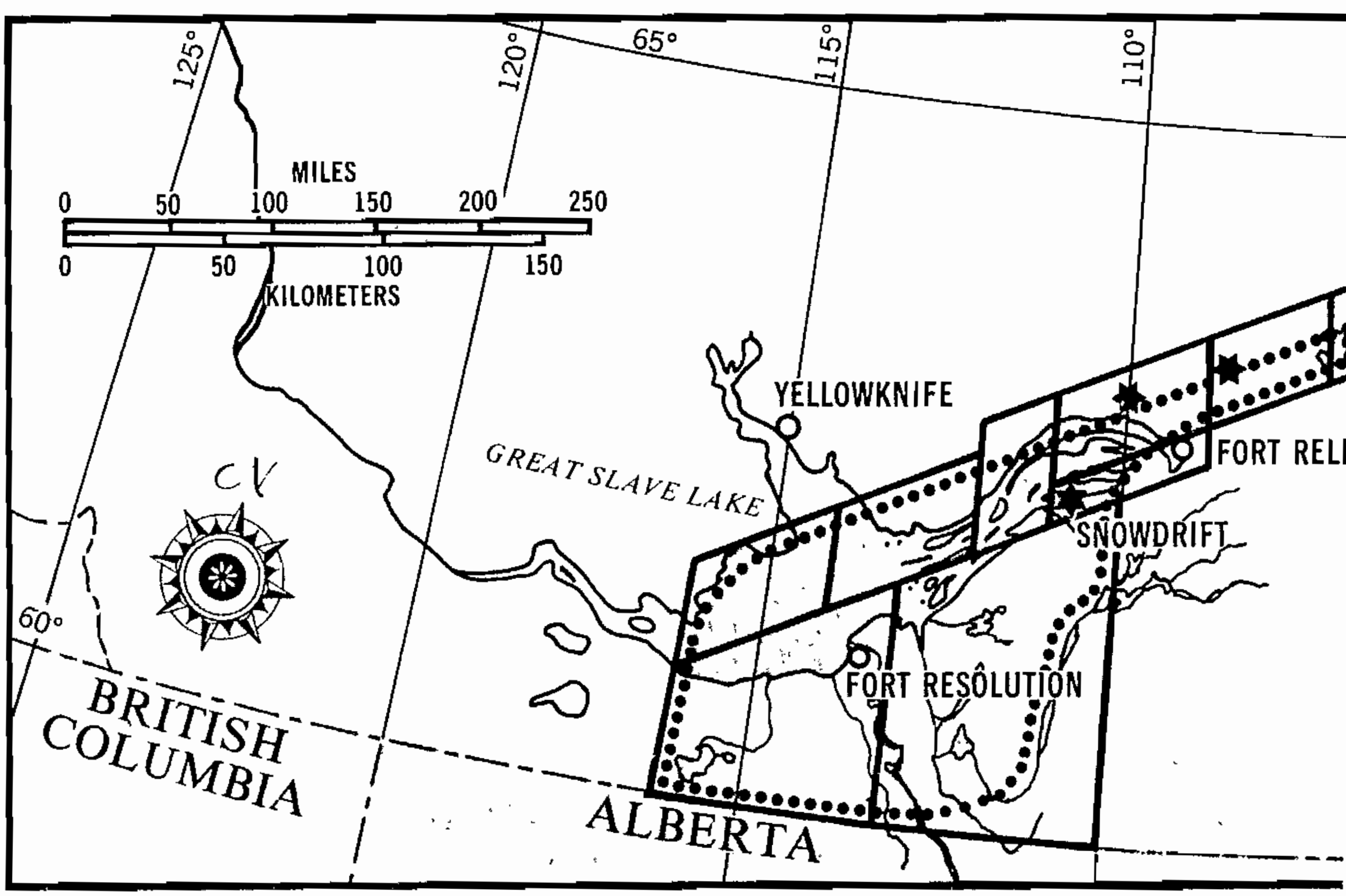
Northwest of Fort Reliance, pieces of metal (plates, disks, and rods) have been verified and recovered. Radiation levels of these parts ranged from 25 to 200 R/h near contact. Thirteen other radiation sources have been identified. One additional piece of nonradioactive debris, a large, burnt piece of pipe has also been recovered.

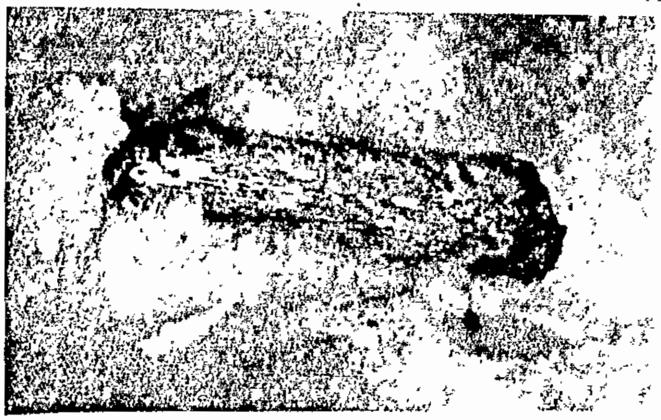
TYPICAL DEBRIS

Right. *Large burnt piece of nonradioactive pipe recovered near Great Slave Lake.*

Below. *First piece of debris located and verified on the ground. The radioactive piece was discovered by Mobley and Mordhorst.*

