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UNATTENDED RADAR STATION DESIGN FOR DEWLINE APPLICATION

GENERAL ELECTRIC COMPANY

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This report examines the feasibility of implementing and maintaining a string of Unattended Radar Stations in the Arctic. The study is conceptual relative to design, installation, operation, maintenance, and support of Unattended Stations and attendant problems such as security, reliability, maintainability, availability, and life cycle cost. Cost Drivers are identified and potential solution alternatives with recommendations presented. The conclusion is that, with reasonable development, economical Unattended Arctic Radar Stations are possible.

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PREFACE

This report, prepared by the General Electric Company for Electronic Systems Division under Contract No. F19628-77-C-0212 was compiled by E. J. Gersten, Engineering Project Manager. Major contributors were W. E. Abriel, S. E. Bell, J. R. Golden, J. T. Gorham, R. M. Johnson and D. J. Murrow.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

78 10 17 018

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

FIGURES

FIGURES

FIGURES

TABLES

TABLES

TABLES

3.4 CIVIL/MECHANICAL ALTERNATIVES

3.4.1 DEWLine Survey

General Electric Company participated in an Air Force sponsored site survey of the DEWLine in August of 1977. The purpose of the trip was to acquaint prospective contractors with, the DEWLine as it now exists, some of the problems operational personnel encounter, and assess the role of the DEWLine in the social order of the Arctic community. The trip was most helpful to the General Electric Company in the development of this study. Highlights of the trip are discussed below.

3.4.1.1 Condition of DEWLine Facilities

A detailed description of each main and auxiliary site is presented in the Base Civil Engineering, BCE Documents. Typically, however, the main and auxiliary sites consists of the following major facility elements.

- o Roads/walkways/taxiways and runways
- o POL Storage and Distribution
- o Power House
- o Radar Platform and Antennas
- o Building Trains
- o Garages
- o Hangars
- o Warehouses
- o Refrigeration Systems for Food Storage
- o Building Heating and Ventilating Systems
- o Power Generation and Distribution Systems
- o Sanitary Waste Disposal System
- o Water Supply and Treatment
- o Solid Waste Disposal

This visit to the DEWLine produced the following observations relative to the condition and care of these facilities.

First, all DEWLine Facilities are maintained in a good state of repair. Furthermore, the structural and electrical distribution elements of these facilities have not aged appreciably and remain in good to excellent condition. Mechanical systems, such as the heat exchangers and auxiliary oil fired furnaces however do show signs of aging and in certain cases have probably reached their economical life span.

The Arctic cold, while harsh to living creatures; has preserving qualities to wood, steel and concrete and as a result, most DEWLine structures, will probably remain serviceable for many years to come.

The roads, walkways, taxiways and runways are of course maintained in excellent condition on all active sites. It is also interesting to note that the roads and runways at Auxiliary Site, Fox 1 which has been abandoned for some years also remain in excellent condition. This suggests that like facilities at the abandoned "I" Sites and the two abandoned auxiliary sites are also still serviceable.

Across the DEWLine such structures as radar platforms, POL storage tanks, power houses, garages, hangars and warehouses all show little aging and remain structurally sound and in good repair except for painting in certain cases.

The building train's timber foundation, structure and exterior shell are in good condition. The interior however does show wear and is drab in appearance. Site personnel have observed vapor trails and frost accumulation in places within the building trains, particularly near building seams. Also, a heating technician from Montreal reported the burning out of the fire pots in some of the auxiliary heating units. This condition was the result of having to drive these units hard during cold spells, and resulted in their shortened life. The efficiency of the primary heating system is also suspect. Inspection of a heat exchanger unit used in the heat recovery system revealed missing tubes as well as excessive scale. This condition coupled with a possible breakdown of the building trains' insulation in places could easily have necessitated over driving the auxiliary heating unit.

In spite of these deficiencies in the building trains appearance and mechanical systems, the trains are structurally sound and will probably remain serviceable for many years to come.

A typical site is shown in Figure 3.4-1, and an abandoned site in Figure 3.4-2. Figure 3.4-3 shows storage facilities presently used.

3.4.1.2 Use of Helicopters

Some years ago the Mid Canada Line (MCL) was constructed. This was an unmanned radar line quite a few miles south of the DEWLine. The line consisted of a manned main station which supported a group of 12 satellite unmanned radar stations. The radar was a doppler radar which used vacuum tubes. The communications were microwave utilizing towers 128 to 280 ft. high. For each unmanned station there was a radar/communications/power and life support module which was kept locked. Nearby this complex was an unlocked emergency module which could be used in case of fire in the main module or by a stranded traveler in need of shelter.

This entire system was maintained by crews flown into the unmanned stations by helicopters. Maintenance was performed according to discipline. The radar, communication and power housekeeping was each maintained by a different crew on a different maintenance schedule. Crews would go into the station for 9 days, others for 6 or 5 days depending on the requirements of the discipline. They did not change boards or drawers but made as many repairs and adjustments on site as possible. Inasmuch as tubes were used extensively, power requirements were high. Approximately 18 KW was required for operation in the unattended mode,

FIGURE 3.4-1
DYE-MAIN

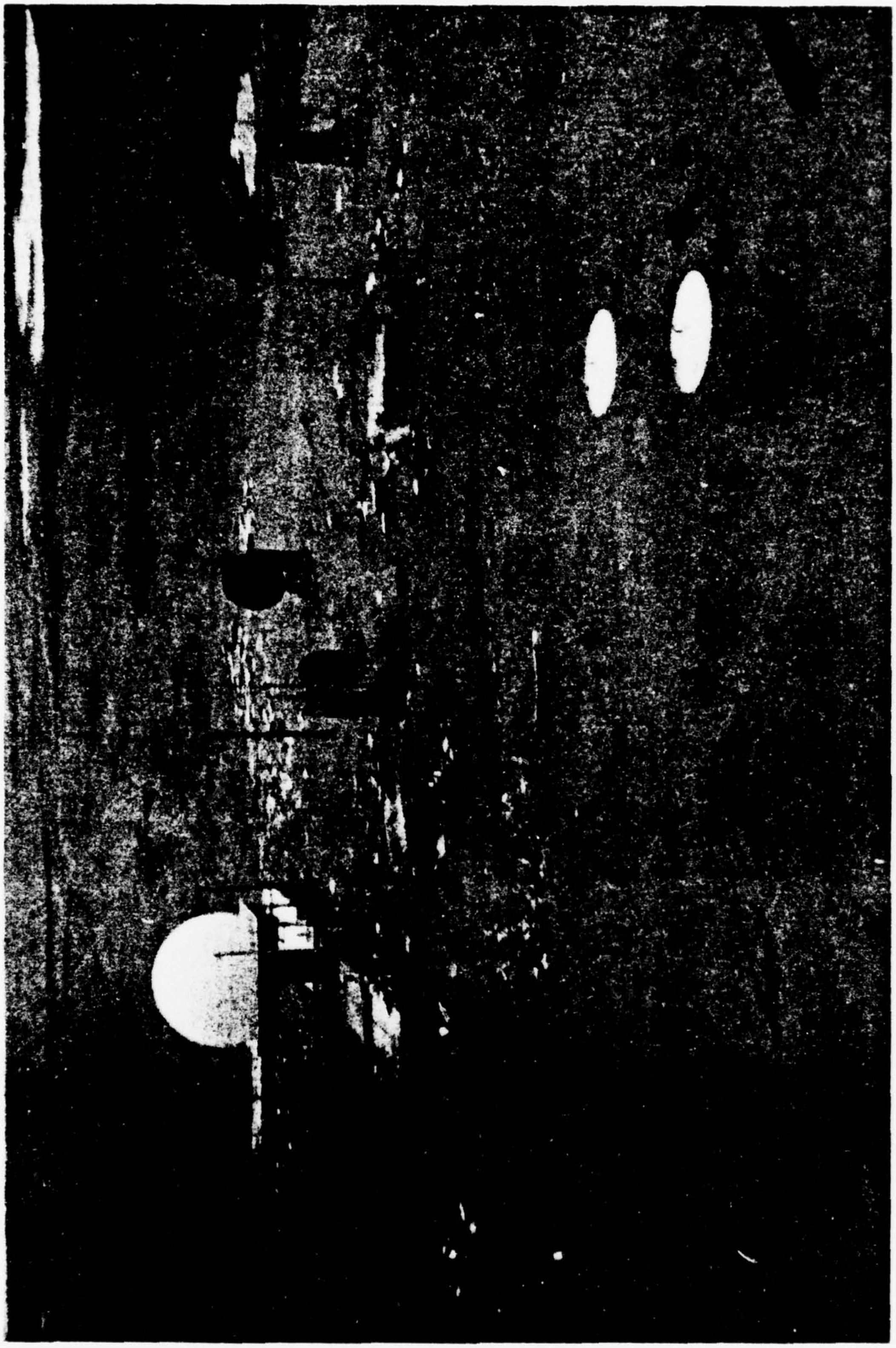


FIGURE 3.4-2
FOX-2

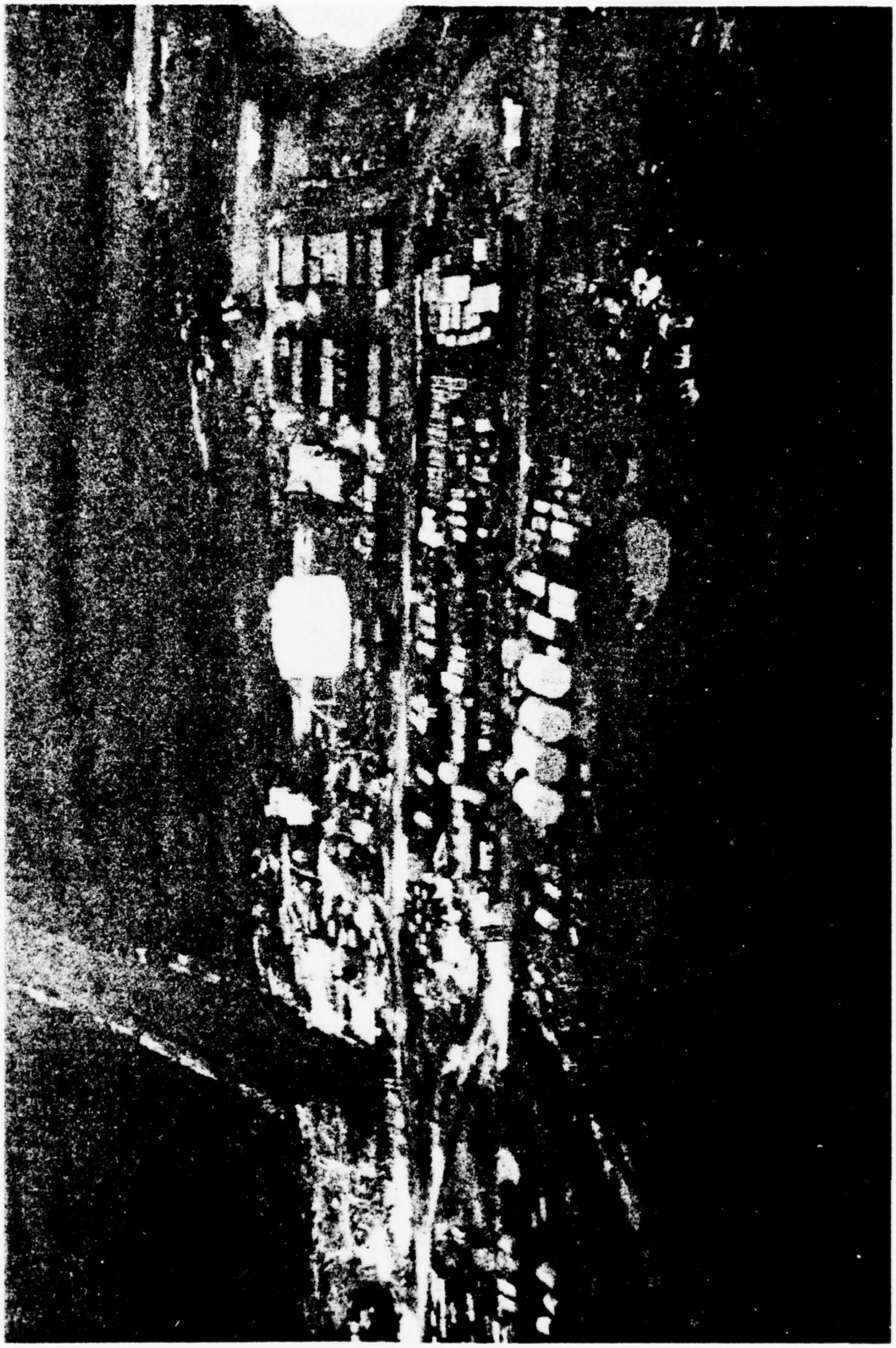


FIGURE 3.4-3
BAR-3

and 30 KW required when the site was attended, with 45 KW of power being the maximum available. The power source was diesel. The entire radar group consisting of one main station and 12 unmanned satellite radar stations was maintained with a helicopter moving men, equipment and supplies from unmanned station to unmanned station to main station.

This whole procedure, according to Bob Parry who maintained the line, and who is now a section supervisor on the DEWLine, worked very well and demonstrated the advantages of unmanned radar as well as the use of helicopters in cold regions of the world.

Helicopters were also used extensively in the construction of the Alaskan Pipeline and continue to be used in its operation and maintenance. They are also currently widely used in oil and gas exploration as well as numerous Arctic research projects.

Helicopter travel is a key element in all these activities and suggests that they are operationally and mechanically practical for transportation in cold regions.

Because helicopter operation is adversely affected by even light icing conditions, icing conditions along the DEWLine have to be considered in the systems maintenance philosphy as well as its design.

Icing conditions and fog do exist seasonally along the DEWLine. It appears that these conditions will make helicopter travel erratic for 3 months during the spring and 3 months during the fall. This was brought to light during a discussion with the Canadian Environmental Service at CAM Main. This view was collaborated thru discussions with technicians at the Canadian Weather Service in FOX Main. They reported icing up of weather instrumentation even at ground elevation. Helicopter pilots in the Alaskan sector reported similar weather conditions.

It appears, therefore, that as long as weather considerations are accommodated in the radar systems maintenance philosphy helicopters can offer a practical solution for Arctic travel.

3.4.1.3 Unrest In The Young Eskimos

The Arctic is growing very rapidly. Oil and gas exploration has proved successful in Alaska as well as in northern Canada. This success has led to the construction of the Alaskan Pipeline and there are currently plans for the construction of a gas line in Alaska as well as one in Canada. Also, there are numerous weather service groups in the area engaged in weather data collection and reporting. Some copper mining is done, and there is growing interest in commercial fishing.

Because of these interests, there is a growing migration of whites into these remote Arctic regions. This, in turn, has caused the introduction of supply depots to support these activities. Medical support, while not swift and easy to reach, is nonetheless available. The white man's presence and his humanitarian ways has materially reduced the mortality rate of the Eskimo in recent decades. This increase in the Eskimo population coupled with the white man's harvesting of the Arctic food supply (i.e. thru sport and commercial interests) has produced a situation whereby the Eskimo can no longer support himself off the land.

This situation has led to a cultural displacement in the Eskimo's social order. He is between two cultures and is not at peace with either one. The frustrations of the young Eskimo appears to be finding their outlet in aggressive bahavior against the white man.

While Canada is experiencing some discontent in the Eskimos it does not appear nearly as great as is found in Alaska. This difference is probably due to how the Canadians handle their Eskimo affairs and because of the higher economic activity in the Alaskan area.

At BAR Main there were reports of breaking and entering, arson, vehicle damage and vandalism. Five such incidents were recorded in the two weeks preceding our visit. POW Main is also experiencing unrest similar to BAR Main. Five people were killed in two days. A couple was murdered on the beach with shot gun blasts. There were two knifings in town and a truck driver crashed and burned. An autopsy was being performed on the driver to determine if he was shot prior to the crash.

To help counteract these social problems site personnel are planning to organize girl and boy scout activities. They also are planning baseball and basketball facilities and introduction of TV programs. These efforts in the community are intended to improve the white man's image and help alleviate some of the tensions.

Inasmuch as these problems do exist today, and since the Eskimo can range as much as 100 miles from his village in the winter months, any unmanned site near an Eskimo village could be vulnerable if this social unrest presists.

It would therefore seem prudent to take reasonable steps in the design of the unmanned radar stations to protect against vandalism.

3.4.1.4 The Eskimo Economy

The Eskimo which habitates along the DEWLine derives his living thru a variety of sources.

A few of the more skillful are engaged in the creation of a number of art and handicraft items. These items are taken to one of the Eskimo cooperatives where they are bought and shipped south to be sold in stores of the larger cities.

He is also employed in commercial fishing, "Arctic Char" being his principle catch which is sold primarily to the larger restaurants in Canada as a delicacy. This fish gets to market thru an Eskimo Cooperative of which he is a part owner.

The Cambridge Cooperative harvests approximately 150,000 pounds of fish each year for sale in the south. The commercial fishing is generally done in locations 30 to 40 miles away from the village, and is serviced by a single engine aircraft which supplies and brings out the catch from the fishing camps each day. The reason the commercial fishing is done remote from the village is because the fishing grounds near the village are reserved for the village Eskimo so that he may supplement his table with his own catch.

The Canadian Government also employs the Eskimo in maintaining the village which in turn supports such activities as a post office, Canadian Custom Agencies, navigational aid stations, weather reporting stations, weather research stations, a small fishing industry and a Hudson Bay Store.

The DEWLine provides some employment for the Eskimo. This however is not significant. They are generally employed in janitorial services and as heavy equipment operators.

It appears the largest single source of income for the Eskimo is thru the Canadian/Alaskan Welfare Systems. In both cases it appears quite generous and enables the Eskimo to own snowmobiles, motor bikes, live-in wooden houses and heat with petroleum oil. While their living standard is modest by any standard it certainly is many levels up from living off the land.

It was the judgment of the DEWLine site survey team that the removal of DEWLine jobs from the Eskimo economy would have only negligible overall consequences to the Eskimo economy.

3.4.2 A/E Consultants

A number of engineering firms were considered as consultants to General Electric for this study program, as outlined in Figure 3.4-4. It was decided early in the program cycle to utilize a Canadian firm if possible, as the largest

FIGURE 3.4-4

ENGINEERING, DESIGN, AND CONSTRUCTION CONSULTANTS

FIRM	SERVICE	LOCATION	EXPERIENCE SUMMARY
The Webb, Zerafa, Menkes & Housden Partnership	Architects & Engineers	Toronto, Montreal, Canada	One of Canada's largest A/E Firms Structural & Architectural Engineering Large number of programs, commercial, educational, residential
Poole Construction, Ltd.	General Contractor	Edmonton, Canada (9 Branch Offices)	Canada's biggest general contractor, $275,000,000 annual volume Experts in northern construction, transportation, logistics Projects include: Industrial, Highways, Airports, Bridges, Dams, Ports, Municipal (water, sewers, etc.), Commercial, Institutional Project locations include: Inuvik, Tuktoyaktuk, Coppermine, Cambridge Bay, Strathicona Sound
Tower Company, Ltd.	Design, Engineer-Construct, Fabrication	Montreal, Canada (Branch offices in Frobisher Bay Resolute Bay Toronto Yellowknife)	General engineering and construction: five divisions: R & D, Design, Construction, Industrial (manufacturing), Operations & Maintenance Supplied station modules for eastern portion of DEWLine, held O & M contracts for DEW Line as joint venture with Federal Electric Foundation design & site construction for Telesat Canada on Arctic communication stations Presently preparing manual for Canadian Govt. on use & transportation of prefab buildings for Arctic Over 30 years of Arctic experience with over 1000 Arctic projects
M.F. Yolles & Partners, Ltd.	Structural Engineers	Toronto, Canada	Structural Design Organization specializing in commercial, educational and governmental structures but significant background in other areas. Has performed as the structural designer of an imposing listing of projects in association with architects and developers. Significant experience in both concrete and steel design. Firm organized in 1952. A specialized organization not providing electrical or mechanical design capability.
Atco Construction	Structure Fabricators	Montreal, Canada	Prefabricated building fabricator, DEWLine & Alaska pipeline applications
Burns & Roe Industrial Services Corporation	Engineers - Constructors	New York	Have provided engineering, design, construction management, operation and maintenance on projects for NASA and the Armed Services Familiar with high-reliability requirements from experience on Project Mercury, Nike-Zeus, BOMARC, BMEWS, SAGE Considerable Arctic experience at Thule, Greenland, on buildings, foundations, runways, roads, water, sewer, heating, ventilating. Also designed heavy-water production plant at Glace Bay, Nova Scotia
Ammann & Whitney	Consulting Engineers	New York	One of larger firms in engineering consulting field, many military projects including PAR, BMEWS Performed several study programs for construction in permafrost from Aleutian Islands through Northern Canada to Greenland Services include preliminary investigations, master planning, engineering & economic feasibility studies, research & development, concept studies, geological & geophysical studies Has in-house staff in structural, civil, architectural, soils, mechanical electrical, protective construction, reliability, computer, dynamic analyses, field survey.

portion of the construction would be in Canada, and knowledge of the laws, customs and environmental requirements of that country was considered most desirable.

Of the organizations contacted, the Tower Company of Montreal appeared to have the most Arctic experience in a range of disciplines from design through construction. The company is a relatively small but very experienced, Arctic-oriented engineering, research, design and construct organization. The President, Dr. George Jacobsen, is a very prominent Canadian Arctic authority. The Project Manager, Mr. G. A. Pankhurst, has a long association with the DEWLine dating from the original site surveys through construction, operation, maintenance and supervision.

The company is organized into five major divisions as outlined in Figure 3.4-5.

The Tower Company has augmented their own capabilities by securing the services of Mr. Robert Shaw of Montreal Engineering Company. As former Executive Vice President of the Foundation Company, Mr. Shaw was responsible for the original construction of the Canadian portion of the DEWLine. In addition, as Deputy Minister for the Department of the Environment, Government of Canada, Mr. Shaw authored Canada's Policy on Environmental Assessment for Federal Activities.

By virtue of their Arctic experience, the engineering consultant team has been most helpful in contributing to our conceptual designs. They are very aware of Arctic construction restrictions and Canadian Government environmental requirements. They are also familiar with security problems, especially vandalism and pilferage.

They have suggested a prefabricated modular design shelter concept that is readily transportable and meets the requirements of installation, fire safety and security.

FIGURE 3.4–5

THE TOWER COMPANY

1. **Research and Development Division:** Through its President, George Jacobsen, Dr. Sc., this Division is actively involved in all phases of arctic scientific research and application of pure science to industry. Mr. Jacobsen is also Chairman and Sponsor of the Jacobsen-McGill Arctic Research Expedition to Axel Heiberg Island, an arctic research effort (McGill University) open to scientists from all nations.

2. **Design Division:** This unit provides a complete service of feasibility studies and design of domestic, commercial, industrial, institutional and defence projects. It has the facility, through its associates, to provide specialists' services as an integral part of the total package.

3. **Construction Division:** This Division of the Company has successfully completed the installation and construction of utilities, buildings and structures throughout the length and breadth of Canada for a wide variety of clients. Contracts originate from public and invited tenders, special negotiations and package proposals on fixed price or special cost formulae.

   The Construction Division has performed pioneer work in the Arctic and other isolated areas since its inception. It was the first to build wholly airlift-supported projects, was the first to use light aircraft with soft balloon tires for landing on totally unprepared arctic terrain. It developed original foundation techniques for permafrost areas and pioneered the use of lightweight prefabricated components manufactured in its own plants, for use in all types of superstructures.

4. **Industrial Division:** Manufacturing facilities are maintained in St. Jerome and Lachute, Quebec, for the production of pre-cut or prefabricated buildings and components in wood, metal, glass or plastic according to design requirements. Modular components are held on inventory for the construction of a general purpose building that is adaptable to a variety of uses under all climatic conditions. This building is found in many forms in virtually all major settlements throughout the Arctic regions. It is also in use in the more settled areas of Canada.

5. **Operations and Maintenance Division:** Services provided by this group include the provision of fully trained and qualified staff for the operation and maintenance of installations such as electrical generating stations, public utilities, mobile equipment and buildings. They also include the services of road and airport maintenance, cargo handling, warehousing and camp operations.

The Tower Company is very familiar with the work presently being done in the Arctic on wind power generation and common fuel utilization as well as unattended weather station developments.

3.4.3 Siting Considerations

Of primary importance in the site selection process are the functional requirements of radar operation and communication. When these conditions have been satisfied, other factors for consideration are logistics of operation and maintenance; security against vandalism, theft, and sabotage; and construction elements. While construction factors such as soil conditions, environment, available material and logistics are important, they are essentially a one-time happening in the total life cycle problem.

3.4.3.1 Existing Sites

Existing DEWLine Sites should be utilized whenever possible for both the manned and for the unattended sites. The Arctic environment is quite dry and equipment does not deteriorate at a very rapid rate. A number of facilities already exist which can probably be used at a cost savings. While there are a number of components in the existing system that should be considered for replacement because they are worn out or obsolete, such as power plants, fuel storage bladders and radar equipment, many site development elements can be used. These include landing strips, beach heads, ports, temporary storage facilities, roads, water sources, gravel, sanitation systems, radar and communication towers.

Logistical systems for these sites are proven, having been in use for some time. The environment, soil, weather and ecological conditions are known. Many of the existing sites will, no doubt, meet the siting criteria for radar coverage, communication linkage and logistics.

The existing and operational 6 MAIN and 21 AUX sites are expected to fit the above condition. The two abandoned AUX sites should have a high percentage of usable facilities. Less information is available concerning the 28 abandoned "I" sites but based on the survey conducted in 1971 and 1972 may have usable air strips. It is reasonable to assume that gravel for construction and other usable materials are available.

If all of the 57 existing and abandoned sites can be used, only 26 new sites would require development to fill the complement of 83 unattended stations.

3.4.3.2 New Sites

It is expected that the site areas will be selected by considering siting criteria requirements. As a first step, suitable areas should be identified from aerial photographs and maps to suit the technical specifications for a radar site. This should be followed by field reconnaissance to pick or confirm a specific location in the specified area which would be optimum for these installations. A consideration in site selection is that care should be taken to locate areas away from permanent native settlements, or from areas used as hunting camps by the local natives.

During field reconnaissance, the location of the optimum site in the selected area should consider suitability for radar and communications as primary considerations.

While some general conditions can be anticipated it is expected that each site will require individual treatment. Soil conditions, (rock, permafrost, etc.), availability of local material, proximity of support base facilities, supply routes, grounding conditions, local ecology and weather are some of the variables that can be encountered. Only after site selection and survey, can a meaningful construction plan be generated for each site and condition that will be encountered.

Access routes for construction of the facility and for the annual re-supply must be addressed. Consideration should be for access by land, sea, and aircraft, using helicopters for normal loads and the shorter flights, and Hercules type air freighter for heavy loads to available airstrips, particularly during construction.

In the case of new sites, where air strips do not exist, it is anticipated that none will be constructed. The unattended stations will be serviced by helicopter, and the construction program can be supported by that form of transportation as well. Therefore, only a helicopter landing pad of locally available material will be constructed. There is a minimum risk to near shore installations of significant exposure from storms, winds, high tides and pack ice. There should be little or no effect on the locating process from these forces. Vulnerability to drifting snow, floods, icing, solidification and other potentially destructive occurrences will require more careful examination and protective designs.

Location and site preparation will be affected by the environmental constraints imposed by the Department of Fisheries and the Environment of the Government of Canada, and by similar agencies in Alaska. In particular, the Governments will no doubt require that nesting areas for migratory birds, fish spawning ground, polar bear denning areas and caribou calving grounds be avoided as much as possible. It will also require that the natural insulation in permafrost areas is either protected or replaced with artificial insulation. Suitable control of drainage will also be necessary.

Satisfying the various Governmental regulations, expecially ecological concerns, can take considerable time, and a construction plan will require site selection determination. For these reasons, site selection must be scheduled very early in the program.

It has been determined that land acquisition in Canada should not be a problem. The Canadian Government will procure the necessary real estate at no cost to the program.

3.4.4 TOWERS

3.4.4.1 Radar Towers

The station design must first consider the functional requirements, that is the radar must be capable of performing its function of gathering data and the communication system must be able to transmit these data. Other elements must also be considered; prime power must be available, security must be provided to protect the system, the equipment must be protected from the elements and it must be supportable. Most anything can be accomplished given enough time and money but the expenditure of the minimum of resources is essential to good design.

The assumed parameters for the radar include a ring array in the order of 20 to 25 feet in diameter, 8 to 10 feet high. A minimum elevation above sea level of 125 feet is required and a height above grade of 10 to 15 feet is necessary to eliminate local interferences. Therefore some structure is required to elevate the radar array at any given location. A statistical check over the existing DEWLine sites indicates that for the 83 sites considered in this study, structures to elevate the radar will be required approximately as follows:

Tower Height (Ft.)	No. Required	Quantitized
70 to 80	2	75 ft. (6)
60 to 70	4	
50 to 60	6	50 ft. (11)
40 to 50	2	
30 to 40	3	
20 to 30	6	25 ft. (66)
10 to 20	60	

While towers are required in all cases, it may seen that most situations can be covered by a single design in the order of 15 to 25 feet high. The cases not accommodated would require towers about double that height which may be accomplished by modularization, that is, additional tower increments. Some four to six situations may require special treatment. Judicious site selection could eliminate the need for these special situations.

The existing DEWLine System employs 27 towers to support the radar antennas. These Towers are all similar in design. They are approximately 50 feet above grade with a platform about 50 feet square, and all can be made to meet the criteria of 125 feet above sea level. A preliminary structural analysis has been made of the existing tower design. The results indicate they are capable of supporting a complete unattended site including radar, power plant, fuel and emergency shelter.

With the removal of the present radar antenna and the radome these towers could be used for an unattended radar application. A minimum of construction and essentially no site preparation would be required. The design has been proven to very satisfactory over the past 20 years. There are no moving parts involved, therefore there is no wear and inspection of the facilities indicated little if any corrosion or deterioration.

This study does not include the consideration for use of the existing radomes. It is doubtful that the characteristics would be consistent with the electronic requirements of the new system. In addition it is probably not practical to assume an additional 30 year life expectancy for these structures.

3.4.4.2 Tower Materials

A number of various materials were considered for support tower fabrication. Pole supports and wooden structures were considered impractical for this application due to the required tower height and wind loading. Reinforced concrete cast on site was rejected because of required material handling and high; on site, labor costs. Precast components for tower elements would probably require prestressing of the concrete due to tension loading. Considering handling and shipping difficulties this concept was eliminated as being non competitive with metal structure elements. However precast foundation components shipped to the job site appears quite attractive.

Structural steel (carbon steel) with a galvanized finish is a very common tower material. It has a number of advantages being readily available from a number of sources. Fabrication, welding and shaping are relatively simple, due to common usage. However the use of carbon steel in the Arctic is subject to some controversy. It does not have good low temperature properties as it becomes brittle or nonductile. There have been failures in welded carbon steel structures at low temperatures, usually traceable to a stress raiser such as a notch or weld undercut. These failures have been dramatic and catastrophic such as ships breaking in two and pressure vessels splitting apart.

Carbon steel has been used extensively in Arctic applications and as far as can be determined the existing DEWLine radar towers are of carbon steel. Most certainly other equipment such as trucks, snow plows, tractors, etc. are used in the Arctic and are composed of carbon steel components. With care in design and fabrication carbon steel can be used satisfactorily in the Arctic environment.

High nickle alloy steel is sometimes specified for Arctic structures because of its good low temperature strength characteristics. As an example the steel in the BMEWS antenna reflector structures at Thule, Greenland and Clear, Alaska are of this alloy and was specified as exhibiting 15 foot pounds at -65^{o}F when subjected to Charpy impact test, (ASTM E-23).

While alloy steels can provide good low temperature properties, they are usually not readily available and quite often require a special mill run. They are usually more costly then carbon steel. In addition the alloys present different problems in fabrication especially welding techniques which can increase manufacturing costs.

Weathering steel (Corten A, Mayari R) was considered because of its unique properties in the area of corrosion resistance, but this factor is probably of less importance in the arctic where corrosion is not a serious problem. It is probable that less tonnage could be utilized as these steels tend to have higher strength than carbon steels. Like the nickle alloy steels they are not as readily available as carbon steel although this factor is diminishing with increased use of the material. Special fabrication techniques, especially in welding is required. These steels do not exhibit good low temperature properties with an average temperature of about -15^{o}F for 15 foot-pounds Charpy V-notch test. Material and fabrication costs are higher than carbon steel even considering the offsetting factor of less tonnage due to higher strength.

Aluminum is often used as a structural material for towers and on a weight basis is stronger than steel which results in less tonnage but greater bulk. Aluminum has good corrosion properties, again probably not an important factor in the Arctic. It does exhibit good low temperature properties but both material and fabrication cost can be greater than carbon steel depending on market conditions at the time of purchase.

It is felt that all the metallic materials considered are viable candidates depending on how the designed or user feels about corrosion resistance and low temperature properties. Recommendations at this time would be carbon steel or aluminum but the designer should select the material at the time of detail design considering the market fluctuations for material cost as well as the factors of fabrication, shipping, erection and maintenance.

3.4.5 Storage

It is anticipated that at the unattended station storage other than fuel will be at an absolute minimum, limited perhaps to a few items such as light bulbs and fuel filters. Assuming prime power is by diesel-electric generation, then fuel will be the largest item of on-site storage and resupply with an estimated 4,000 gallons (27,000 pounds) required on an annual basis.

Arctic A fuel, which is essentially JP-5, is presently used on the DEWLine for diesel fuel. As it will probably continue to be used at the logistics nodes where comsumption is very high compared to the requirements of an unattended station, it is recommended for use in the unattended case. A variation of this principle might be considered if the power generator finally selected exhibits an unacceptable efficiency with this fuel. It may be used with aircraft or helicopter jet engines and as a heating fuel.

Arctic A oil is the only fuel that need be stored at the unattended site. Not having a requirement for gasoline reduces the fire hazard and simplifies the supply problem. Since the stored fuel is not suitable for the vehicles usually employed by the local natives the threat of loss through theft is reduced.

Present practice on the DEWLine is to assume a shelf life of 5 years for Arctic A fuel. It is tested on an annual basis for the first 3 years and every six months for the next 2 years. Stocks are rotated as required to assure consumption before deterioration.

A minimum of one year's fuel supply should be stored at the unattended station. Allowing for emergency refueling of maintenance helicopters which will use the same supply as the diesel generators a minimum of 4,500 gallons storage capacity is required.

Emergency resupply may be provided by helicopter on a less than annual basis if required. It is advisable to provide at least two separate tanks which may be partitioned to provide additional cells. This will prevent a disastrous loss in the event any one cell is ruptured or otherwise unintentionally emptied. Tanks may be of aluminum or steel but if steel is employed they should be plastic lined. In detail design consideration might be given to pressurizing the tanks with an inert gas which will eliminate the necessity for air vents and retard oxidation and condensate formation. This would also provide a positive pressure head to aid in filtration and eliminate the need for pumps in a gravity flow design should filtration be a restrictive constraint.

Detail design will develop the required plumbing and valving to transfer fuel from the tank cells as required, using techniques as employed by large aircraft with multiple tankage. This transfer can be done automatically by use of the on site microprocessor or remotely from the manned node.

Fuel storage may be provided in tankage external to the shelter in a conventional "tank farm" or possibly in underground storage. However underground storage would probably be quite difficult as most locations will be on permafrost or rock terrain. Arctic experience has indicated that an absolute minimum of excavation is desired. Present practice is to elevate all piping to avoid permafrost penetration and the resultant problems of frost heaving and thaw settling. External storage imposes the requirement of some kind of heating to provide fluid flow and is much more difficult to protect against theft, vandalism and accidental damage.

Good design practice dictates that in permafrost affected areas outside storage tanks should be insulated from the ground. This may be accomplished by setting them on a spread footing over an insulating fill foundation or above an air space. Setting them on concrete or steel supports resting on pile foundations surrounded by insulating material to permit free passage of air underneath the tanks is also acceptable. Inside storage eliminates many of these problems. Heat is available to assure fluid flow and protection is much easier to achieve. Detail design can consider the options of self sealing tanks in the event of penetration or an external "bullet proofing" material such as those presently being used in military applications and described in Figures 3.4-6 and 3.4-7. In the quantities involved internal storage need not constitute a fire hazard. There are may applications of inside fuel storage such as ships, factories and homes where adequate fire safety measures are well proven.

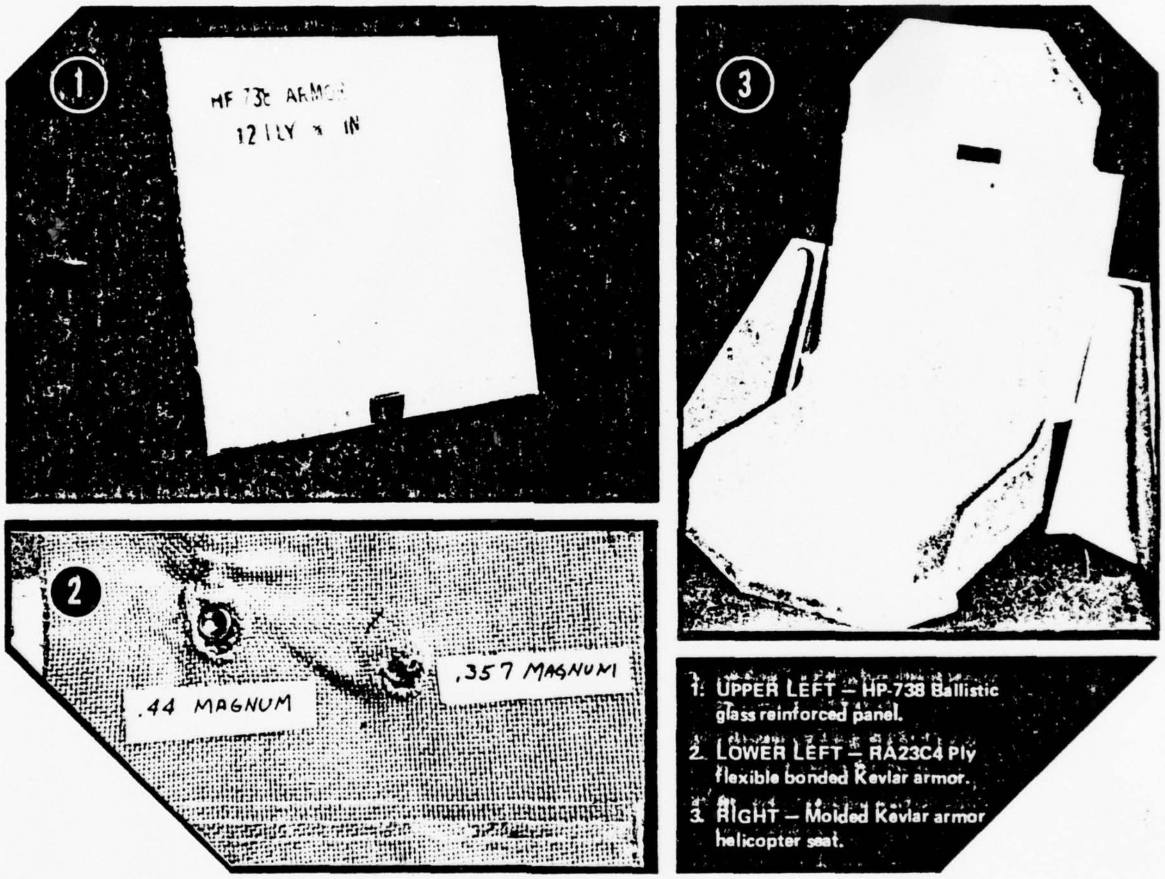
For the unattended station design the recommendation is for inside fuel storage. The incorporation of the fuel storage into the station facility is described under the shelter description, Section 3.4.6.

Fuel resupply systems to the unattended station may vary depending on the site location and logistics system. Distribution along the line will probably continue to use the present barge system. There may be some locations where existing fuel transfer facilities can be used but the basic unattended station design will accommodate resupply by helicopter. Various concepts have been considered such as tanks built into the helicopter and the use of sling loads of standard oil drums. The most attractive approach appears to be a series of specially designed tanks with a capacity of the maximum pay load of the helicopter, about 500 gallons with the aircraft recommended. Multiple trips, probably 8, would be required from the barge, which need not stop, to the station. The tanks would be filled from the bulk tanks on the barge and air lifted to the station where the fuel would be transferred to the storage tanks.

FIGURE 3.4-6

REINFORCED PLASTICS DIVISION

ARMOR MATERIALS AND PRODUCTS



1. UPPER LEFT — HP-738 Ballistic glass reinforced panel.
2. LOWER LEFT — RA23C4 Ply flexible bonded Kevlar armor.
3. RIGHT — Molded Kevlar armor helicopter seat.

RUSSELL has been supplying HF-738 rigid FRP armor to government agencies, banks and other security services for many years.

Close technical liaison with DuPont over the past 5 years has resulted in processing and fabricating expertise in producing Kevlar rigid and flexible armor.