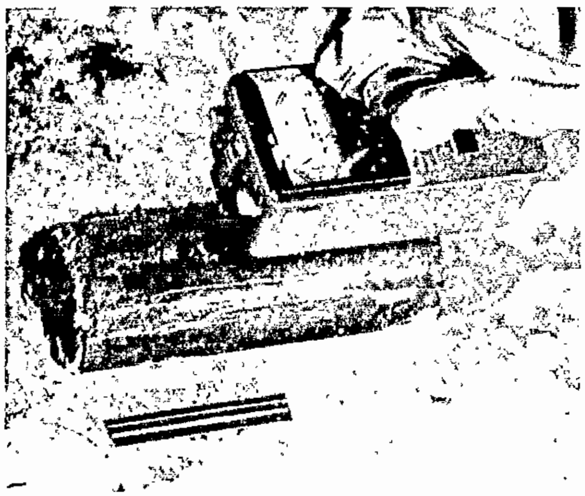




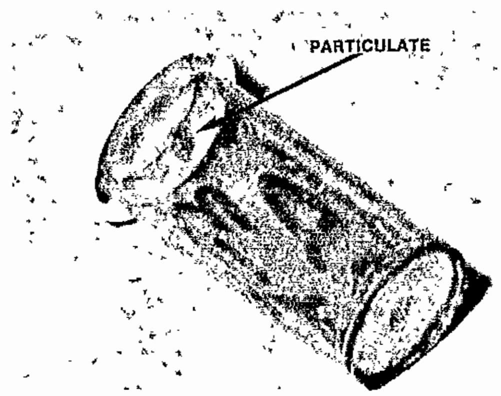


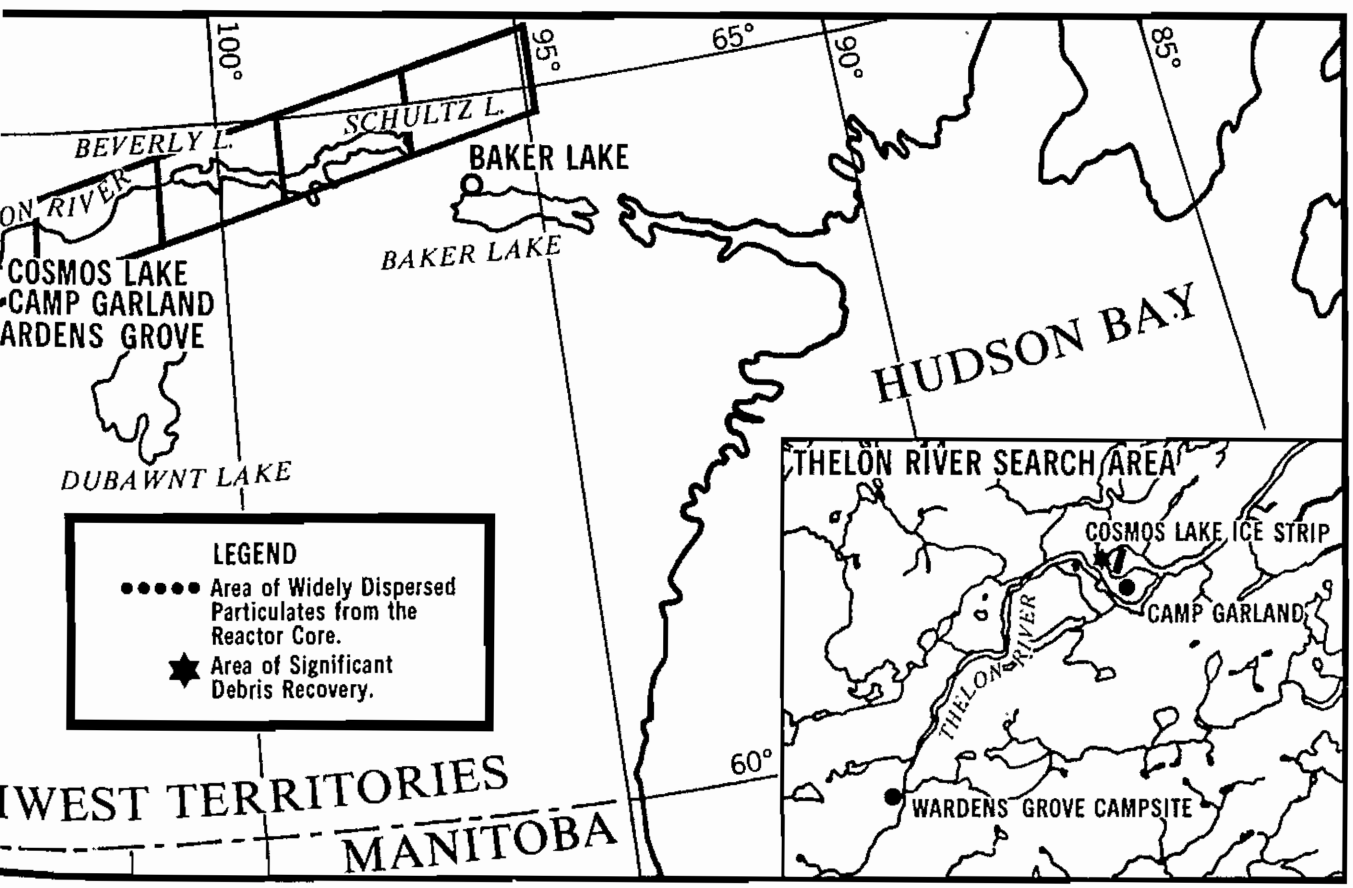
Left. *Small piece of debris, typical of many recovered.*

Below. *One of a series of metallic cylinders found between Fort Reliance and the Thelon River.*



Below. *Vial containing a small piece of radioactive debris. The vast majority of the objects which made up the debris of Cosmos 954 ranged in size from fingernail down to microscopic.*





To the northeast of Fort Reliance, several shiny metal cylinders have been recovered. The radiation levels were from 25 to 100 R/h near contact. Twenty-two other radiation sources in this area have also been identified, many as being natural uranium occurrences.

One metal object and its support rods have been recovered in the Thelon River area. It had a radiation level of 15 R/h near contact. An additional 16 radiation sources were also located in this general area, but all were found to be natural occurrences.

The material in the vicinity of Snowdrift appears to be small bits and pieces of debris, the size of a fingernail or smaller. The radiation levels appear to be low, 1 R/h or less near contact. The community of Snowdrift was surveyed by a Canadian Nuclear Accident Search Team, which found small radioactive particles, but no evidence of contaminated persons.

About 100 radiological objects have been picked up. Based on reasonable assumptions about the original total radioactivity inventory these objects represent only on the order of one percent of the original inventory.

Radioactivity Remaining In The Environment

In addition to the radioactivity contained in the larger pieces of debris described above, a considerable inventory of radioactive fission products is contained in finely dispersed microscopic particulate material originating from the material contained in the reactor core. This inventory is centered at 113 degrees 15 minutes west and 61 degrees north, an area of elevated radioactivity of more than 20,000 square miles.

As predicted, larger pieces of the reactor core particulate were found in the center of the search area centered on the Great Slave Lake. A survey of Great Slave Lake indicated an elevated radiation background. If this elevated radiation background is caused from widely dispersed particulate matter from the reactor core, then the phenomena is consistent with the theory that the reactor core disintegrated into small particles in the atmosphere during reentry. The reactor core particulate discovered on Great Slave Lake and the recovery of particles at selected areas to determine density and distribution patterns appears to indicate that on the order of 75 percent of the estimated core materials are within this area.