- This new materials technology has made possible *lightweight* armored products for personnel, vehicle and equipment protection.
- Reinforced plastics, employing Kevlar, can substitute for most conventional armors with significant weight saving for equivalent protection.

FIGURE 3.4-7

MILITARY APPLICATIONS

Fragmentation and Spall Protection

AIRCRAFT:

- Blast Shields for pilot/co-pilot
- Seats
- Fuel tank and engine shielding
- Hydraulic line protection
- Custom shapes for critical component shielding

GROUND FORCES:

- Tank and Personnel Carrier Armor
- Personnel protection — Helmets — Body Armor — Automotive vehicle Spall and Frag Barriers
- Equipment protection — Electronics — Missile storage — Field Shelters — Ammo. Containers

SHIPS:

- Deck stored ordnance, missiles, etc.
- Critical equipment — Navigation — Radar — Ship Controls
- Above deck gun crews

BANK SECURITY

Small Arms Protection

- Panels for enclosures, doors, teller cages
- Surveillance camera protection
- Flexible body armor for Guards
- Armored Car and Personnel Protection

POLICE AND LAW ENFORCEMENT

- Vehicle liners
- Portable shields
- Bullet resistant riot jackets
- Bullet resistant undercover vests
- Bomb blast shields
- Prison Guard enclosures
- Firing Range barriers
- Police Station counters and partitions

FLEXIBLE KEVLAR
vs SEWN KEVLAR ARMOR

1. Improved blunt trauma resistance
2. No ballistic deterioration from moisture

MATERIAL		TYPE	WEIGHT/SQ. FT.–1/4" THICK	MAX. SIZE	THICKNESS
Rigid	Glass	HF-738	2.6 Lbs.	48" x 110"	1/8" to 2"
Rigid	Kevlar	RA-41A1	1.8 Lbs.	44" x 110"	1/16" to 1-1/2"
Semi-Rigid	Kevlar	RA-22C3	1.25 Lbs.	44" x 110"	1/16" to 1"
Flexible	Kevlar	RA-23C4	1.25 Lbs.	44" x 110"	1/32" to 1"

HF-738 TEST DATA

Thickness	Protection Level	Firing Distance
1/4"	Up to and including .357, 158 Grain Jacketed Bullet	5 Feet
3/8"	Up to and including .44 Magnum and 12 Ga. Shotgun Rifled Slug	5 Feet

*Detail Test Data on Rigid and Flexible Ballistic Armor available on request.

Small portable pumps are readily available with capacities for pumping rates of 100 gallons per minute or more which could be used for the transfer. The five minutes or so required will probably be less than the round trip time of flight. A hose or pipeline at the station from the fuel tanks to the helipad would be available. The same piping system would be used for emergency refueling of helicopters as described in Section 3.4.15.

To meet the ecological requirements the permanent storage system will require a revetment (berm) at ground level. However, this is relatively simple as a "pond" 25 feet in diameter need only be slightly larger than six inches deep to retain the entire 4,000 gallons of fuel. Therefore a berm (dike) one foot high at a 25 foot diameter would fulfill the requirement.

There are potential sites in the Fox basin area that are not accessible by water. The helicopter resupply from barge to site is not practical. There is tank capacity in this area that could be used for long or short term fuel storage. The fuel would be brought in by fixed wing aircraft and local distribution by helicopter.

While the storage tanks would be at an unattended location, security would be a problem. Unattended storage would be limited to the time required for the helicopter to make local distribution. The area is very remote and accessible only by foot, air or very special vehicles in summer or by snowmobile or sled in winter. There are no settlements in the area. The theft of any quantity of fuel is not practical. The fuel itself is limited in use, and will not serve in applications requiring gasoline. The tanks can be made secure by the application of bullet proof reinforced plastic material such as described in Figures 3.4-6 and 3.4-7. Operating valves would be enclosed in a reinforced concrete vault with flush mounted steel door and lock system.

3.4.6 Shelters

3.4.6.1 Radar

The shelter requirements for the unattended station may be considered as three basic elements, electronic, power and life support. The electronic requirement includes the radar, communication, and other equipment components for navigational aide, weather reporting and the like. The radiating elements of the radar will dictate the size and general shape aspect of the shelter required. The radar assumed for this study entails radiating elements at approximately 25 feet in diameter and 8 feet high. These elements will probably require support structure, although this may be incorporated in the radiating element itself. GE has recommended the radiating elements be encased in some form of radome to provide weather protection. It is estimated that the radar will require approximately two cabinets of electronic components. An additional two cabinets are assumed for communication equipment and one for weather, navigation aids, etc. for a total of 5 electronic equipment cabinets. A concept for the radar shelter is shown in Figure 3.4-8. This arrangement assumes the electronic equipment is sheltered independently of the radome. Figure 3.4-9 depicts an alternate concept with the radome providing weather protection and insulation added to the support structure so the entire area may be utilized.

3.4.6.2 Power

The General Electric recommended system assumes that 3.1 KW of power will suffice to operate the unattended station in the normal mode. An additional 3.1 KW of power would be made available on demand, when maintenance functions are being performed and personnel are present with minimum life support function being provided. These requirements result in an arrangement of three diesel electric generators of 3 to 4 KW each, one for normal operation, one for demand power and one spare. In addition to the generators, starting batteries and

FIGURE 3.4-8

<u>RADAR EQUIPMENT</u>
SHELTER ENCLOSED

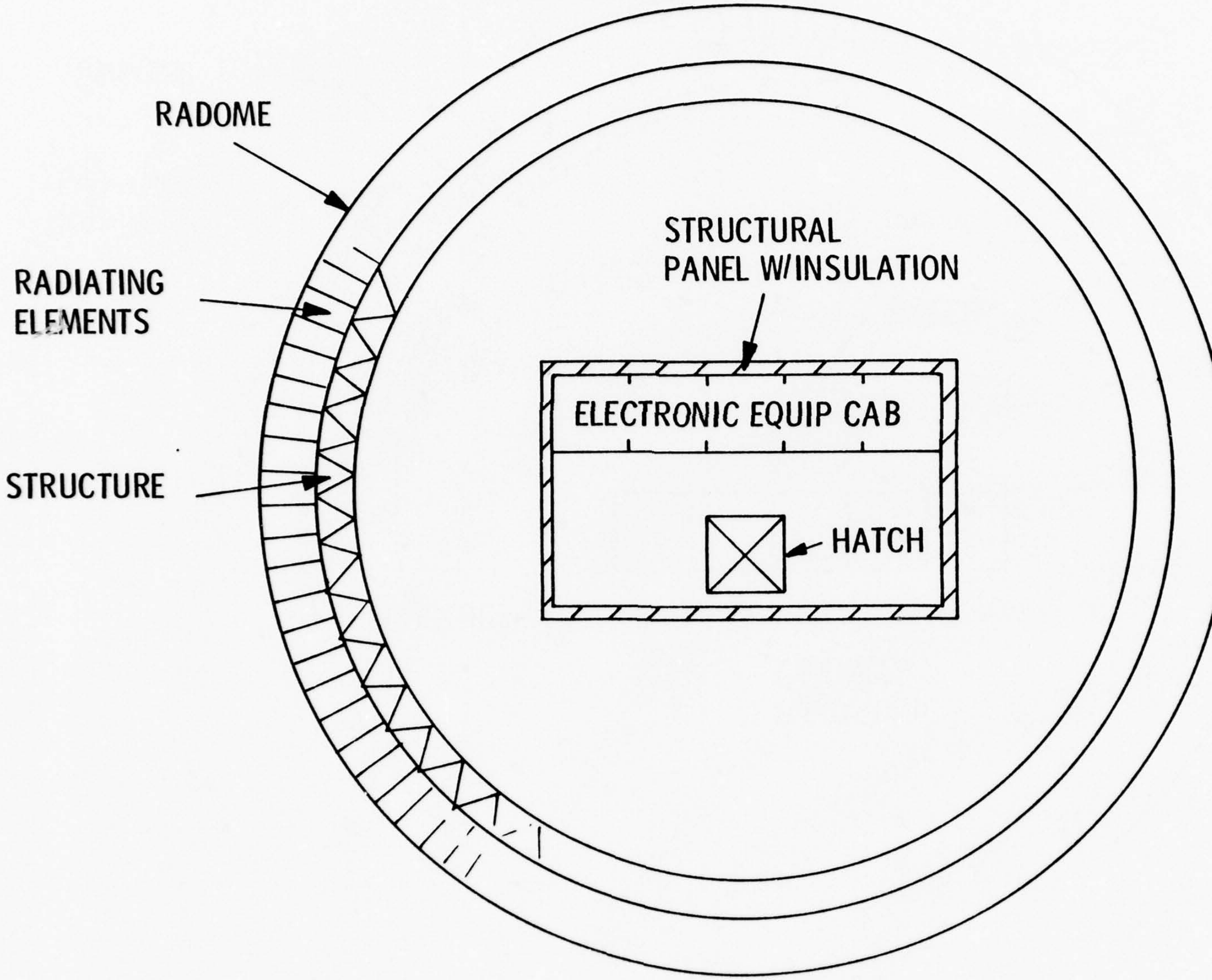
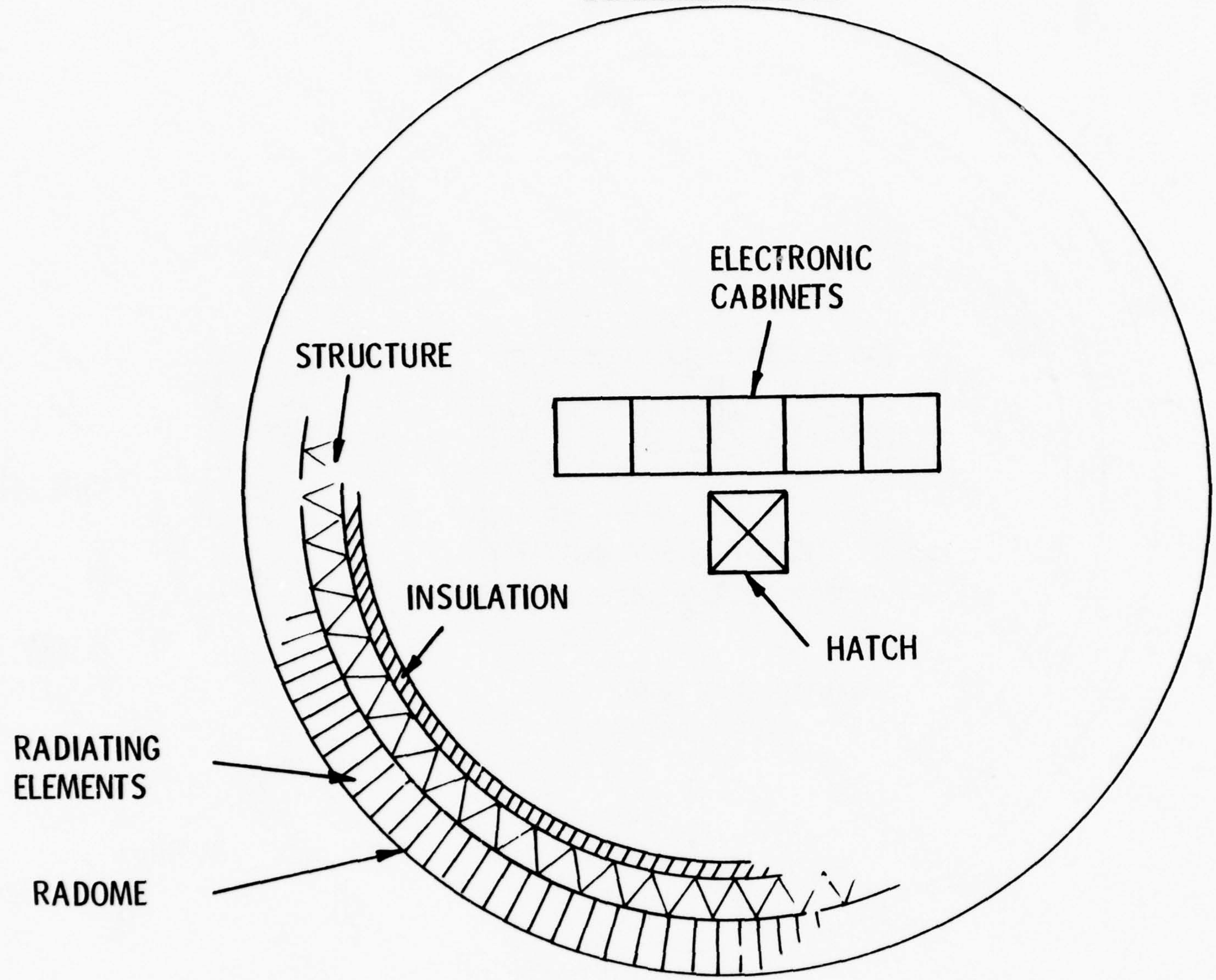


FIGURE 3.4-9

ELECTRONICS EQUIPMENT RADOME ENCLOSED



controls for remote starting, stopping and synchronization will be required. As previously discussed in Section 3.5 under Storage, provision within the shelter for a minimum of one year supply of diesel and emergency jet aircraft fuel is recommended, approximately 4,500 gallons.

It is certain that there are a number of diesel generator combinations that will satisfy the requirements. The Onon Company of Minneapolis provides sets in the desired power range as does the Pioneer Gen-E-Motor Corporation of Chicago and the Kohler Company of Kohler, Wisconsin. The Lima Company employs a British built Diesel by Lister which, within the limits of this study appears most attractive from a reliability viewpoint. In any event, the unit selected at final design will probably not differ considerably from those discussed. All are relatively small, about the size of an automobile engine and relatively light ranging from 200 to 500 lbs. An indepth study of the diesel generator is beyond the scope of this report. Considering 83 sites each with 3 generators, a total of 249 units are required, not including training or spare units. With a purchase of this magnitude it is safe to assume a manufacturer will provide special services and make at least minor modifications. Therefore, it is assumed that most of the desired features of the various combinations of engine generators will be available. The physical description for a typical set is outlined in Figure 3.4-10, the Lima/Lister unit fits these parameters.

The units would be skid mounted for ease of handling and to provide vibration isolation. Intake air would be ducted from outside to prevent drawing cold air into the shelter in the winter. An internal louver can be provided to allow cool air circulation in the shelter in the summer months.

The exhaust muffler is integral with the engine and the exhaust pipe, 1-1/4 to 2 inches in diameter, can be positioned to exit from the shelter to prevent frost formation. Auxiliary oil sumps, not necessarily integral with

FIGURE 3.4-10

DIESEL-ELECTRIC GENERATOR

4 KW AC, 120 volt, 60 Hertz, single phase governed at 1800 RPM

Starting - remote, local or hand start by pull rope (engine equipped with compression release).

Air cooled by flywheel fan

Air intake, 4 to 6" ducted, with filter

Exhaust - engine mounted muffler, 1 to 2 inch flexible exhaust tube

Size - Length: 36 inches
Width: 20 inches } overall
Height: 30 inches

Weight - 550 lbs.

Vibration damped skid mount

Auxiliary oil sump.

the engine, could be provided to eliminate the necessity for short term oil changes or resupply.

It is recommended that the required annual fuel supply be inside the shelter. Plastic lined steel or aluminum tanks with bullet proof jackets or self sealing linings should be considered as previously discussed in Section 3.4.5 under Storage.

3.4.6.3 Power and Life Support

The shelter requirements for life support vary depending on the maintenance philosophy and the desires of the using agency. A power and life support module to support up to six personnel in comfort is shown in Figure 3.4-11 and 3.4-12. This concept is a combination of modular, air transportable cubes, bridged by prefabricated floor, wall and roof panels, supported on a space frame platform. The arrangement is a grouping of six 9 x 9 foot units and four 9 x 6 foot units. The configuration provides a minimum of external wall area. The maximum dimension of 9 feet was selected to minimize the plate effect on lift of large containers for the pre-installed equipment, and temporary partitions removeable after installation, would be used for shipping where they are not required in the final configuration. The exterior walls, floor and ceiling would be composed of a number of acceptable materials that are hard wearing and repairable by semi-skilled labor in the field. A number of materials have been considered including steel, aluminum, fiberglass, various plastics, plywood and composites. The most likely candidate is a sandwich panel with an outer skin of galvanized finished steel or aluminum. The center section is of a suitable material to provide insulation of R20 in the floor and side walls and R30 in the ceiling. A hard, non toxic, fireproof plastic such as General Electric LEXON is suggested for the inner skin. The panels must be structurally sound and required structural elements must be incorporated. Final detail design considerations should include

FIGURE 3.4-11

POWER & LIFE SUPPORT MODULES

27' x 24'

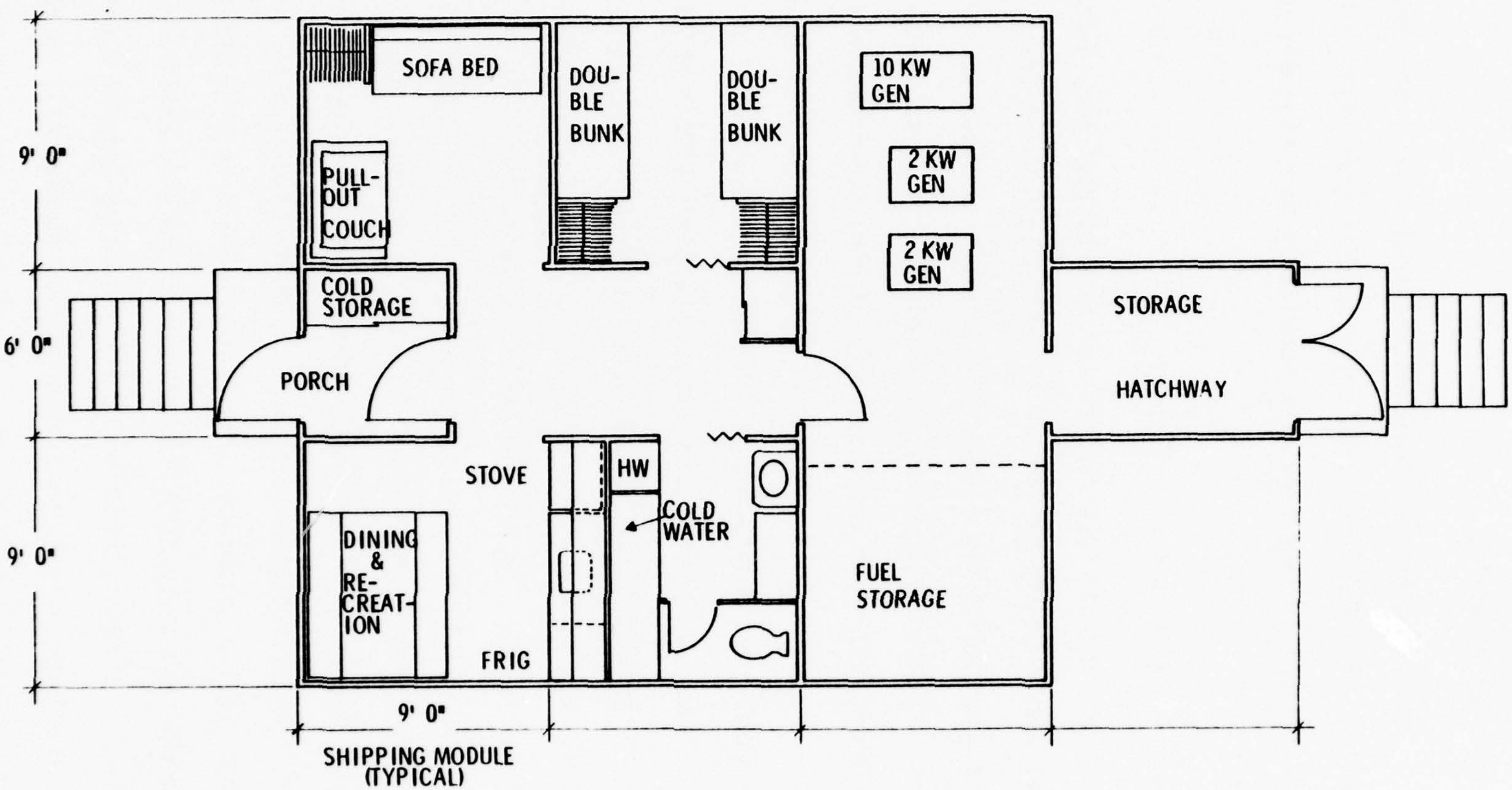
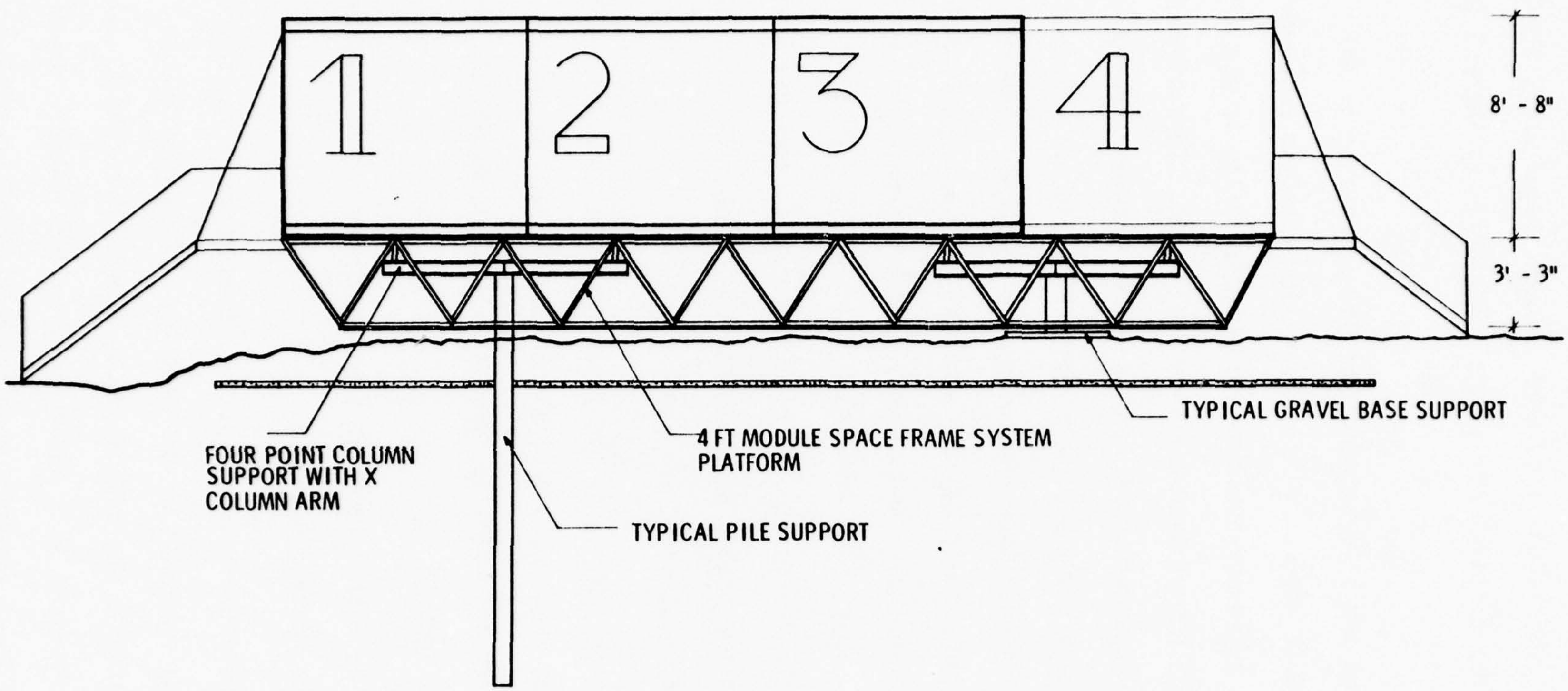


FIGURE 3.4-12

POWER & LIFE SUPPORT MODULES



the requirements for the following features: transportable, fireproof, weatherproof, non-toxic, corrosion resistance, insulated, secure, repairable, non-attracting to animals, minimum of penetrations and acceptable sealing and joint designs.

Due to the magnitude of the life support facilities provided in the concept shown in Figure 3.4-11, a 10 KW generator is required for adequate power when personnel are present. The building should be raised above grade to prevent snow accumulation and eliminate heat transfer into the ground. To achieve this, a lightweight space frame system using a 4 foot module to provide a proper platform for the 6 shipping modules and the 6' wide connecting link is suggested. The space frame ships well and permits a minimum number of ground supports. Figure 3.4-12 shows two typical ground support systems. One using a floating footing for a well drained gravel site and a second using a single pile or a cluster of piles for use in areas of poorly drained fine grained soils. The 4 point X shaped support permits the footing or pile to be well protected inside the building perimeter where the ground is always in the shade and unaffected by direct and reflected solar heat gain.

To maintain the permafrost table, as stable as possible throughout the seasons, an insulation mat as shown should be placed also under the entire building approximately 2' deep extending up to 5' on all sides except on the north side where 3' is sufficient.

Exterior doors should be metal clad with a thermal break, insulated and fitted with refrigerator type weatherstripping.

Door hardware should be lever handle plastic coated to allow use with mittens. Three heavy duty ball bearing hinges per door with a weight and pulley door closer are essential. The design of the door sill should prevent accumulation of snow which otherwise will cause twisting and prevents the proper closure. It is recommended to use hardware with top and bottom strikes.

All inside doors should be of fire door quality, fitted with door closers. The power plant and living area form individual fire control zones, each area protected by its own fire fighting system. Each area should have its own long life battery operated emergency lighting system. Each 24' x 36' structure should have a complete First Aid and Emergency Kit containing survival rations, clothing, tools, shelter and hand operated signalling device enclosed in a sealed fireproof container, stored below the entrance platform.

The food preparation area should have a cook stove operating on standard fuel with a heat exchanger to heat the hot water tank. A kitchen counter with sink and icebox or refrigerator and storage cabinets should be provided.

The washroom should have a hand washbasin with spring loaded faucets and aircraft type recirculating toilet. A water storage tank of approximately 250 gallons can be kept from freezing by a heat exchanger from the power plants.

It is suggested that each area be heated by individual space heater. The BTU requirements to be established after the available waste heat from power generation and electric equipment has been evaluated.

Ventilation and fresh air intakes should be directed to the crawl space below the building to reduce snow infiltration. All openings should be properly fitted with insulated dampers and screens. An escape hatch in the ceiling should be located in the living area to allow access to the roof from inside the building.

The shelter described above will, as previously mentioned, support up to six personnel in comfort. However, the requirement for such a shelter should be seriously questioned. Given the maintenance concepts described elsewhere in this report, emergency or unscheduled maintenance visits to an unattended station would probably not be required more often than once in 4 months or so.

Diagnostic data available to the emergency maintenance crew will enable them to perform the required maintenance function in less than 3 hours. With the redundancy available in diesel generators these units would only be changed out at an annual or semi-annual scheduled maintenance visit, therefore, any replacement parts would be carried by the emergency crew and would probably not exceed 30 pounds in weight.

It is almost certain that an emergency maintenance crew would not embark on a mission with prior knowledge of poor weather or other factors that would cause them to be trapped at an unattended station. The transport vehicle, assumed to be a helicopter, is required by law, at least in Canada, to contain survival equipment and rations. With the above factors considered it is doubtful that the small emergency maintenance crew, probably 2 men, would require anything by way of life support. Therefore, it is suggested that no life support other than shelter be provided. Figure 3.4-13 is a plan view of a power and fuel storage complex that would fit under a 25 foot diameter radome. It is composed of two identical 9 X 9 foot units each containing a power generator and fuel storage tankage, and one 9 X 6 foot unit with a power generator and roof and deck hatches. The general physical description as discussed above for the life support shelter would apply to this concept as well.

Under this concept personnel would have some space in the power area and additional space in the electronic shelter could be made available, but no life support equipment, or emergency rations would be provided. With a minimum of penetrations and adequate protection at doors and hatches, with no food or equipment than can be readily removed the likelihood of theft is considerably reduced.

Consideration of the probable configuration of the radome and electronic shelter indicates that all functions can be combined in one enclosure. Figures 3.4-14 and 3.4-15 show a possible configuration. Radar radiating elements forming

FIGURE 3.4-13

POWER AND LIFE SUPPORT

MINIMUM CONFIGURATION

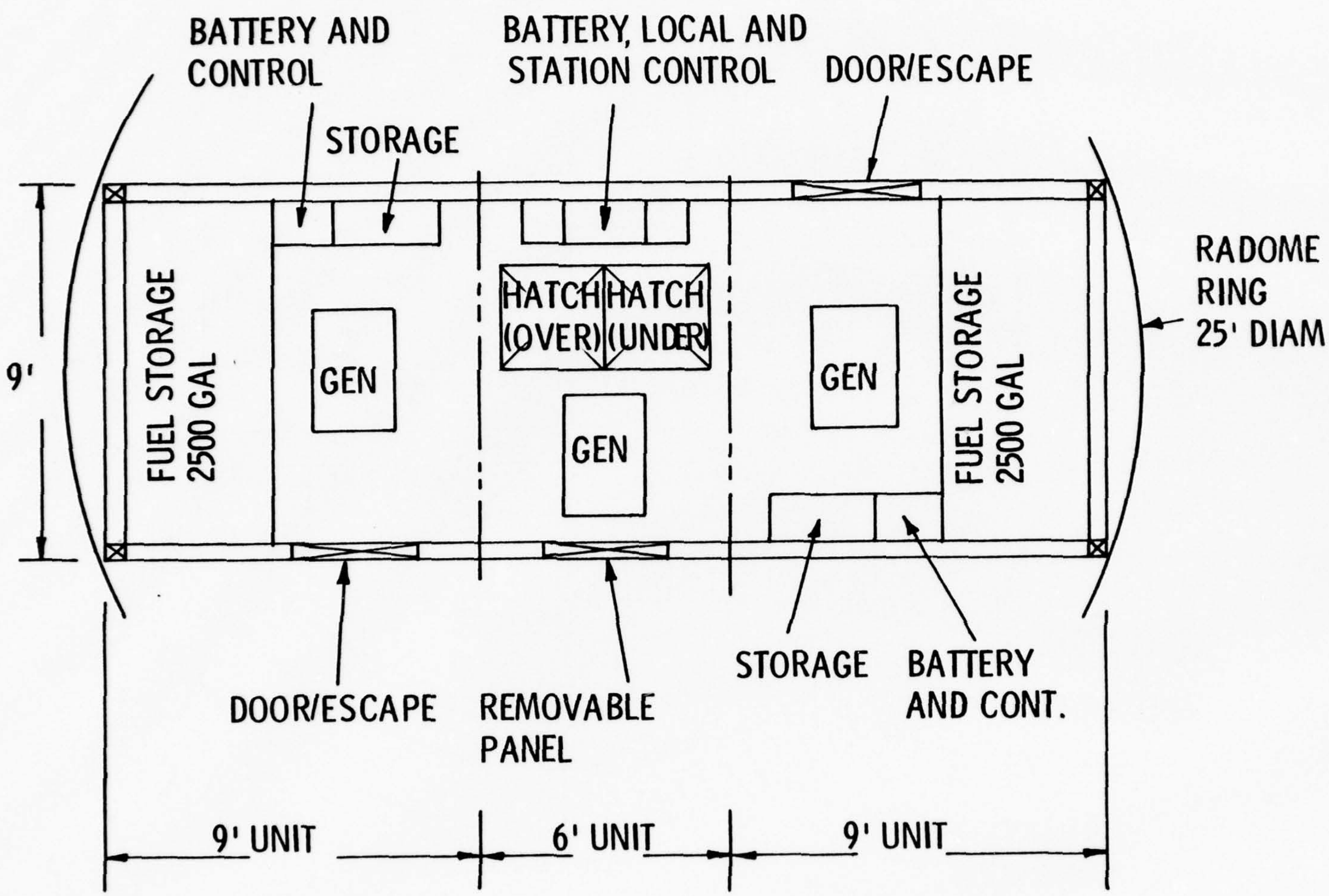


FIGURE 3.4-14

ELECTRONIC/POWER/LIFE SUPPORT COMBINED CONFIGURATION

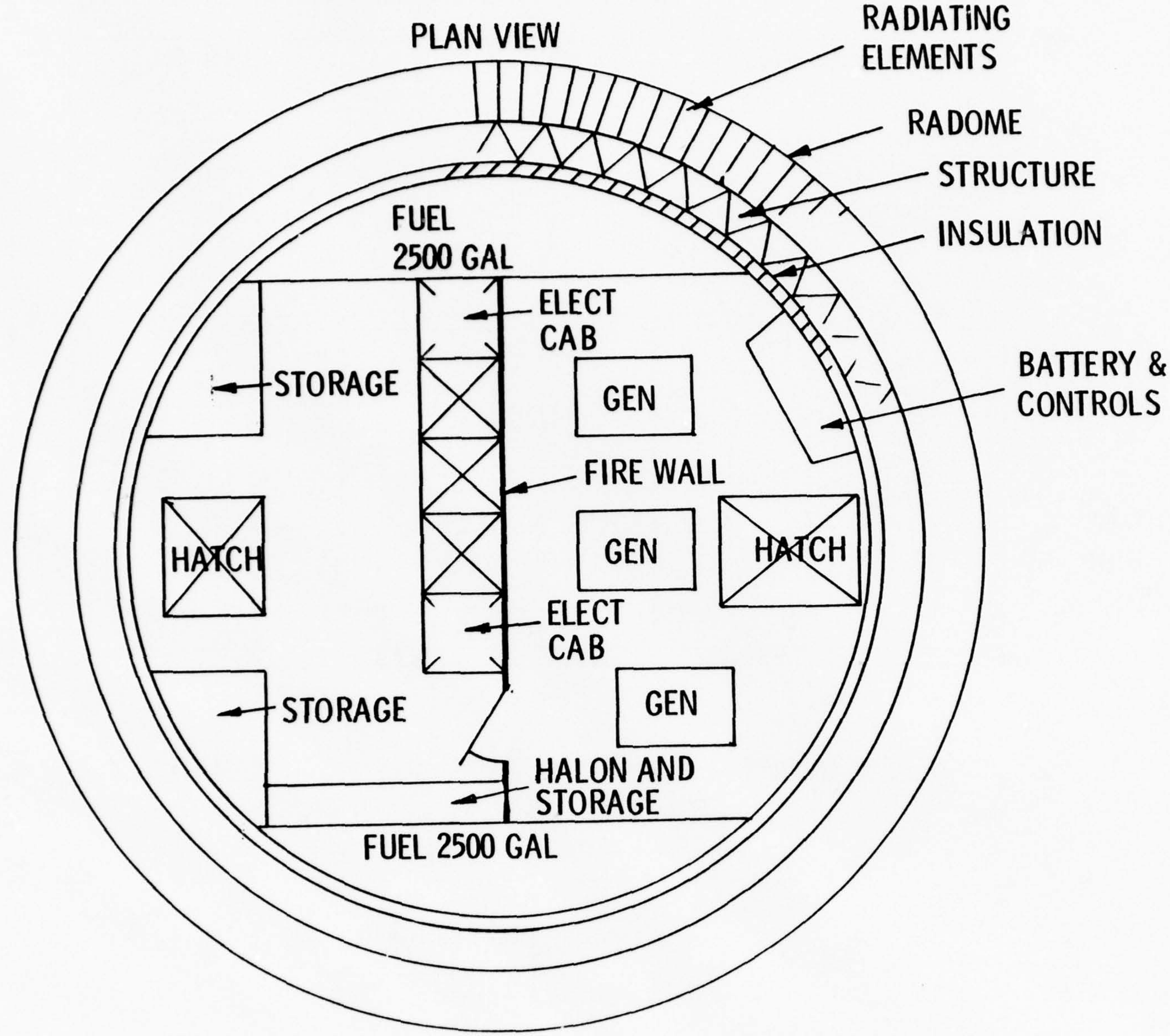
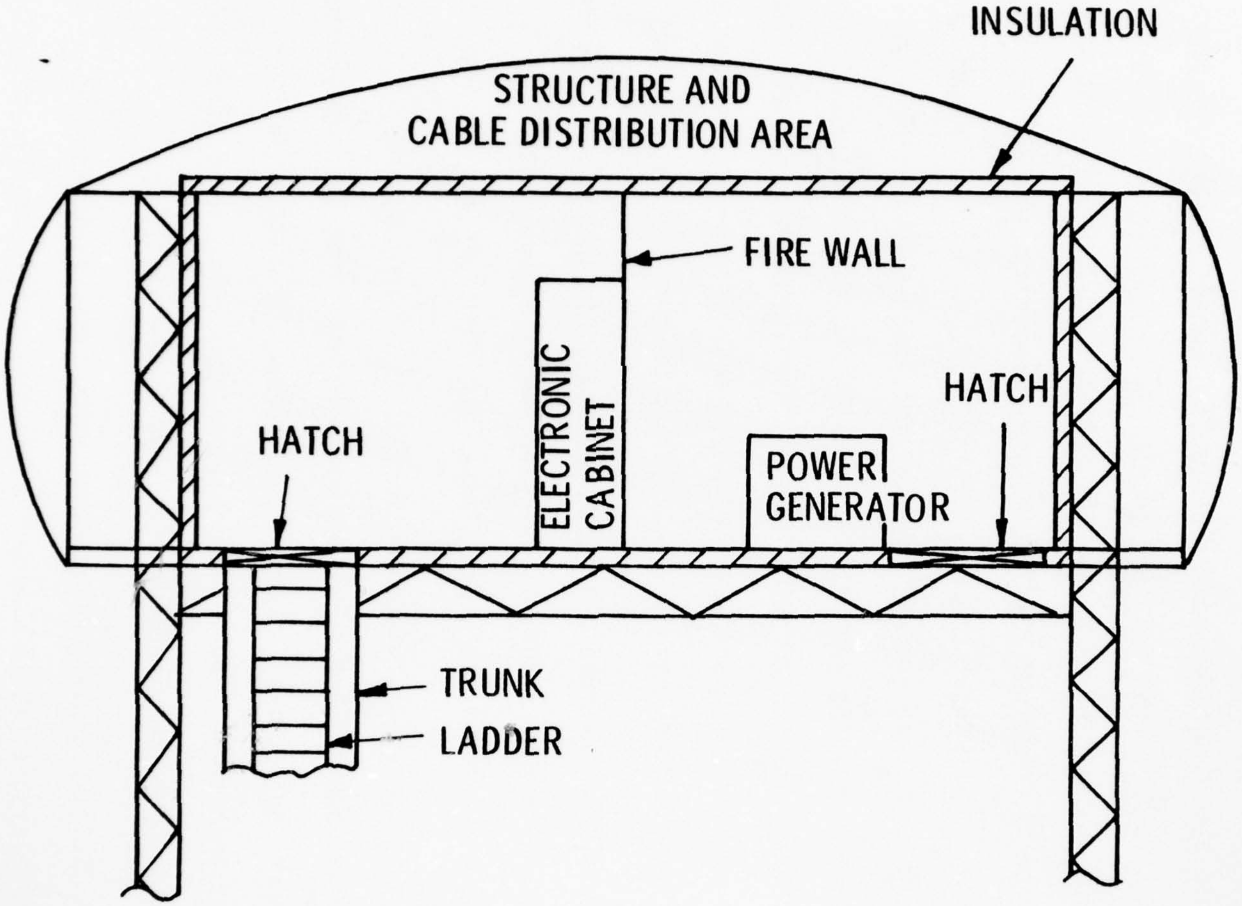


FIGURE 3.4-15

ELECTRONIC/POWER/LIFE SUPPORT
COMBINED CONFIGURATION
ELEVATION VIEW



a ring 25 feet in outer diameter is assumed covered by a weather protecting radome. Allowing for elements 8 feet high the outer parameters are then fixed. Radiating elements are assumed to be 18 inches deep supported by a ring structure 12 inches in depth which is covered internally by 6 inches of insulation. An inner skin is provided to protect the insulation. If the final radar design does not include a radome then weather protection would be incorporated in the insulation sandwich as described in Section 3.4.6.3. Fuel tanks which are sections of a cylinder are positioned at either side of the interior and sufficient space is provided for the required five cabinets of electronic gear which are separated by a fire wall from three power generators. A hatch in the power area will accommodate a complete engine generator set, and would also provide an emergency exit. Overhead rigging gear would be built into the structure to accommodate handling for engine change out. A hatch in the electronic side would be the main personnel entrance and would be large enough to pass an entire electronic cabinet in the unlikely event that it would be required to change this equipment.

Due to the structure and radar radiating elements side wall penetrations would probably not be practical but roof and floor penetrations could be used for engine air intakes and exhaust pipes and for fresh air circulation intakes.

In this concept life support facilities are not provided. It is assumed that survival equipment and rations would be used from the supplies carried in the transport helicopter. There is sufficient floor space in the electronics portion of the station for two double deck camp cots. If desired, folding cots of this type could be provided in storage at the station.

The facility combining the radar, electronic equipment, power and fuel storage in a single radome shelter is the General Electric recommended approach. It is a compact design providing all the required functions of the station shelter. It imposes no additional wind loading, the governing factor, to the support tower structure than would the radome alone.