Preliminary Conclusions

The following preliminary conclusions, based on all available data, were reached early in April:

- The reactor core has disintegrated and shed radioactive particulate matter over a wide area.
- Calculations based on reasonable assumptions relative to the total original radiation inventory indicate that the majority of predicted radioactive material can be accounted for within the search area.
- It is highly probable that all detectable large radioactive pieces have been located and recovered.
- With the best technology presently available, it will be impossible to locate and recover any more than a small percentage of the remaining debris which consists for the most part of small particles.
- Further recovery of any remaining pieces is not practical on the land mass and not possible on Great Slave Lake due to its widespread dispersion, the nature of the terrain, and the lake thaw. In the judgment of senior operational staff (Department of National Defense, Atomic Energy Control Board, Department of Energy Mines and Resources, and the U. S. Department of Energy) in Edmonton, in consultation with Canadian experts from Department of National Health and Welfare and DFE in Ottawa, health hazards created by the remaining particulate matter is minimal and will continue to decrease in the future.

Final evaluation will be made when more conclusive information is available and final analysis and tests are complete. Ongoing surveys of inhabited areas, including temporary and seasonal habitat are to be continued under the supervision of the Atomic Energy Control Board. This decision was made in Ottawa at cabinet level.

Estimates of the inventories of the long-lived isotopes strontium 90 and cesium 137 from the satellite reactor, which are of particular concern, indicate that they are only about one hundredth of the amounts of those isotopes currently residual in Canada from world-wide fallout from atmospheric nuclear weapons testing.

The possible remaining radiation hazards to man and the environment as deduced from the above analysis are well understood and defined.

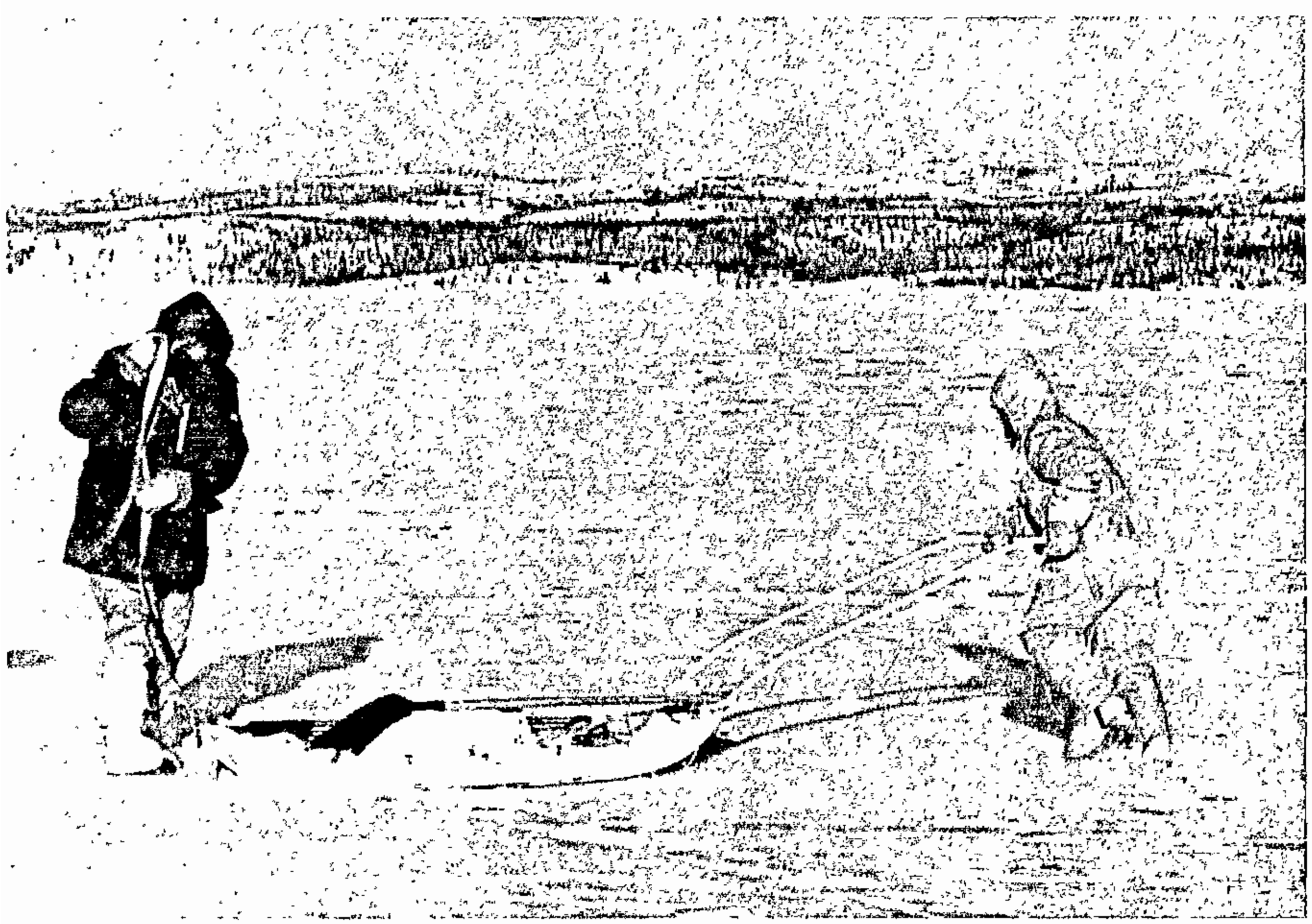
Radioactive debris being prepared for removal. In general, the materials were wrapped in plastic film to prevent dispersal of any dust or fine particles. The more radioactive objects were then manipulated into special shielded containers for safe transport.

LESSONS LEARNED

Introduction

Cosmos 954 is the seventh nuclear spacecraft to return to the earth within the last 10 years. Two Russian moon-bound craft loaded with radioactive fuels to heat their capsules burned out in the atmosphere with the detected release of some high-altitude radiation, and one predecessor of 954 broke up reentering the atmosphere and fell into the Pacific Ocean north of Japan. A U. S. Navy navigation satellite with a nuclear isotope power pack disintegrated in the atmosphere over Madagascar; a meteorological satellite was aborted on launch from Vandenburg AFB and the nuclear isotope package was recovered intact; as Apollo 13 returned from an unsuccessful moon flight the astronauts had to jettison their moon lander, and its nuclear isotope power pack plunged into the Pacific near Australia. (U. S. nuclear isotope power sources provide power directly without the nuclear chain reaction involved in operating a power reactor with its generation of associated fission products.)