All the components of the station would be pre-installed and pre-tested before shipping. It would be disassembled, with false partitions added as required to form six shippable units. Two units would be light in weight, each approximately 22 ft. long, 7 ft. wide and 8 feet high. Four heavier units containing equipment would each be 12.5 feet long, 7 ft. wide and 8 feet high. After delivery to the job site the units would be reassembled on a tower of the required height and all site elements to form the unmanned station.

3.4.7 Fire Protection

Fire protection is extremely important for remote unattended radar installations. In addition to the potential for system outage and equipment loss, fire is a definite threat to the lives of visiting maintenance personnel.

A multi-path approach is taken for fire protection. The primary path involves prevention, through use of fire-resistant materials, proper enclosure of required combustible materials (e.g., fuels) and good housekeeping. Next, a path involving isolation is also followed.

The power generation area would be separated from the electronic area by a fire wall, and each area would have a hatch for egress.

The third path to fire protection is detection. Fire hazard unfortunately cannot be entirely eliminated, and, when it occurs, it is totally unpredictable, and therefore detection and remote reporting of the hazard at the earliest possible time is important.

A number of good fire detectors are available. Applying these detectors to their best advantage entails surveying each area as to the possible threat of fire or explosion and selecting the detector which offers the greatest sending reliability in the shortest possible time and incorporating into a well-thought-out alarm system.

Some of the types that would be considered are rate-compensated thermal detectors, ultraviolet or infrared optical detectors, products of combustion detectors, or precombustion condensation nuclei detectors. If considered appropriate a time delay could be incorporated into the system. This would give visiting maintenance personnel time to assess the threat and react to the situation. Detector spacing and overall system design would be in accordance with NFPA (National Fire Protection Association).

One detector that could very well serve the site's needs is the products of combustion detector (ionic). This unit is very sensitive to particles of combustion in the air and can be applied effectively in many situations. This detector in combination with a visible smoke detector (photocell) can offer excellent detection in modules containing electronic or electrical equipment. Also, insofar as electronic cabinets are concerned, detection could be accomplished inside the cabinet as well as in the room environment. The selection of detectors singly or in combination for each protected area should be addressed at detail design.

The typical unattended site would be divided into fire zones:

1. Power generation module
2. Electronic equipment module

Each zone would be monitored by fire detectors singly or cross-zoned. Crosszoning requires that at least two detectors in each zone be provided and wired on separate circuits.

Pre-alarm would be accomplished upon actuation of any one detector. This pre-alarm signal would be displayed on the local and remote control/annunciator panels. It would also actuate an audible alarm to alert site personnel when the site is attended.

The local control panel would have battery stand-by power. Manual pull stations would also be strategically located in each fire zone.

The fourth path to fire protection involves suppression and control. A suitable extinguishing agent that could be automatically released upon command from the control panel is Halon 1301 which has been selected over water deluge or powder systems for this application.

Halon 1301 has a low boiling point ($-72^{o}F$) and is colorless. The Halogen compound reacts with the transient combustion products that are responsible for rapid and violet flame propagation. This reaction terminates the combustion chain and thereby stops the flame propagation. Halon 1301 has very low toxicity. This is important because it gives personnel a measure of time to prepare themselves before evacuating the enclosure. It also permits arriving personnel to enter the enclosure with minimal danger of the gas upsetting their body functions. It is a safe and effective fire-extinguishing agent for use on a Class A (cellulosic materials), Class B (flammable liquid), and Class C (electrical) fires. It leaves no residue nor will it attack or react with normal materials of construction. It is particularly advantageous for use against fires involving delicate electrical, mechanical, or electronic equipment and high-value storage areas.

The extinguishing system would provide high-speed release of Halon 1301 based on the concept of total flooding of the protected area. A uniform extinguishing concentration will be created within the enclosure by the rapid release of a predetermined amount of Halon 1301. The amount of the agent required would be based upon the size of the enclosure, the expected ambient temperature, and the concentration required to extinguish. Where products of combustion detectors are used, the automatic release would be accomplished by activation of any two cross-zoned detectors within a fire zone or protected area.

Because the unattended modules are designed to have little to no leakage with the outside environment, a small amount of Halon 1301 can provide excellent protection. When the modules are attended ventilators would automatically be shut on fire detection. Also, upon release of the agent site power could be selectively or completely shut down.

The multipath approach to station fire protection minimizes risk from the most formidable destructive force - fire.

3.4.8 Environmental Control and Energy Utilization

Details of the heating requirements are covered in Section 3.3 under Total Energy Concepts. The discussion here is included merely to demonstrate that supplemental heating is not required at the unattended station either in the unmanned or manned situation, when considering the "survival only" shelter concept. Figure 3.4-16 is a summary of the requirements and availability of heat. It may be seen that the electronic equipment will be maintained at 35°F with an outside temperature of -65°F merely with heat generated within the cabinets. The entire shelter volume in either the separate power-electronic shelter concept as shown in Figures 3.4-9 and 3.4-13 or the combined concept shown in Figures 3.4-14 and 3.4-15 including the fuel tanks, can be maintained at 40°F with an outside temperature of -65°F with the heat recoverable from a single engine generator as would be the situation in the unmanned case. When maintenance personnel are present and two engine generators are activated the entire shelter volume can be maintained at 70°F with an outside ambient of -65°F. Summer equipment cooling requirements can be met by natural convection with an external air temperature of 80°F. When maintenance personnel are in attendance a forced air circulation system could be activated if required to maintain a comfortable working environment.

FIGURE 3.4-16

ENVIRONMENTAL CONTROL

- REQUIREMENTS

	HEATING	COOLING
- EQUIPMENT	(35° at -65°F) SELF CONTAINED	(100° AT 80°F) CONVECTION
- FUEL	(40° AT -65°F) FROM GENERATORS	(100° AT 80°F) CONVECTION
- PERSONNEL	(70° AT -65°F) FROM GENERATORS	(80° AT 80°F) LOUVERED FAN

- AIR SUPPLY
  - DIESEL - DUCTED & LOUVERED
  - PERSONNEL - LOUVERED FAN

Shelter enclosures will be designed to prevent infiltration. Penetration will be held to an absolute minimum, no windows will be provided and doors (hatches) will be double sealed.

Personnel visiting the shelters will generate water vapor which must be carefully controlled. The ventilation system will be integrated with the heating system to automatically purge humid air from the shelters during and after a visit by a maintenance crew.

The insulation in the floor, walls and ceiling and all pipe, wire, conduit and other metal which penetrates the insulation must be sealed by vapor barriers to prevent moisture from entering the insulation where it could form ice or water and reduce the insulation value.

It is not envisioned that any air intake for power generation or fresh air would exceed 6 inches in diameter. They would be floor penetrations with screens and snow deflectors. Required louvers would not be exposed wall mounted but would be in ducted circulation boxes inside the module to prevent weather related malfunctions.

3.4.9 Configuration

As discussed in Section 3.4.4, Radar towers, some form of tower is recommended for any site location. While most may be relatively short, 25 feet high, the fact that towers are required suggests a number of designs where the support systems, (power, fuel, emergency quarters, communications, etc.) might be incorporated into the tower, or may be in addition to the tower structure.

An initial thought might be of a configuration where the radar is elevated by a cylindrical self-supporting tower which is enclosed and houses the support systems forming a silo like structure as in Figure 3.4-17 (1). While this might seem to be a simple solution, there are objectionable features, some of which are easily overcome. The cylindrical cross section implies hoops or ring sections which provide inherent strength but are usually more difficult to transport and erect. It is also generally less efficient in floor area utilization which can be changed by use of a square or rectangular cross section tower.

The tower resting on grade imposes the problem of a heated facility on permafrost. The tower could be elevated on piers to provide air circulation under the first enclosed level as in Figure 3.4-17(2).

Towers for support of communication antennas could be mounted on the top of these structures if appropriate.

While considering the vertical concept thought might be given to an elevated helicopter landing pad on the top of the complex as in Figure 3.4-17 (3). Roof top heliports are quite common and would provide the advantage of being wind swept and free of drifting snow. Significant advantage would be gained in the area of site security as well in that egress would be restricted to the top of the structure.

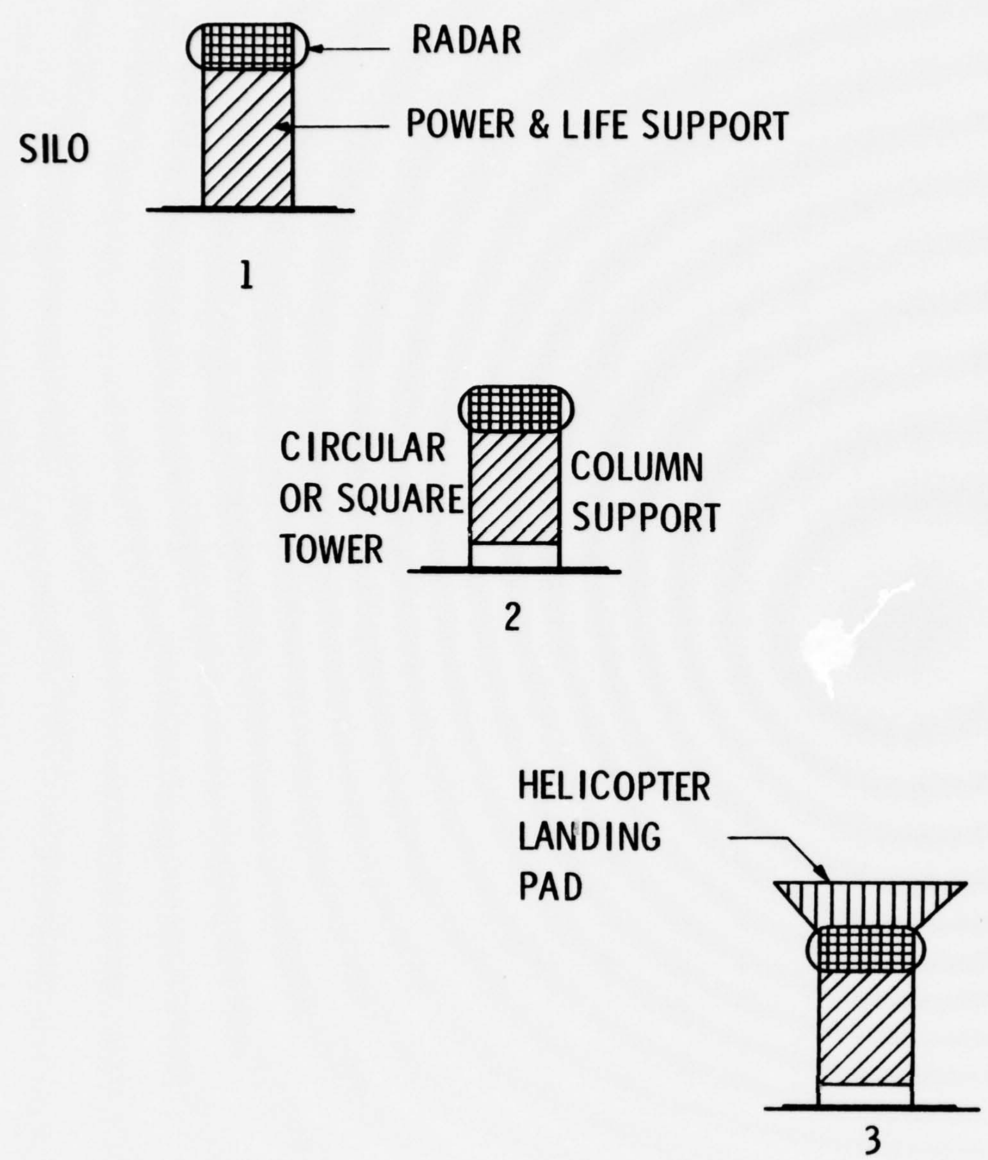
Communication antenna towers on the structure would be incompatible with the elevated helipad but possibly reflector type antennas could be employed at the pad edges.

While these concepts have some attraction they also have some objectionable features. Rigid (free standing) towers require fairly complex foundation designs to overcome the overturning moment imposed. Also the vertical concept provides a flue effect which is a disadvantage from a fire safety consideration. The possible necessity of refueling helicopters on the tower top also add to the fire safety problem.

The elevated concept with enclosed towers would impose high wind loading on the structure. It also requires more complicated erection procedures and equipment.

FIGURE 3.4-17

ENCLOSED TOWER



As there are some disadvantages to the solid tower concept then open tower designs are suggested. Figure 3.4-18 (4) depicts a tower of sufficient height and stiffness to accommodate the radar with the support equipment in a separate structure. The open tower allows for greater simplicity in foundation and erection and the open structure resists the wind loading. The tower may be free standing or guyed.

Moving the support equipment modules under the tower as in Figure 3.4-18 (5) simplifies the design and shortens transit time and cable lengths.

The support equipment modules could be placed on top of the radar as in Figure 3.4-18 (6) and perhaps the helipad added as in Figure 3.4-18 (7). While these concepts would provide additional security they would add to the tower loading with a resultant increase in structural stiffness requirement, foundation design and erection complexity.

The oil rig concept as shown in Figure 3.4-19 (8) is a well proven technique although with limited high arctic application. It provides a compact design and affords good security provisions.

A variation of the oil rig is shown in Figure 3.4-19 (9) where the support modules are separated from the radar tower and the helipad placed on the roof. This concept would enlarge the helipad and eliminate some of the objections of the vertical arrangement approach.

While the oil drilling platform is of proven design they would probably be expensive for the DEWLine application and difficult to erect. Off shore oil rigs must provide their own real estate which is not true of the land based drilling rig or of the DEWLine Radar Station. While Arctic station land is not free, (insulating pads are required over permafrost), it is less expensive than fabricated and erected platforms with some possible exceptions where insulation (gravel) is not readily available.

FIGURE 3.4-18

OPEN TOWER (RIGID OR GUYED)

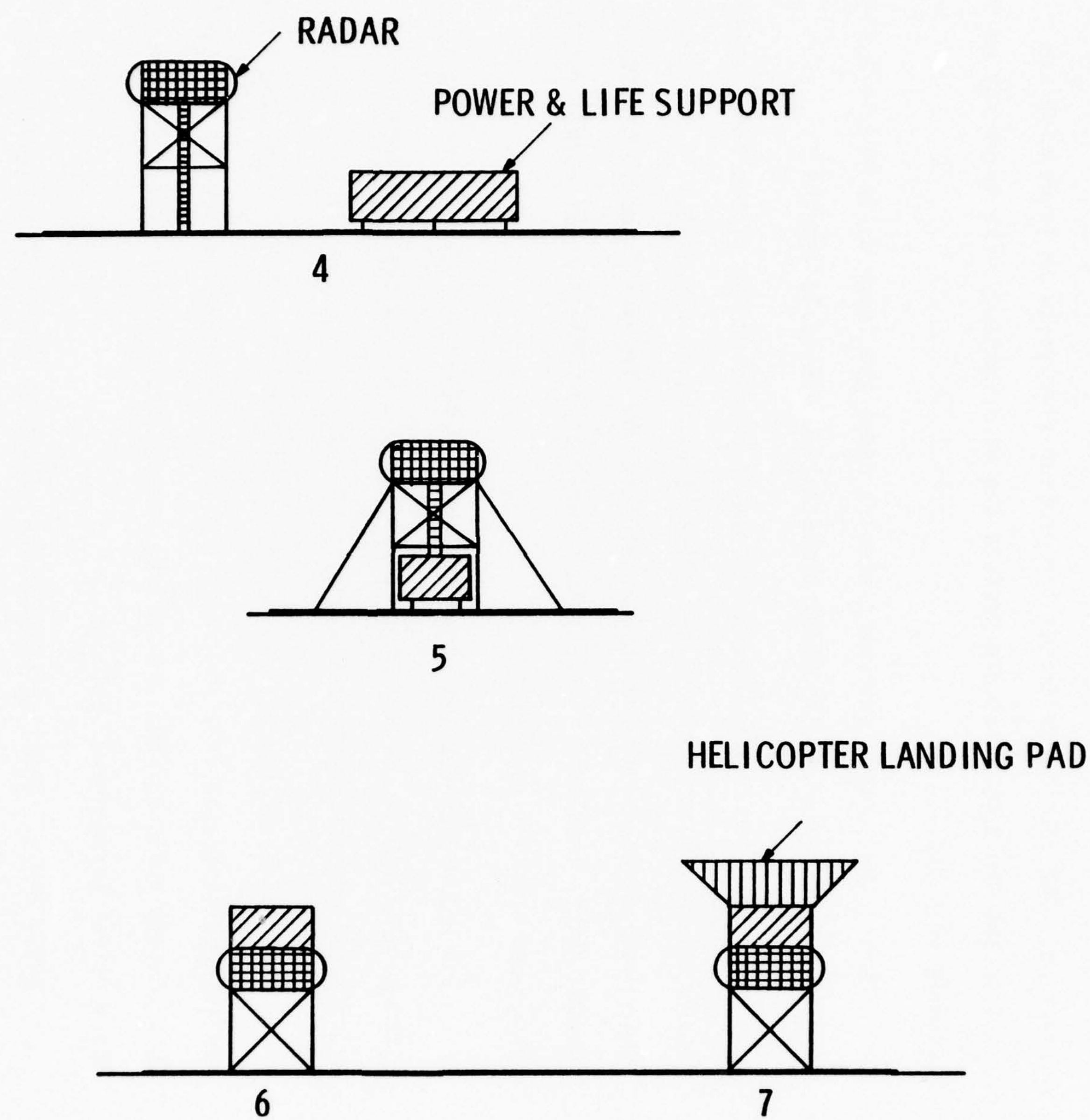
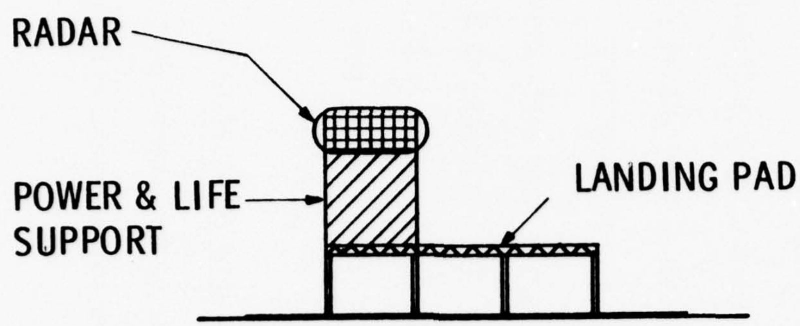


FIGURE 3.4-19

DRILL PLATFORM



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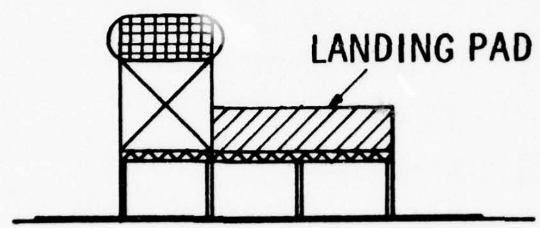

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The present DEWLine Sites have employed a design that has proven very satisfactory over the past 20 years. The radar is elevated on a guyed platform and the support equipment modules are placed underneath. In all existing DEW Installations the existing towers are of the required elevation. There are no moving parts involved, therefore there is no wear and inspection of the facilities has indicated little if any corrosion or deterioration. It is quite probable that the existing towers can be used directly in practically all cases. Where sites have been abandoned and the towers removed the foundations may be found to be usable. On new site locations a similar or even identical design could be used with known and proven techniques. Figure 3.4-20 (10) depicts a new radar and support equipment module using the present tower configuration.