One of the fail-safe procedures used by designers in handling the hazard of a nuclear power pack bearing spacecraft is to shoot the reactor into high orbit after its use is ended. Unfortunately, as in the case of Cosmos 954, the procedure may fail. Thus we may for years face the possibility of other reentries and the need for emergency nuclear search, measurement, and cleanup readiness. Such a readiness for emergency search and clean up would also be available



Recovery operations were hard work. The low temperatures, weather conditions, and the problems of working on snow and ice surfaces, coupled with the remote locations and difficulties of access made relatively simple tasks exhausting and time consuming.

Snowshoes and specially designed arctic clothing were furnished to all field personnel; proper dress for control of moisture and exposure to arctic air and winds was a basic part of the survival preparation.

for other types of nuclear accidents or health threats involving nuclear materials.

Although the Nuclear Emergency Search Team (NEST) was organized and equipped for a broad charter of potential nuclear emergencies long before Cosmos 954 was launched, it was available to speedily apply to a specific problem because of concerned pre-planning.

In the interim between the conclusion of the Morning Light Operation and the request for another similar emergency response request, planners may want to consider the following:

Specific Observations

U. S. emergency response people have proved they can work effectively in a difficult environment. Morning Light represented a genuine emergency response, much larger than any simulation that would have been reasonable to fund. To some degree the costs of participation in Morning Light represent an investment for invaluable experience.

First international foray of U. S. emergency capability worked well in a similar cultural, and language environment. The Canadians were outstanding hosts, both in technical support and personal consideration. This likely represents the best of international assistance conditions that we could ever expect to encounter; many other situations could be far from ideal.

Severe environmental conditions greatly reduce the net effectiveness of individual specialists involved in a search and cleanup. Morning Light severe cold meant workers could only operate for short periods --- sometimes only a few minutes at a time. The same reduced effectiveness could apply to other environmental constraints in other settings. This would not only include environmental extremes but also include factors like panic and traffic which arise in a dense urban disaster area. Hostile environments require more people, more reserves, to withstand the additional environmental fatigue and to carry out tasks which take longer to accomplish in extreme physical stress.

Whenever a fixed time deadline threat is involved in an operation under severe environmental conditions, two to three times as many people will be required to do the same task as fair weather planning would anticipate. If the time available to complete the task is limited and the environment is severe, it is imperative to staff to withstand the energy lost to environmental stresses --- or it may be too late to complete a vital mission.

Equipment can survive extreme low temperatures if the rate of change of temperature is controlled. Sudden temperature change can shatter sensitive instrumentation; protective procedures to assume gradual temperature change can keep the equipment useful. (Procedures and equipment accommodations should be developed to counteract any foreseeable environmental difficulties for all anticipated settings.)

Data from early results of a search and cleanup operation are often critical for setting the direction of the completion of the overall task. Every effort should be made to assure prompt and free flow of analysis data generated from previously recovered materials. It is important not to allow any delay or impediment to the free flow of necessary information among participants.

The U. S. emergency response capability should be equipped to be as self sufficient as possible when operating in other countries. It is obvious that transportation, communications, equipment and command authority are all potential Achilles' heels when control rests in unknown hands of unknown quality. Fortunately, this was not a problem with the Canadians, but might be serious in other circumstances.

The U. S. Air Force might be called upon to furnish airborne platforms for emergency response searches in areas of the world where local governments could not do so. Most commercial aircraft are neither equipped or insured to do very low altitude survey work. Consequently, aircraft with the right flying characteristics must be made available through government channels; we could therefore expect governments with limited aircraft resources might also request that U. S. emergency response assistance include aircraft support.

The long Morning Light C130 flights overloaded the data processing capability of our van transported computers. Because of the large area surveyed on each flight, one hour of flight time required 4 hours of computer time and this created a serious backlog problem. Considerable analysis of the airborne radiation data is necessary to associate navigational data with the count rate and spectral data to identify low-level sources in the presence of natural and other man-made radiation background. Consequently, to recognize and locate low level sources from the air over large areas required computer processing of the full record which was an extensive task.

The ability to simultaneously respond to more than one emergency needs to be provided. The limits of duplicate equipment and personnel available when a major callout is already underway should be continuously reviewed in relation to minimum home front protection. Sufficient capability should be developed and maintained so that the minimum protection of U. S. citizens is never depleted.