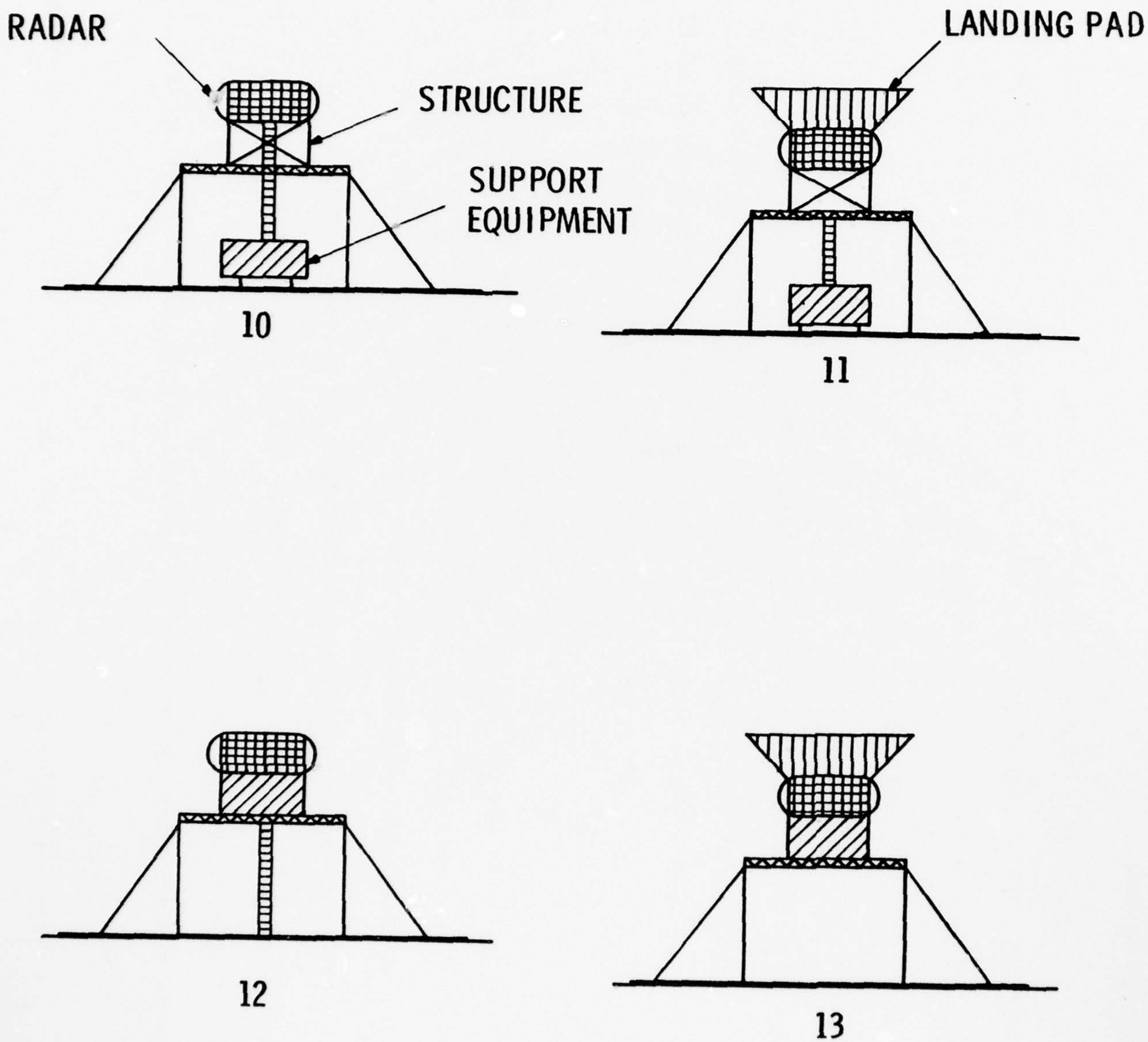
The radar antenna is shown elevated on a structure from the existing platform to provide a clearance angle of approximately 45^{o} for the radar beam.

Figure 3.5-20 (11) shows a modification using the same configuration as Figure 3.4-20 (10) with the addition of a helipad. This concept has little security advantage as the support equipment module is at ground level, but the elevated helipad has the advantages of being above surface blown snow and will be wind-swept clear.

If the elevation of the support equipment module is desirable for a security advantage and for direct access to the radar it could be accomplished as shown in Figure 3.4-20 (12). Existing towers would have to be extensively checked for loading capability if this arrangement is used.

The addition of the elevated helipad is shown in Figure 3.4-20 (13) with the advantages as previously described. Again load capability of the existing tower design must be checked.

FIGURE 3.4-20
PRESENT PLATFORM USE



Some other concepts that might be considered include the single stand water tower type in Figure 3.4-21 (14) and the stiff leg water tower style of Figure 3.4-21 (15). Both would probably complicate foundation construction and be costly to erect.

An exoskeletal design that appears quite attractive is shown in Figure 3.4-21 (16). This concept employs a power equipment shelter that has sufficient rigidity inherent in the shelter panels to support a short tower section and the radar shelter.

The exoskeletal model appears to be a logical approach where a power equipment shelter is required or desired separate from the electronic shelter. Where the two may be combined then the configuration resolves into one simple unit, the radome/electronic/power shelter combination all supported by a simple open structure tower as shown in Figure 3.4-21 (17) and previously discussed in Section 3.6.3.

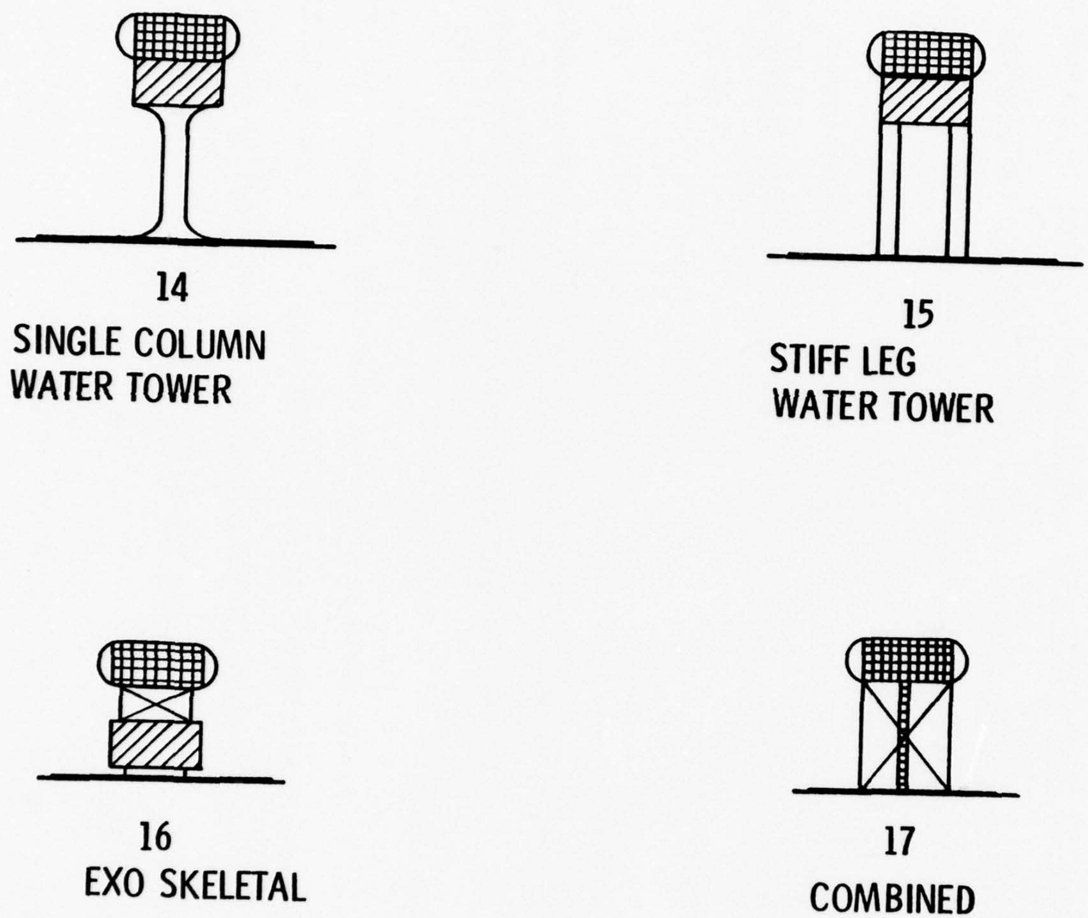
The figures used in the above discussion were intended to convey the various design concepts. They are roughly to scale but are not intended to convey actual dimensions required for practical design considerations.

It may be noted that a radome is required for the radar antenna. While a spherical radome is usually most desirable considering performance, wind loading and ice loading, a toroidal (doughnut) section could be used in cases where a landing pad or communication tower is positioned on top of the radar antenna structure.

A system of stairs and landings either open or enclosed might be considered for the lower portion of the ladder trunk, especially in the tall tower concept. However for security reasons (see Section 3.4.10) it is recommended that at least the upper 10 feet of access be a trunk enclosed ladder.

FIGURE 3.4-21

VARIATIONS



In the unlikely event that very tall towers are required to elevate the radar than other configurations must be considered. Due to time and resource limitations on this study a detailed analysis has not been performed, however; indications are that at tower heights much over 50 feet the structural system becomes more sensitive to seismic conditions than to wind loading. The electronic equipment would probably continue to be housed in the radome because of performance losses. To reduce the elevated weight the power plant and fuel storage would be housed in a separate shelter within the tower structure but at a lower elevation, Figure 3.4-22 C. Approximately fifteen feet of elevation for the power plant would preserve the security aspects of the elevated design, would prevent drifting snow problems, and provide for decoupling the heated structure from the permafrost layer.

The recommended shelter system is shown in Figure 3.4-14 and has been previously described in detail in Section 3.4.6.3. This unitized configuration would be prefabricated and sectionalized. Equipment components could be pre-installed and tested prior to sectionalizing for shipping.

The shelter system would be supported by a tower of appropriate height to satisfy the individual site situation. In the case where existing DEWLine radar towers are employed, Figure 3.4-23, a support tower of about 10 feet would be required to raise the radar above the existing 50 foot radar platform and provide required radar clearance.

In utilizing the existing DEWLine Towers consideration was given to using the plenum under the tower as the electronic and power shelter as shown in Figure 3.4-24. This plenum is approximately 15 x 50 feet in plan and 8 feet high which provides more than adequate space. However the walls are plywood, the floor and ceiling are also of wood, and there is no insulation. Considerable

FIGURE 3.4-22
OPEN STRUCTURE

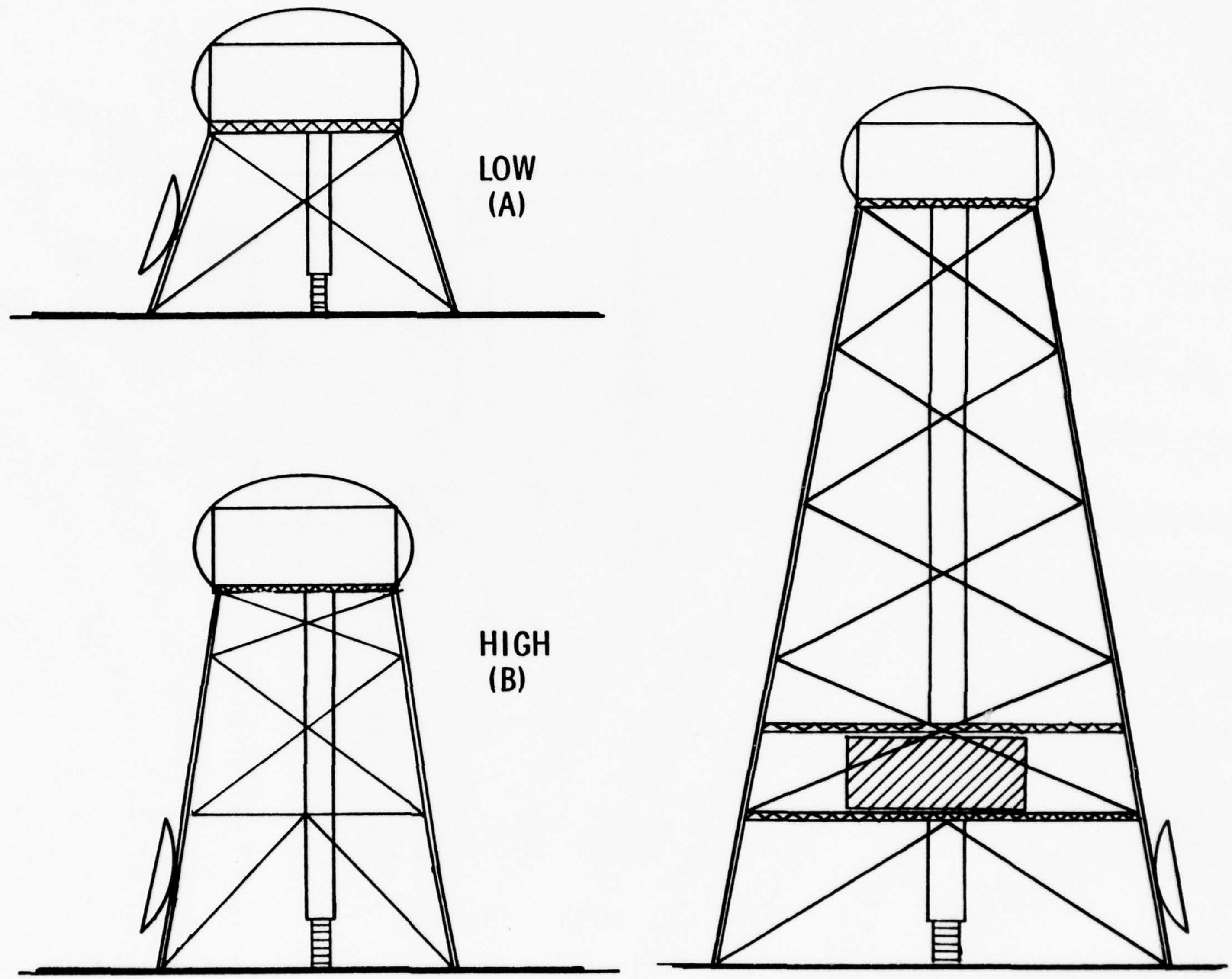


FIGURE 3.4-23

EXISTING PLATFORM

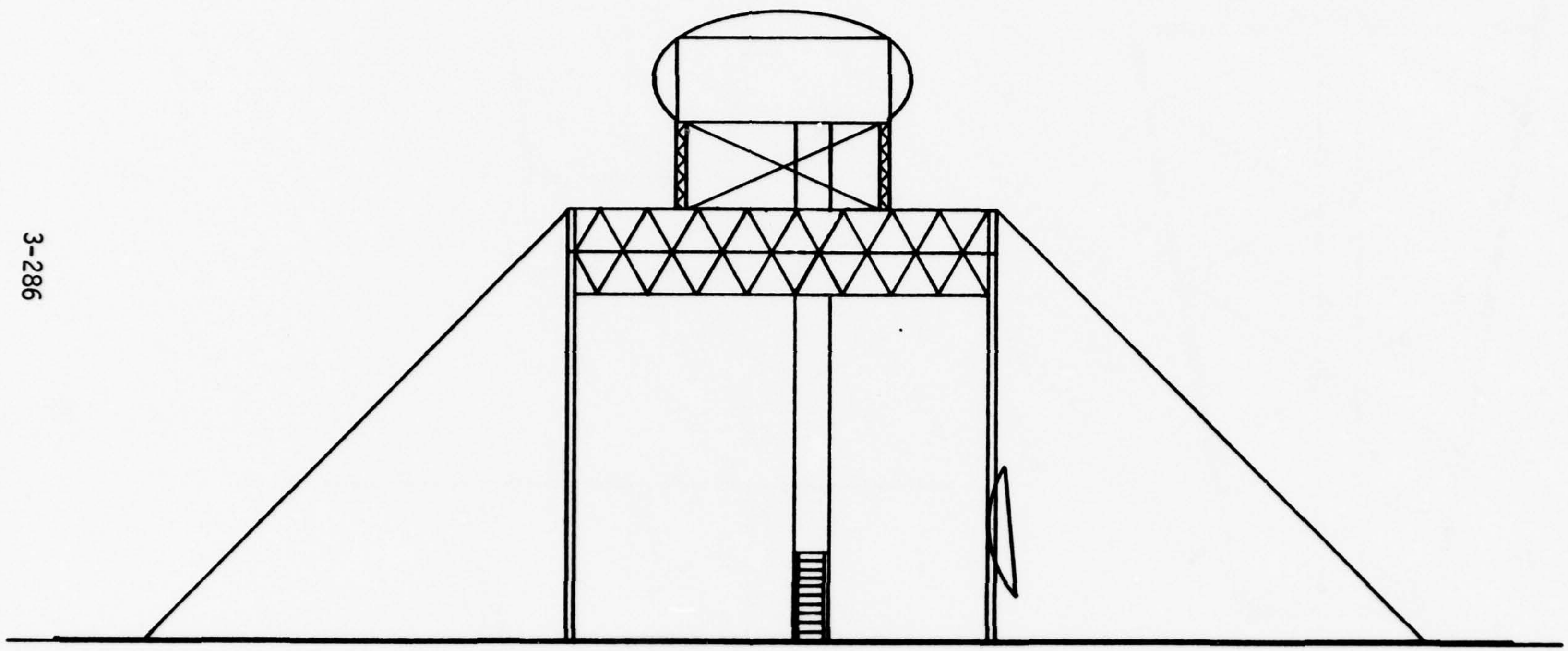
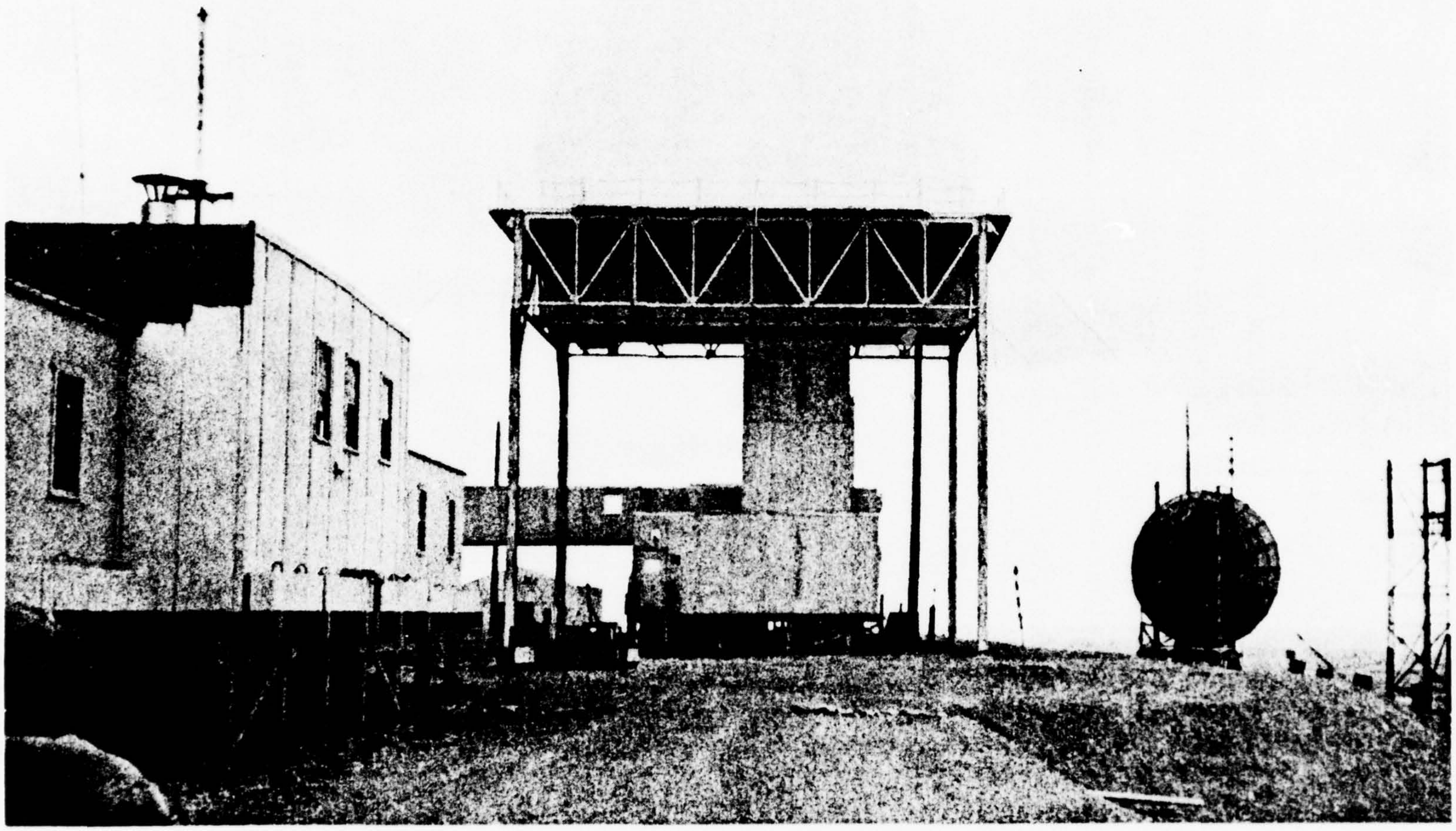


FIGURE 3.4-24



TOWER & PLENUM
POW-MAIN

on site work would be needed for the required modifications which would be quite expensive, (DEWLine rates are 3.5 times labor rates at Washington, D.C.). In addition the radome and radar, elevated some ten feet above the platform level, would still be required. Because of electric line lengths the electronic equipment would probably be required to be housed in the radome. This leaves only the power generation and fuel supply to be housed in the plenum. It does not seem advisable to put this facility in a wooden structure from a fire safety viewpoint. It would also be more difficult to effectively use the heat generated. Considering all of these factors it is not recommended that the plenum be considered for incorporation into the unattended station design.