U. S. SEARCH AND RECOVERY READINESS

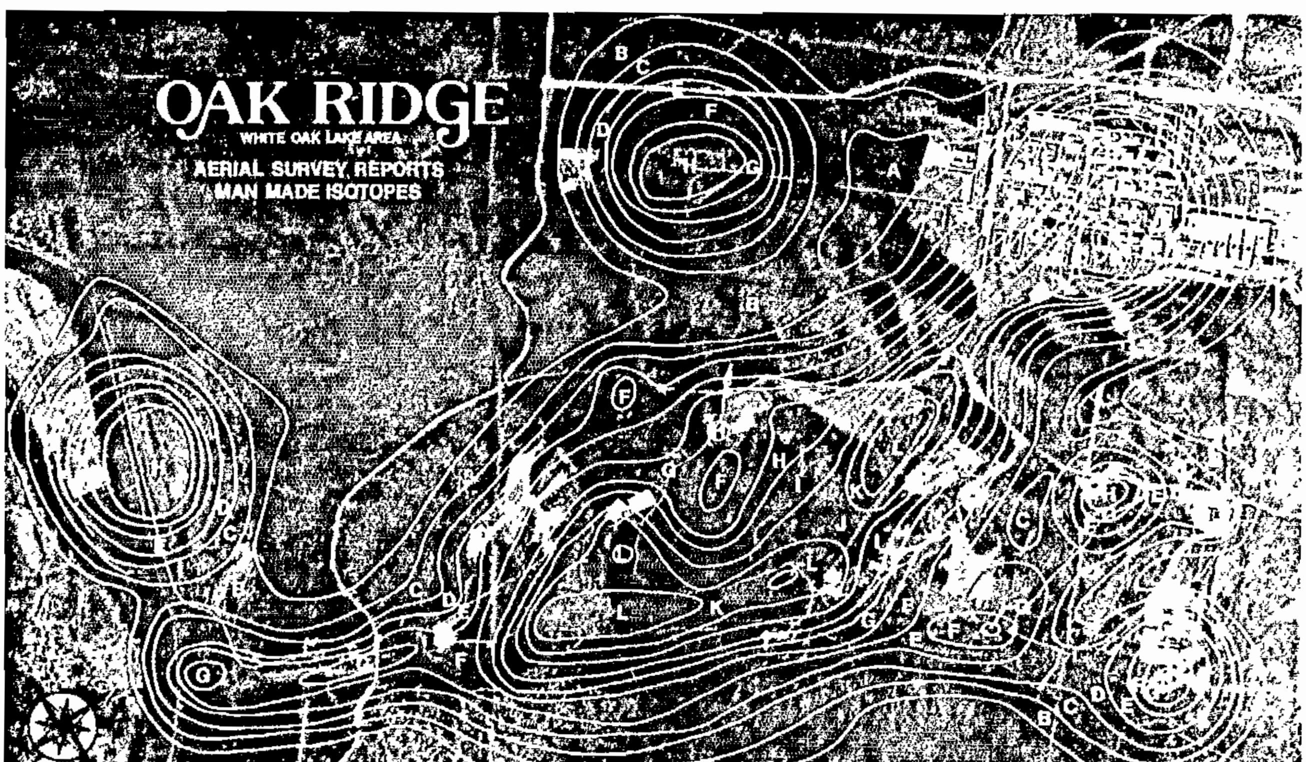
The U. S. ability to support Operation Morning Light is a result of a long term effort to develop and maintain an integrated capability to locate, identify, and recover man-made radioactivity in the environment by means of both airborne and ground level search and recovery techniques. It has taken many years for the U. S. Government to build up the broad technical assets of the Nuclear Emergency Search Team (NEST).

The development of these resources began more than twenty years ago with the first air transported nuclear measuring systems, and culminated with the full nuclear emergency search team being formally organized among the national laboratories and DOE contractors in 1974. The sequence of development is summarized here:

Development of Aerial Nuclear Measuring Systems

In the mid 1950's, a series of events occurred which led to the development of an aerial radiological measuring system by the United States Coast and Geodetic Survey and the Oak Ridge National Laboratory. These events included the United Kingdom Windscale reactor accident, radioactive cloud releases from nuclear weapons test in Nevada, and urgent requirements to locate uranium ore deposits throughout the Western United States.

The Windscale reactor accident in England involved a partial core destruction and subsequent release of radioactive gases for a period of several days. These gases and particulates blanketed a large area surrounding the Windscale facility and severely taxed the health physics capability to continually monitor the affected areas. No airborne capability existed at the time to provide a rapid large area assessment of the problem.

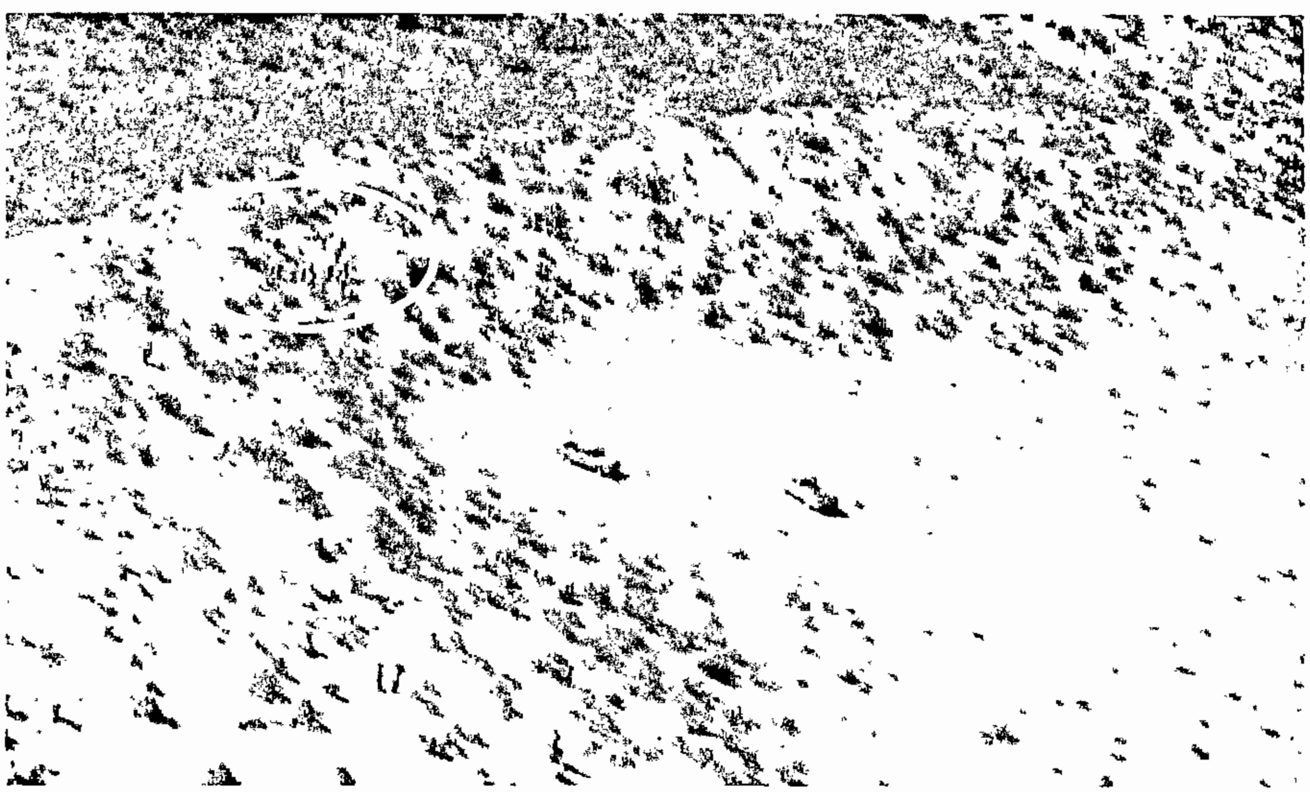


Typical radiation survey map showing data produced by airborne nuclear radiation detection equipment.