Where new sites are developed the same shelter complex as described above would be supported by a tower to provide 25 feet of elevation above grade as shown in Figure 3.4-22 (A). Additional tower height may be added for any sites where required to meet the 125 feet above sea level condition, Figure 3.4-22 (C).

The "Secure Station" concept as shown in Figure 3.4-25 and Figure 3.4-26 employs the principle of vertical resupply and has the advantage of being quite secure. Access is only practical from the tower mounted helicopter pad. Detail design must consider a number of options and variations to the basic concept. The helipad support structure is flared out from the radome to provide the required 40 foot diameter of the pad. This adds some height to the structure and the space available could be used for power generation, fuel storage and electronic components. Hatches would be provided in the pad deck to allow emplacement or removal of these equipments as well as for personnel access.

Variations to the ground access ladder system should be addressed. The diagrammed arrangement indicates a ladder to the communication antenna and a platform. There is a gap between the platform and the radome shelter hatch.

FIGURE 3.4-25

SECURE TOWER

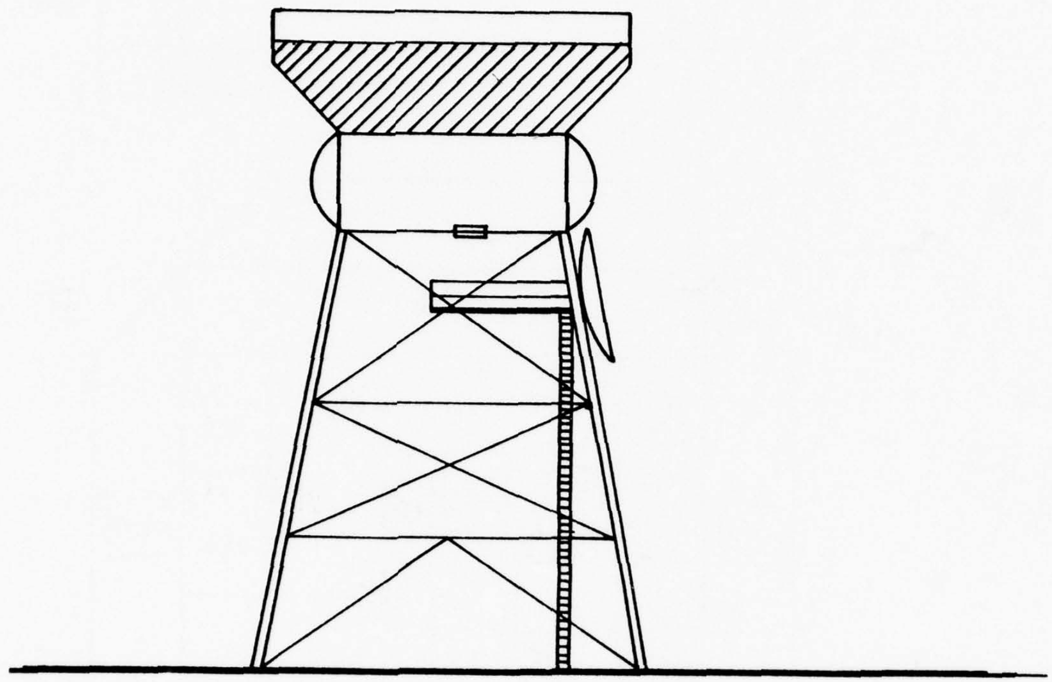
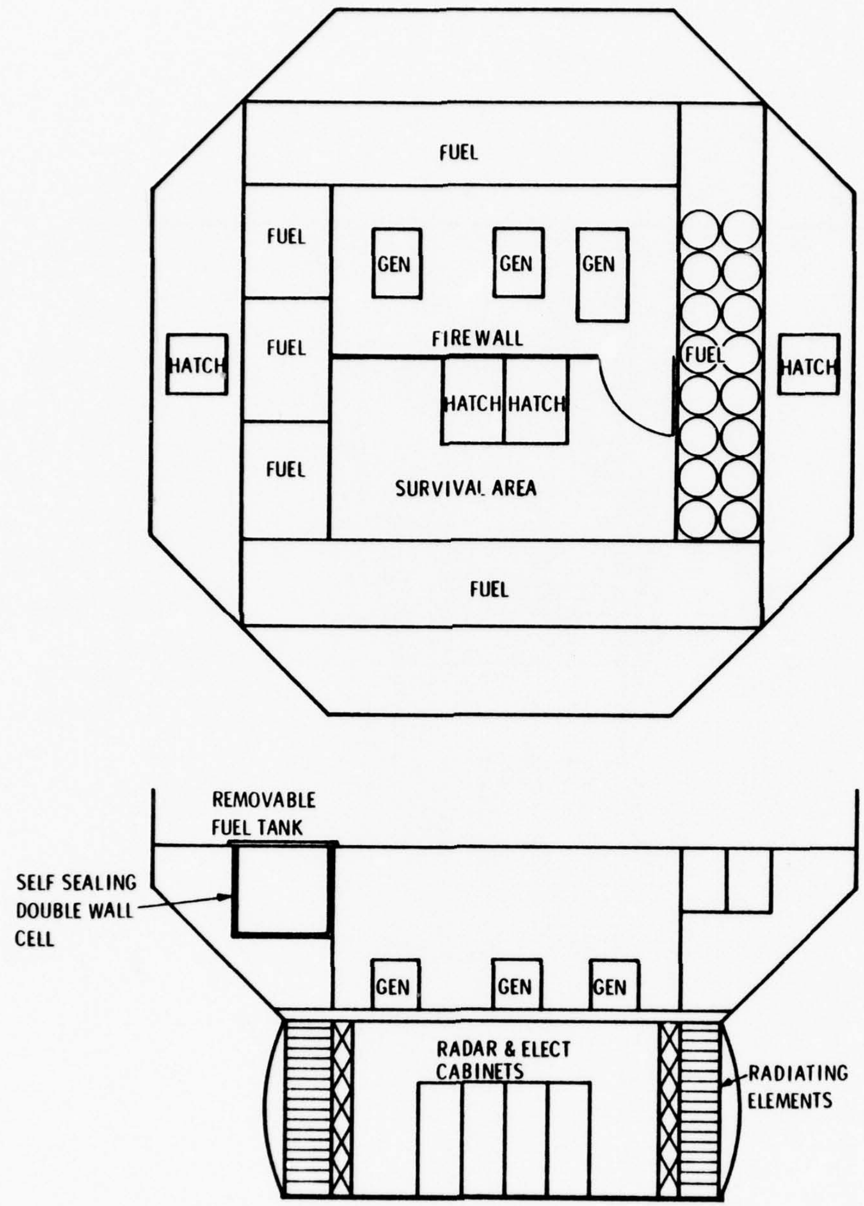


FIGURE 3.4-26



FUEL
FUEL
GEN
GEN
GEN
FUEL
FIRE WALL
HATCH
FUEL
HATCH
HATCH
HATCH
FUEL
SURVIVAL AREA
FUEL
REMOVABLE
FUEL TANK
SELF SEALING
DOUBLE WALL
CELL
GEN
GEN
GEN
RADAR & ELECT
CABINETS
RADIATING
ELEMENTS

This gap is filled by a ladder within the shelter which is lowered and withdrawn as required. Other arrangements including enclosing the ladder and platform may be considered as long as the principle of limited access is maintained.

The Secure Tower concept shown has not been selected as the recommended candidate because of design complexities and higher initial costs. However, this approach might be considered where severe security problems are anticipated or especially unfavorable terrain is encountered.

A helicopter pad should be constructed as close as practical to the unattended station tower. A distance of 200 feet from obstructions may be required but ships and oil rigs successfully use pads that violate this principle. A separation distance of 20 feet from the tower base to the helipad is considered practical. The pad would be a level area of locally available gravel roughly 50 feet in diameter and elevated about one foot above the surrounding terrain. This slight elevation will prevent drifting and help maintain a snow free area. The pad will be equipped with navigation aids as described in Section 3.3. In permafrost terrain a "path" of gravel would be provided from the pad to the tower and a working area of gravel would be formed around the base of the tower. An earth berm (dike) about 1.5 feet high would be formed approximately 25 feet in diameter around the tower base to meet the requirements for diking the oil supply storage.

The helicopter pad would be provided with electric service for emergency starting of aircraft and local lighting. This service would be operable from within the station and conduit would be laid directly on the ground to a post mounted terminal at the pad.

Emergency refueling of aircraft would be available at the pad from the same fuel as stored in the station for power generation. As this refueling would occur in emergency situations only, elaborate facilities need not be provided. In fact the same piping system as used for fuel resupply may be utilized. A dry pipe could be laid directly on the ground or slightly elevated with valve control from within the station. A small pump could be provided in the station if gravity flow in very cold weather should prove to be a problem. A flexible hose, stored in the station, would be used from the helipad end connection of the pipe to the helicopter and would also be used to drain the pipe of the residual fuel, about 4 gallons, after refueling. If the distance from the tower to the pad, as developed by final design, is short enough, a portable hose system, stored in the station could be considered for emergency refueling and for resupply. A non-metallic hose has the advantage of being a poor thermal conductor and will have little tendency to chill the fuel which inhibits fluid flow.

After initial installation there will be very little material handling requirements. Except for fuel resupply which has been previously discussed and the planned change out of a power generator, all items of repair and resupply are easily hand carried. A diesel generator unit weighing in the order of 300 to 500 pounds would be lowered from the station with built-in handling tackle. On the ground it could be moved to the transport helicopter by a small, hand pulled caterpillar sled or dolly such as those used by furniture movers. This piece of equipment would be brought to the site with the replacement generator in the helicopter when a change is programmed. The helicopter would be equipped with handling equipment for on and off loading.

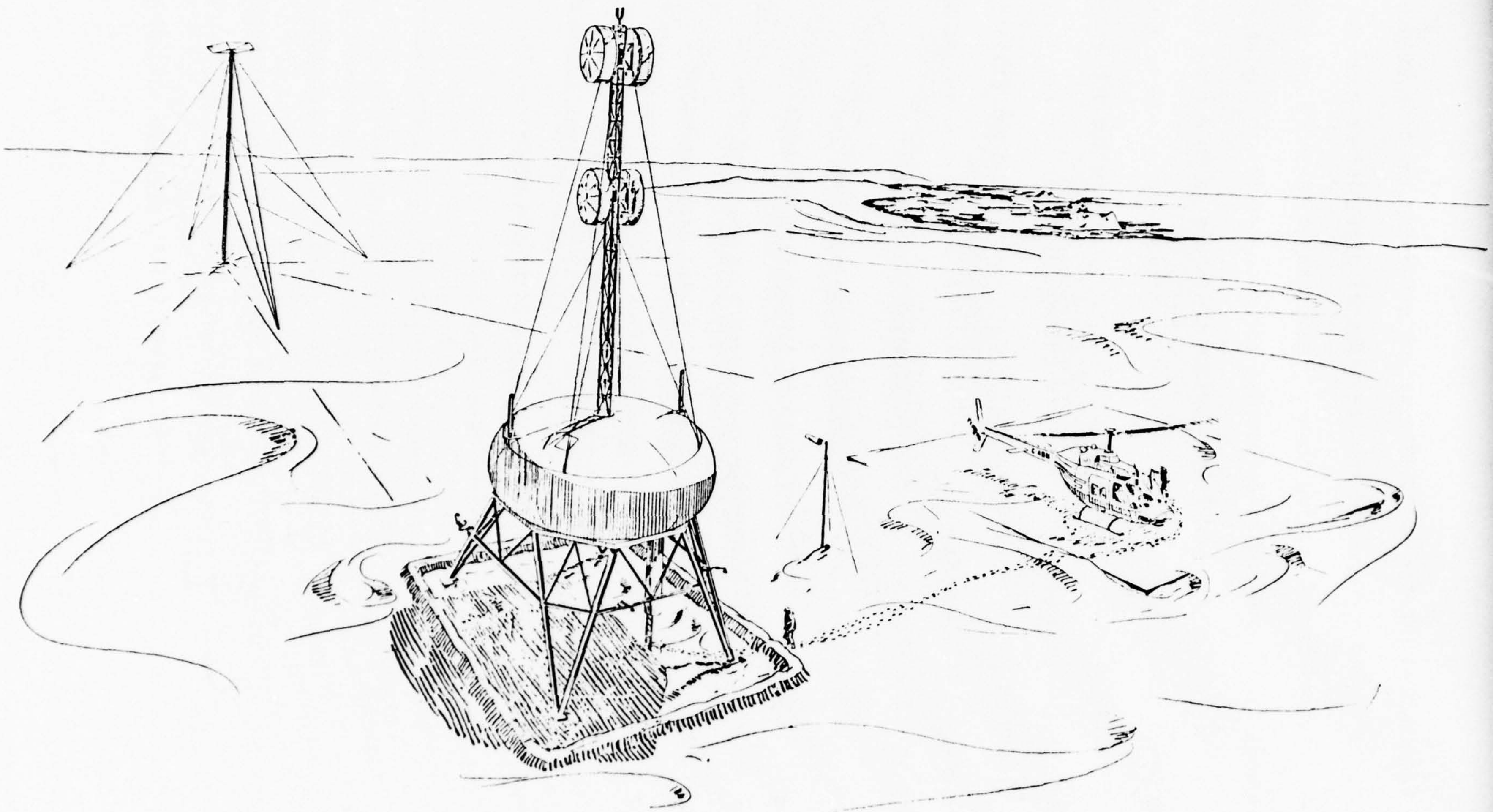
Considering the foregoing discussions outlining the maintenance and resupply concepts it is not recommended that any special provision be made for transport from the helipad to the station tower. The distance is short and material handling is not a difficult problem. Replacement parts are small and may be hand carried, fuel resupply and engine generator replacement would be on a preplanned basis during reasonably good weather. However, as discussed previously each site will require individual evaluation. Very heavy snow accumulation for example might present special problems requiring site unique designs. Non availability of a local supply of gravel could make the "Secure Towers" concept attractive as construction of a site working pad could be avoided. Or a constructed helipad as shown in the Oil Rig idea might be considered.

Figure 3.4-27 is an artist concept of the baseline configuration. It depicts the unified design with electronic power plant and fuel supply combined in the radar shelter. No on-site life support is provided. The two UHF/VHF antennas, approximately 8" in diameter and 6 feet high are mounted externally on the radome edge.

The tower extending from the top of the radome is shown supporting the microwave communication reflectors as required by the study baseline system. A ceiling and roof hatch would be incorporated into the final detail design to provide access to this equipment. It may be noted that the recommended system includes a satellite rather than microwave communication system.

The large tower in the background is a navigation beacon antenna. It is a guyed tower approximately 120 feet high supporting the antenna elements of about 10 foot radius. A ground screen consisting of radial elements 500 feet in length are required. In permafrost areas it is suggested that this equipment be installed during the spring or fall when the ground is frozen to preclude the requirement for a site working pad especially over the large area required for the ground screen radials.

FIGURE 3.4-27



Weather sensing equipment described in Section 3.3 is mounted to the tower structure.

A technical description of the various antennas, navigational aids and weather station equipment is found in the appropriate sections of this report.

Figure 3.4-28 is an artist concept of a recommended station design similar to that described above, but mounted on a modified DEWLine Radar Tower. This configuration uses the GE recommended satellite communication system and the antennas are shown mounted on the existing tower.

The artist concept shown in Figure 3.4-29 depicts a tall tower configuration with satellite communication antennas mounted on the tower frame.

3.4.10 Security

The need for on site security has been identified as the need to guard against theft, vandalism, sabotage and, to some extent, roving animal life.

The incidence of vandalism caused by native and resident northern people is a relatively new, and unfortunately growing problem but, so far, is encountered chiefly in and near to the larger settlements. It is not a problem of any magnitude in the more remote areas where the individuals and parties are hunters and travellers whose reasons for being on the land are of a serious nature.

Nevertheless every precaution should be taken to remove temptation from vandals. This should be achieved, wherever possible, by locating sites as far as practicable from coastal hunting and fishing areas and on terrain that discourages casual visits.

In no case should there be any provision for emergency food or shelter for travellers. The people of the north are totally self-reliant in this respect, and to encourage them to be otherwise would be to invite increased visits, if not settlements, at these sites.

FIGURE 3.4-28

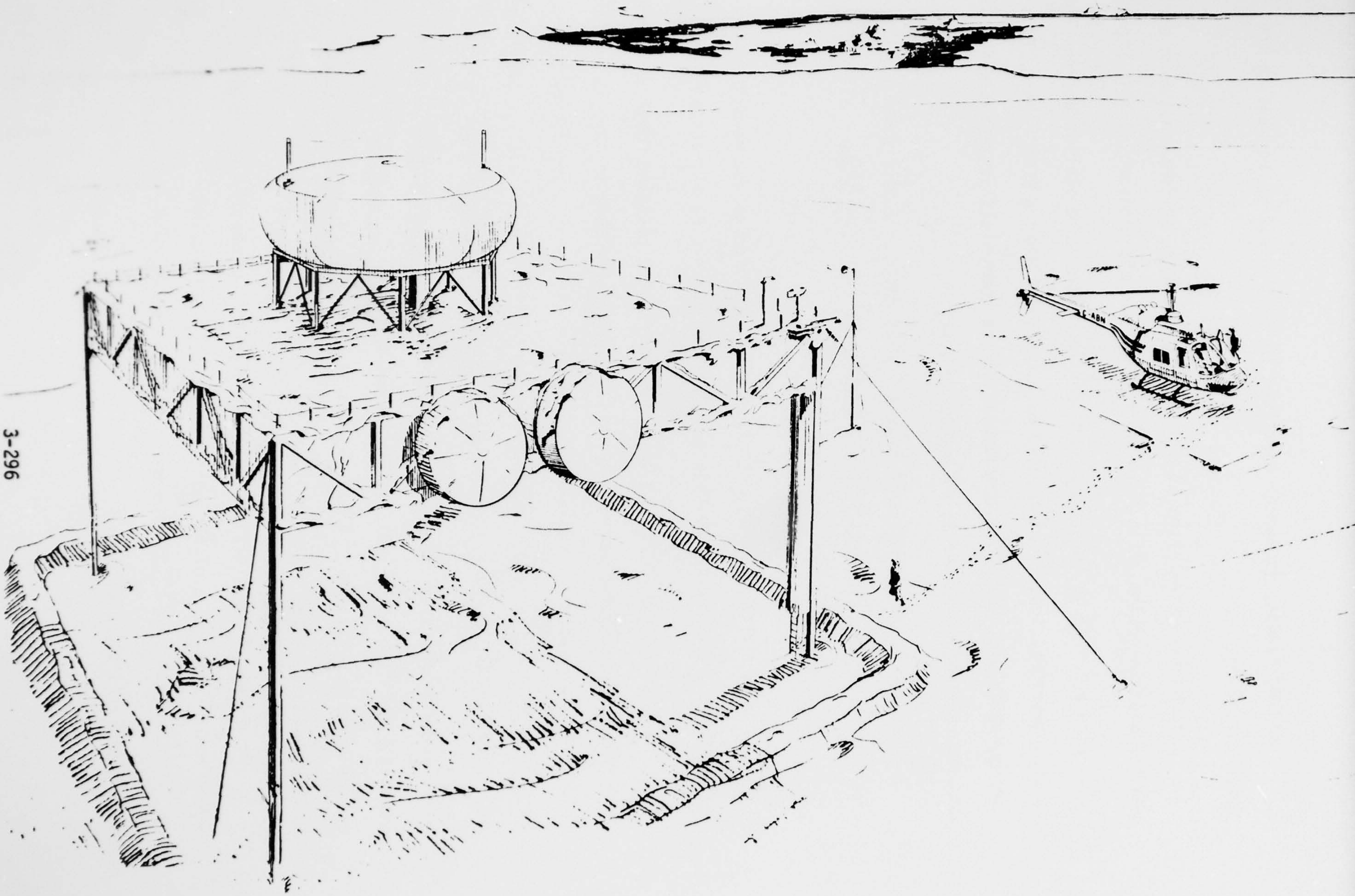


FIGURE 3.4-29

All site should be clearly posted with signs, in the languages of the area, stating that no food, fuel or accommodations are available and that the sites are under constant surveillance.

Generally intruders have a psychological need to remain undetected and unobserved, a formidable deterent to breaking and entering as well as vandalism would be the installation of an intrusion detection and site monitoring system.

The site could be equipped with an electronic fence that surrounds the area and signals an audible on site alarm as well as an alert signal at the nearest support base. This system could be coupled with a visual scanning system that could be triggered at the time of an alert signal. It should be considered, however, that response time would probably preclude the immediate apprehension of an intruder and is not considered to be necessary.