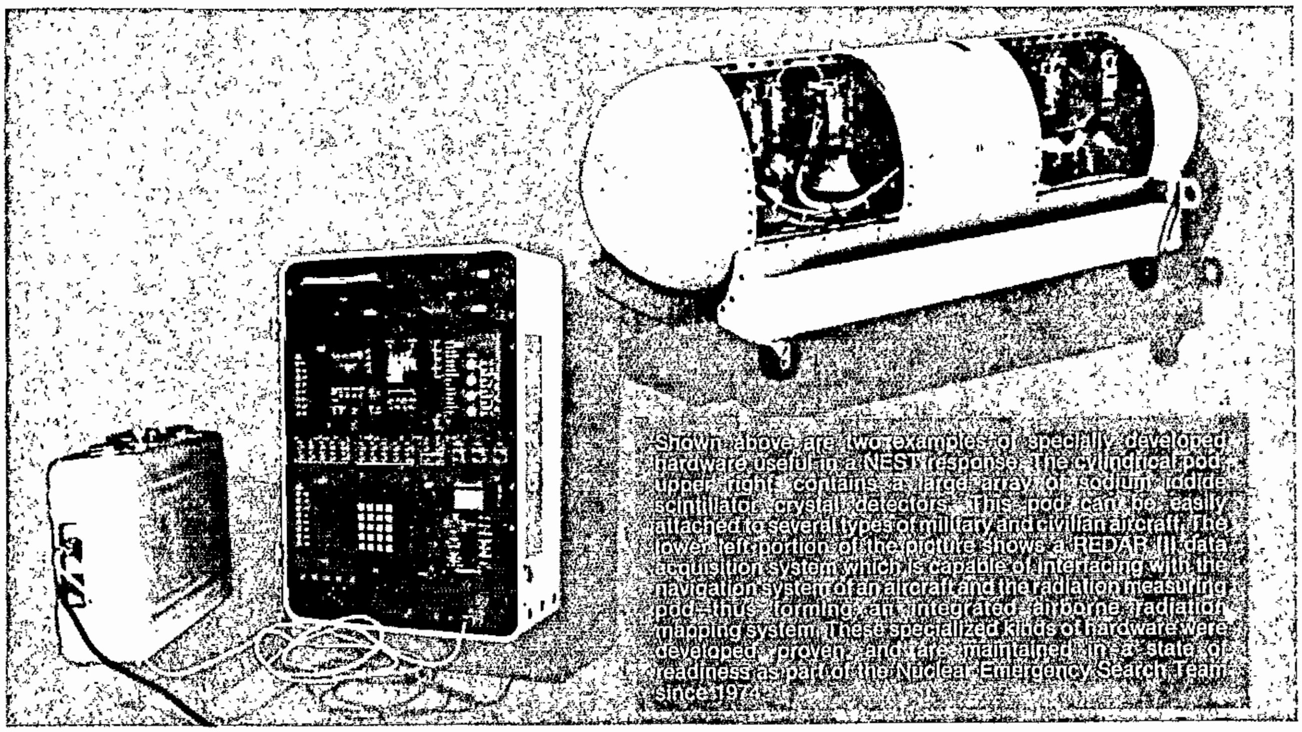
A radiological measuring system had been developed to aid in locating uranium deposits in the Western United States; the same technology had been temporarily called upon to track several radioactive clouds released by the Weapons Test Program at the Nevada Test Site. The system proved very useful in the cloud tracking operation but the Coast and Geodetic Survey asked the Atomic Energy Commission to relieve them of the cloud tracking activity. In 1969, the Atomic Energy Commission asked one of its prime contractors, EG&G, Inc., to begin developing a second generation system.

Since that time an improved and expanded remote sensing capability has been developed and operated for the U. S. Government by EG&G; it now incorporates both nuclear and photo optical instrumentation with a variety of aerial platforms, performing both routine and accident response functions. For example, a 330 millicurie cobalt 60 source lost in interstate shipment between Salt Lake City and Kansas City was located in two days following a search along 1200 miles of highway. A more difficult search occurred in 1969 when a U. S. Air Force Athena missile, with a low energy cobalt 57 source, accidently strayed 400 miles into Mexico. Radar tracking provided a three by ten mile footprint for the target area that more than 50 military personnel had combed for three weeks; the aerial system located the source in a 2-1/2 hour search.

Routine aerial surveys to determine normal background radiation patterns have also turned up significant findings. A survey of the Humbolt Bay Nuclear Power Plant revealed very-short-lived isotopes in the reactor plume. Upon investigation by plant authorities it was discovered that a coincident failure of a fuel element cladding, an air filter, and a stack monitor had resulted in release to the atmosphere of the isotopes recorded by the aerial survey. Also, routine surveys and analysis of three consecutive years' data over a New York reprocessing facility, revealed increasing levels of off-site



Impact area of the Athena missile located by an airborne nuclear radiation detection survey.



Shown above are two examples of specially developed hardware useful in a NEST response. The cylindrical pod, upper right, contains a large array of sodium iodide scintillator crystal detectors. This pod can be easily attached to several types of military and civilian aircraft. The lower left portion of the picture shows a REDAR III data acquisition system which is capable of interfacing with the navigation system of an aircraft and the radiation measuring pod—thus forming an integrated airborne radiation mapping system. These specialized kinds of hardware were developed, proven, and are maintained in a state of readiness as part of the Nuclear Emergency Search Team since 1974.

radionuclides including a steady buildup of cesium 137 of as much as 30 percent per year some one to five miles offsite in the plant watershed.

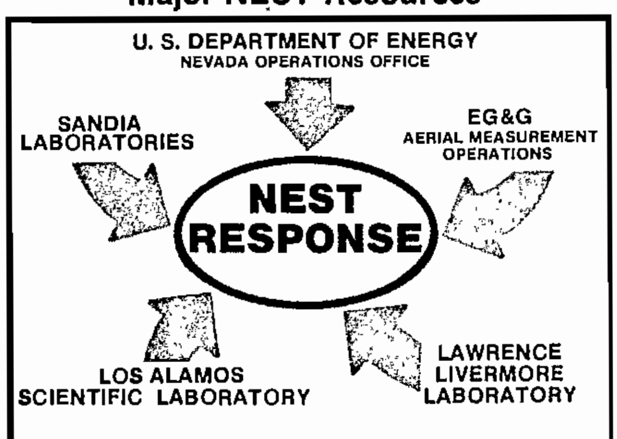
Over the years, the aerial measurements surveys have repeatedly identified potential problems at Department of Energy nuclear facilities and operating nuclear power plants that site personnel had not picked up from ground-level monitoring programs. This has included such highly controlled areas as the Savannah River Plant, Hanford, Oak Ridge National Laboratory, the Nevada Test Site and the Rocky Flats Plant.

Creation of the NEST Emergency Response

The Nuclear Emergency Search Team (NEST) was organized in 1974 among U. S. weapons laboratories and their associated contractors to assure public safety as it might be affected by an emergency involving nuclear materials. NEST provides scientific advice and technical assistance to local government authorities who are responsible for coping with the emergency.

The NEST organization is essentially an on-call organization comprised of the best scientific and technical talents of the United States which respond to NEST as needed. Thus, the makeup of NEST reflects the nature of each particular emergency situation as it arises.

Major NEST Resources



Lawrence Livermore Laboratory, the Los Alamos Scientific Laboratory, the Sandia Laboratories, the EG&G Aerial Measurement Operations, and the Department of Energy Nevada Operations Office are the core of the NEST response.

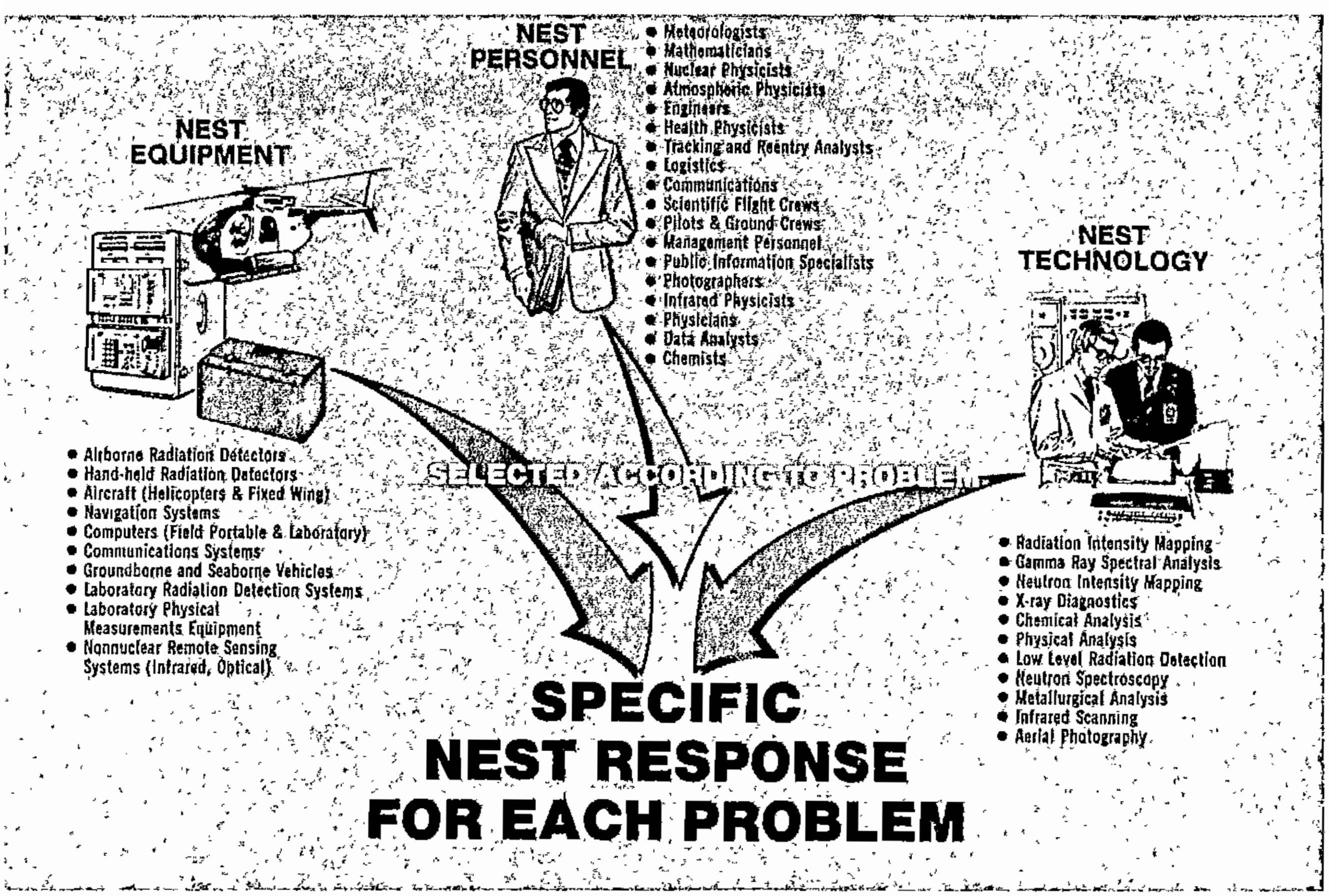
When a NEST alert is sounded the participants stop routine activities and devote their effort to the NEST problem at hand. When the NEST problem is resolved the participants return to their usual occupations.

A NEST response begins with the earliest communication of threat information to the Department of Energy Emergency Action Coordinating Center in Washington, D. C. Reserve personnel and equipment are prepared to:

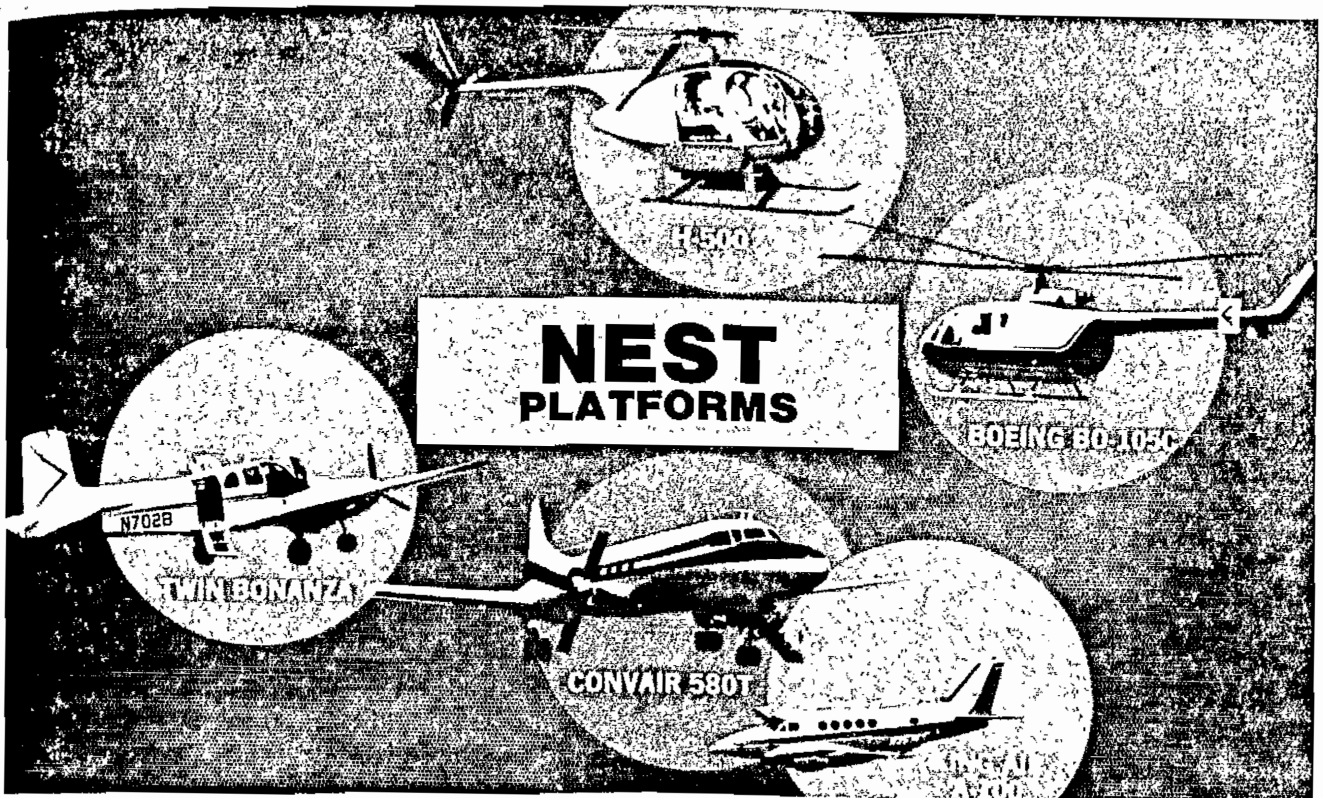
- Evaluate the technical credibility of the suspected emergency;
- Search for the radioactive material;
- Identify the nature and quantity of radioactive material;
- Assess the probability of nuclear yield or spread of radioactive material;
- Assess the potential for personnel injury and property damage in the event of activation or release; and to
- Assist in the render safe and disposal operations.

If the nuclear radiation aspect of an emergency is not well defined, an advance NEST party of two to six people can be immediately deployed to the scene to provide direct technical assistance in evaluating the emergency and recommending additional disciplines or technologies. NEST response for on-site support has been planned to allow maximum flexibility in selection of appropriate resources.

In the case of Morning Light, the Team's mix of skills were specifically fitted to the problem. To support the mission of aiding the Canadian government in locating the radioactive debris, the Team enlisted scientific help including radiochemists,



The NEST capability draws from a unique array of personnel, equipment and techniques.



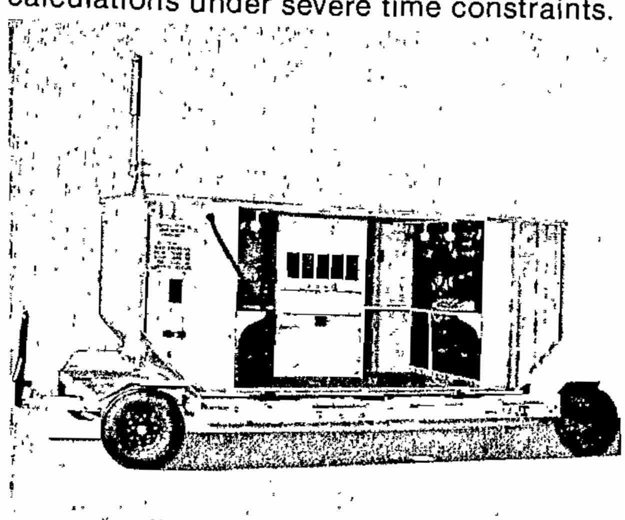
A fleet of three fixed wing aircraft and four helicopters fitted out with specialized remote sensing and navigation equipment are part of the NEST resources. The capability includes aircraft, air crews, scientific flight personnel, ground support, and data reduction and analysis staff. These aircraft are regularly deployed throughout the United States conducting remote sensing operations for U. S. Department of Energy related programs.

health physicists, metallurgists, reactor physicists, reentry scientists, and meteorologists.

Seven aircraft are dedicated to support NEST, including both fixed-wing and helicopter. (In addition, the radiation survey equipment can be flown on a variety of military aircraft.) At any given time these aircraft are deployed throughout the United States conducting remote sensing operations for energy development programs.

The NEST logistics support equipment is continuously being improved. An air transportable communication center was recently added. A microwave repeater will be added in the near future to permit the NEST command and control staff to monitor working point activities from a distance.

There are now nearly 200 technical personnel who have been directly involved in NEST activities including the support of Operation Morning Light. Senior laboratory personnel have participated in NEST exercises in depth and have had the opportunity to perform advanced calculations under severe time constraints.



Various categories of NEST equipment have been integrated into "pods" air transportable on wide bodied commercial aircraft. The "pod" shown here is capable of providing telephone, radio, and regular and slow scan television communications.

SCHEDULED FINAL REPORT

A final technical report will be published for distribution early in 1979. It will consist of a summary overview of the operation and the following specialized sections:

Two on management; one on the Federal government's evaluation and preparation for an impending nuclear emergency. How did Washington react? Another describing the actions of the Nevada Operations Office of the Department of Energy which was charged with coordinating and directing U.S. technical support to the Canadian search operation.

Five scientific-technical sections are planned: the pre- and post-impact reentry calculations, the ground-based recovery operations, health physics practices, the recovery analysis and evaluation techniques and their use in further refinement of the search pattern, and the airborne data acquisition including both instrumentation and data reduction.