There is no need for fencing and the savings would be much better applied to ensuring that any penetration into the site is detected. The installation of windows will be avoided and the need for securely sealed means of entrance cannot be overstated.

The General Electric recommended configuration would utilize a single shelter combining the electronics, radar, prime power systems, fuel and other storage and space for emergency survival, as previously described in Section 3.4.6.3.

The enclosure would have no windows. The two hatches in the floor would open inward. The hatch in the power area would be flush mounted on the outside with no handles or means of opening from outside the shelter and no ladder or access to it. The shelter would be elevated a minimum of 25 feet above grade with the only access through the electronics room hatch accessible only by ladder. The lower five feet or so of the ladder would be exposed to prevent snow drifting but the remainder would be enclosed in a trunk. The situation facing a would be intruder may be described as follows: He is at the top of a 25 foot ladder enclosed in a tube with little space to maneuver tools such as pry bars or axes. It is dark since he could not activate the key lock light switch at the base of the ladder trunk. The trap door he must penetrate is overhead with no handles or other aids and is fitted with a flush key lock. He is being subjected to a piercing screeching noise since he could not deactivate the intrusion alarm, also key locked at the base of the trunk. He has been warned by multi lingual signs that his intrusion has been detected by authorities at a manned location. He has also been advised that there is no food or equipment of value to him in the enclosure.

Other devices could also be employed such as cipher locks or radio frequency locks, and depending on possible legal ramifications, noxious gas, tear gas or other deterrents could be emitted in the ladder trunk. These various locks could be remotely controlled from a manned location if detail design considerations determines this option to be desirable. Also consideration should be given to providing a "panic" button at the tower base. Notice to a stranded traveler would indicate the activation of the button signals a manned location that an emergency exists and he is in need of assistance. A communication system to the manned node could be provided if desired.

The recommended system would have all fuel stored in the radome shelter. Tanks can be protected against penetration as previously described.

Bullet proof materials that have reasonable RF properties are available that might be considered for radome coverings. The use of these materials could protect the radar against vandalism. Since the rest of the shelter structure is nearly impenetratable, good total site security can be achieved. Attention to the details of security, as outlined above will provide reasonable protection against vandalism and theft. While there is no doubt that a properly equipped saboteur could gain access to the buildings and their facilities, secure construction and an adequate alarm system combined with the natural protection of isolation and the severe environment should provide time and means for appropriate countermeasures.

The animals of the north ranging from the mouse sized lemming to the well known polar bear are attracted to settled areas through curiosity and by the search for food. They are not normally wantonly destructive. The normal absence of people at the sites, a program to discourage visitors, and extreme care in the removal of garbage after site visits will render this factor one of minimal concern.

Where natives are settled near an unmanned station consideration might be given to the employment of a native guard or caretaker. While of little practical value the involvement of natives in the security aspect at a reasonably low cost can be a good investment. Other forms of native involvement, such as providing telephone and TV service, is discussed elsewhere in this report.

3.4.11 Construction Considerations

With respect to structural foundations, it has been assumed for these preliminary recommendations that most of the sites west of Cambridge Bay will be on permafrost containing fine materials such that all structures will be supported on piles drilled into the permafrost. Steam drilling is no longer permitted. A few of the sites east of Cambridge Bay will be located on bedrock suitable for direct construction on the uninsulated rock. Most of the eastern sites, however, will probably be on permafrost effected rock such as that found on the coast of Baffin Island or on heavy boulders in permafrost areas. Under such condition, gravel insulating pads, under spread footings and incorporating careful drainage, design, will be necessary.

Designs will have to consider type and distribution of permafrost, ice lenses, pingos, taliks, etc., depth of the active layer during summer months, land formation, topography, and drainage and availability of borrow areas for aggregates.

It may be noted that in the General Electric recommended approach only foundations for towers need be considered.

In the siting of the original DEWLine it was possible, in most cases, where insulating pads were required to locate on either rock or to find a coarse, free draining material for use as an insulating pad under structural foundation. At a few sites it was necessary to crush rock for pads. When possible the siting of the unmanned radar station should be such that this crushed rock pad material can be reused. It should be noted that in areas where there is an active layer of permafrost, regardless of whether piles or spread footings are used, it is necessary to construct this "working pad" of insulating gravel to ensure that there is no loss of insulation which would disturb the thermal regime.

In areas with an active permafrost layer the preparatory work on site should begin in early April. Excavation of borrow material should begin as soon as the weather permits (usually in early May) so that as much work as possible can be done before the thawing of the active layer begins and thus at a time when borrow materials can be excavated and transported. Careful scheduling of this operation is essential. Insulating gravel pads should be laid down in all areas where construction work or site maintenance or operations are to be carried out under summer conditions.

If it is necessary to level land the work should be carried out as much as possible by filling operations either under conditions of frozen ground or in summer using end dump methods. If cuts are necessary they should be made using accepted methods of preserving the permafrost level and should immediately be protected by gravel pads.

Regardless of whether the foundations for the structures are piles drilled into the permafrost or spread footings on gravel pads, an air space must be maintained under any heated building or under any structure which might transmit heat into the ground. In every case the underside of a heated building must be carefully insulated.

There will be varying conditions across the Arctic and several variations in foundation designs will probably emerge such as rock, piles and spread footings, as the more detailed surveys are undertaken. In general soil conditions can be expected in roughly the following categories; permafrost 35 locations, rock 30 locations, mixed 18 locations.

The fact that some of the sites will be in high seismic zones will present no special design problems since there are available computer programs to assess any area in the north and readout the seismic design factors for each site. The area around the McKenzie Delta is in a Seismic Zone 3. The ground is generally silty and the design of proper structures on this permanently frozen material is not difficult. Another Seismic Zone 3 occurs on Baffin Island where ground is permafrost affected rock. This may cause minor problems in siting and design but arctic construction specialists are available to carry out this work.

In site preparation and site construction, it is anticipated that a minimum of construction equipment will be required. It is felt that a rubber tired machine with the flexibility to undertake multitasks might be used. Consideration should be given to such as a Catapillar 966 which can be equipped as front end loader, bulldozer, backhoe, crane and compressor for drilling. It can also be used as a towing unit. This equipment is adaptable to transportation by a Skycrane helicopter.

A great deal of Arctic construction is presently underway especially for oil and gas exploration and development. It is certain that Arctic construction contractors will develop many new techniques and specialized equipment that will be of benefit to the unattended station program.

With all of the various parameters that can effect the site construction program it is advisable that the site survey cycle be started as early as possible. A meaningful construction program and schedule cannot be generated without the data generated by the detailed survey process.

Weather, terrain, soil, transportation and phasing out old facilities indicate at least four general groupings for construction planning should be considered, Western, Central Canada, Eastern Canada and South East Extension. There should be no difficulty where presently existing sites are used. A transportation net and local work areas are already established. A similar situation can be expected at the abandoned sites but some problems should be anticipated. As previously mentioned, if all of the 57 existing and abandoned locations can be utilized then only 28 new sites of the required 83 unattended stations would need be completely developed. While this is probably optimistic it is reasonable to assume that not more than 40 sites would be completely new.

Different techniques, methods and schedules will be required. Arctic construction is developing at a rapid pace and full advantage must be taken of old as well as new technology. Air transportation by helicopter and fixed wing craft will probably emerge as the most reliable method of supply. Innovative ideas such as flying in precast concrete foundation sections and bolting them together on the job site and perhaps staging the northern portion of the South East Extension stations from ship or barge without developing a land base, should be encouraged by potential construction contractors.

3.4.12 Weather and Terrain Features

The construction of military installations at Thule in Greenland, Fort Churchill on Hudson Bay and the original DEWLine taught engineers much about working in the Arctic. Techniques have been developed to enable man to work and live under the severe conditions of the Arctic environment.

Methods of building and types of structures have been developed for the types of terrain found in the Arctic so that the natural ecological regime is not disturbed and structures are permanent and efficient.

In the eastern Arctic, in particular, high winds occur and blowing snow combined with temperatures in the $-40^{o}F$ to $-60^{o}F$ range can create a condition known as "white-out" which can isolate a site for as much as ten days at a time. Summer fogs often isolate sites for similar periods. The psychological effect on men trapped at a site under such conditions must be given careful consideration. Personnel sent north should either be familiar with working in the Arctic or should be screened carefully, trained and indoctrinated, before they are sent there. Construction contractors should be carefully selected to assure famili-arization with arctic conditions.

3.4.13 Ecological Impact and Protection

The Canadian Arctic falls within the jurisdiction of the Federal Government of Canada. There is no provincial jurisdiction in this area. Projects proposed for the region must be submitted to the Land Use Advisory Committee established under the Northern Territories Land Use Regulations and administered by the Federal Department of Indian and Northern Development. It is possible that this committee will require that the project be subjected to the Federal Environmental Assessment and Review Process (EARP) administered by the Federal Department of Fisheries and the Environment. This entails registration of the project by the "proponent" department which in this case might be the Federal Department of National Defense. This is followed by submission of a report which provides a project description, a review of the local environments, an assessment of the impacts which the project is likely to have on them and a description of measures proposed to protect or enhance the natural environment. An EARP panel, chaired by Environment Canada, and including in its membership a representative of the proponent and others, is set up to assess the project and review the submission. The panel has the power to require further information, prior to recommending to the Minister of Fisheries and the Environment, and the Ministers of Indian & Northern Affairs and the proponent department that the project be allowed to proceed as proposed or proceed with specific modifications or, in critical situations, not be permitted to proceed.

In the case of typical repetitive installations such as those proposed for unattended radar chains, it should be possible to submit an overall project description with typical designs and some general statements with regard to potential impact. It will, however, be necessary to provide environmental descriptions of the proposed sites by regions, or on a site by site basis in more sensitive areas. This will entail visits to proposed sites along the line by teams consisting (as conditions dictate) of botanists, wildlife and fisheries experts, and sociologists for those areas having native populations.

These groups will be baseline studies of the areas in which stations may be located and more detailed studies as required. The cost of such work is borne by the proponent whether done by his own experts or by Environment Canada. Public hearings and a non-government Board of Review are possible requirements.

The Government of Canada will have to be assured that the delicate environment of the Arctic is not disturbed to any significant degree, that construction operations and re-supply will not damage that environment and that all installations are in accordance with best Arctic practice. The Government will want to be satisfied that the project does not disturb such things as the thermal regime, the nesting grounds of migratory birds, spawning beds of fish, the calving grounds of caribou, beluga whales, and narwhales and the denning areas of polar bears. The Government will also wish to ensure that the life style of the native peoples is not disturbed.

It should be noted that the whole EARP system is designed to avoid unnecessary environmental checks, 90% of all projects are cleared in the first preliminary review process. However, the proposed replacement of the DEWLine is so complex that no doubt the more sophisticated EARP procedures will be necessary.

While the above discussion deals only with the situation in Northern Canada, a similar set of circumstances will exist for those sites located in Alaska where state and federal regulations will apply. Also the provincial Governments of Laborador, New Foundland and Quebec will be involved in the regulatory process.

With a station design providing no life support facilities, waste material presents no problems. All waste generated by a visiting team will be removed when the team departs. Diesel exhaust from a 4 KW generator has a negligible impact. The process of satisfying all of the involved agencies will require considerable time but there should be no real problems in gaining final acceptance.

3.4.14 Obstruction Lighting

The Canadian Government regulations for aircraft warning obstruction lights are delinated in the publication "Standards for Obstruction Markings" TP-382, published by Transport Canada, Air, Civil Aeronautics. Chapter 1, paragraph 1.1 Objective is quoted:

> 1.1.1 The objective of this publication is to provide information and guidance on methods of marking structures that are either real or potential hazards to the safe operation of aircraft. Conditions which require that a structure be marked are not included.
>
> 1.1.2 It is a practice of Transport Canada to assess individual structures to determine whether or not they constitute a hazard to air navigation and thus require marking in accordance with the standards of this publication. Where the application of these standards would create technical or economic difficulties, a detailed study will be made to determine if a lesser standard may be accepted.
>
> 1.1.3 Persons planning the construction of a structure which might create a real or potential hazard to aircraft operations are therefore advised to forward details on the precise location of the proposed structure, its over-all height above the immediate ground level and above mean sea level so that such an assessment can be made.

While each potential hazard must be judged individually it is general practice to exclude structures below 150 feet in height from the requirement of obstruction lighting. U.S. regulations which would effect the Alaskan sites are undergoing some revisions but in general they too do not require obstruction lights on structures less than 150 feet high.

The General Electric suggested system employs radar towers well below 150 feet with a satellite communication system which eliminates the need for tall towers. Except for navigation aids which may be needed for visiting maintenance teams, obstruction lights will probably not be required, as the navigation lights would be used only on demand there is no impact on normal operating power load.

At the manned stations having aircraft landing strips required obstruction lighting is assumed to exist and procedures for operation and maintenance are in place.

It may be noted that usual practice is to employ a dual light unit in the event of a single bulb failure. The lamps are usually operated at a less than rated voltage, that is lamps of 130 volts rating are operated at 120 volts. Three or more years continuous operation of a single lamp is not unusual.

3.4.15 Safety

Considering safety requirements no areas of special concern have been identified however the following comments require consideration.

Fuel storage design has been previously discussed. Cellular design in metallic containers with bullet proof coverings and/or self sealing liners are recommended. Normal good fuel handling practices must be used.

Electric grounds are sometimes difficult to achieve in the arid Arctic. and especially in barren rock areas. However, a good station ground system is required considering power, electronic, lightning and helicopter emergency refueling systems.

The trunk enclosing the tower access ladder can serve the multiple functions of security protection, weather protection and a personnel safety cage.

Considering the power levels and the tower elevations there should be no RF hazard associated with the unattended station design.

A safety belt should be provided for personnel working near an open hatch such as would occur while changing a power generator unit.

3.4.16 Growth Potential

Consideration should be given to the possibility that demands on the unmanned station might increase beyond those presently postulated.

Assuming the radar diameter remains fixed at 25 feet then the interior space available in the electronics section would probably accommodate one or two additional complete cabinets of equipment. The spaces presently allocated to storage could be used and overhead storage racks or cabinets could be employed.

In the power area it should be noted that the generators presently shown (Figure 3.4-14) are sized for 4 KW. It is quite probable that larger machines, up to 8 or 10 KW each could be accommodated in the space available. The fuel supply is presently sized for 5,000 gallons which is 1/4 larger than the assumed annual consumption of 4,000 gallons. Additional storage could be provided by overhead tankage, probably in the order of 2,000 gallons in the overhead structure area, with no increase in module height. The insulating envelope would be extended to enclose the tankage. By increasing module height the storage capacity could be increased to almost any desired amount. Below floor storage could also be considered but is less desirable because pumping would be required. However transfer of fuel to the upper tanks could be done at a scheduled maintenance visit with no drain on normal operational power consumption.

Should growth requirements exceed the limitations of the electronic-power-radar combined station module there are a number of options available by adding

AD-A060 061 GENERAL ELECTRIC CO SYRACUSE N Y ELECTRONIC SYSTEMS DIV F/G 17/9

UNATTENDED RADAR STATION DESIGN FOR DEWLINE APPLICATION.(U)

JAN 78 W E ABRIEL, S E BELL, J R GOLDEN F19628-77-C-0212

UNCLASSIFIED ESD-TR-78-176-VOL-3 NL

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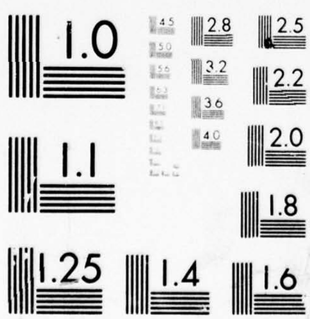


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

shelter systems to the radar radome. The radome is elevated in all cases either in a new configuration or when using an existing DEWLine Tower. Therefore space beneath the radome could be used without violating any of the security concepts that have been considered in this study.

3.4.16.1 Logistic Nodes

The goal of the unattended radar program is to design an unattended radar system that will perform the DEWLine Mission with high reliability at substantially reduced life cycle cost from the current O & M costs. Supporting this unattended radar system will be logistic nodes whose mission requires that a number of diverse operation and maintenance activities be accomplished on site. These activities will require facilities which are economical, comfortable and pleasant if efficient and long term reliability of the radar system is to be achieved.

The baseline system requires that six logistic nodes be established for the support of the unattended radars. A logistic node can be located at an existing DEWLine Main Station, Auxiliary Station or any other location which can offer appropriate economic and/or logistical advantages and still satisfy the baseline requirement. The locations of these six baseline nodes and any GE recommended departures from this established baseline is discussed in detail in the Logistic Section of this report. The purpose of this discussion is merely to outline how the logistic node requirements could be accommodated at various candidate locations.

While many locations are possible, the logistic node must possess characteristics such as being strategically located along the unattended radar line, easily accessible by air transport as well as sea lift and have facilities there that can be used directly or adapted to node requirements.

The DEWLine Main Sites and certain auxiliary sites as well as Fort Chimo possess these characteristics. Fort Chimo while not a part of the current DEWLine is strategically located on the eastern seaboard. This relatively large Arctic village is capable of providing food and lodging for site personnel as well as electric power to the node. Helicopter shelter, landing, fuel and maintenance requirements can also be accommodated at Fort Chimo. These services in turn will materially reduce the number of support contract personnel required to operate and maintain the node.

A breakdown of the functional areas required at a logistic node, their space requirements and how they could ba accommodated at a main site, an auxiliary site or at Fort Chimo is shown in Tables I, II and III.

Matching the logistic nodes facility requirements against facilities now existing on main or auxiliary sites indicates that the following structures or facilities could be used directly or adapted to logistic node requirements.

They are:

- o Building Trains
- o Garages
- o Warehouses
- o Hangars
- o Powerhouses
- o Heating Systems
- o POL Storage

The utilization of these facilities, to the greatest extent possible, rather than the building of new facilities is recommended for the following reasons:

- o The facilities and their associated mechanical and electrical systems are already in place and functioning.
- o Building shells are in good to excellent condition.

- Electric power distribution is in good condition.
- Water storage, treatment and distribution is in good condition.
- Refurbishment and updating of aging building elements would be less costly than the expense of demolishing and disposing of the old facility and replacing with a new building system.
- Building trains on main sites offer sufficient space so that logistic node functions can be located in one building system. Building trains on auxiliary sites can be expanded to offer the same advantage.
- Much of the refurbishment for main site nodes could be accomplished incrementally on a module by module basis. This will permit a good deal of flexibility in scheduling the work.

3.4.16.2 Building Trains

The building trains are an assembly of 16' x 28' module units constructed of prefabricated plywood insulated panels and sheathed with aluminum siding. They contain bedrooms for personnel, administrative offices, kitchen and dining room areas, recreation areas and certain small shops. In addition they house radar and communication equipment as well as power services, sanitary waste systems, water storage, plumbing system and heating and ventilating equipment.

A typical main station has two (A & B) building trains connected by an overhead bridge. Train A is typically made up of 22 occupied 16 x 28 module units and train B is composed of 26 occupied module units. Comparing this available space with the technical and living area requirements indicated in Table 3.4-1 shows that there is sufficient space in a typical main station building trains to accommodate these needs. The surplus space would either be closed off or converted into recreational or storage space in adapting a main station into a logistic node.

A typical DEWLine Auxiliary Station contains one building train which is composed of 23 occupied 16 x 28 module units. Comparing this available space with the technical and living area requirements shown in Table 3.4-2 shows that there is insufficient space in the train to accommodate the logistic nodes needs. This, of course, means that a new building annex would have to be constructed to accommodate the additional requirements. Providing an annex rather than a separate unattached structure to the building train would permit all logistic node functions to be accommodated in one building system. It would interface with the existing building train near or at the mess hall area and should be oriented with due consideration to the problems of drifting snow.

The DEWLine Surveillance Radar Antenna at the main and auxiliary stations is housed in an unheated radome located on a guyed steel platform which straddles one end of a building train. The antenna and radome would be removed and salvaged or disposed of. The steel platform would then be fitted out with a complete unattended radar module, including diesel generators and fuel storage on top. Locating this unattended radar contiguous to the building train is particularly advantageous because it can then be used as a training facility for indoctrinating new site personnel. Obviously this concept could be modified by providing site power to the modules and simulating diesel power generation and fuel storage if safety and operating considerations outweighed training advantageous. Directly below the unattended radar module in the building train will be located the technical area. The living area, administrative office and storage would be accommodated in the case of the Main station in the remainder of the building trains and in the case of the auxiliary station in the remainder of the building train and the annex.

TABLE 3.4-1

Facility Space Requirements for

Logistic Nodes Located at

A DEW Line Main Station

Functional Area	Space Required: Area	Space Required: No. of 16'x28' Bldg. Train Units Req'd.
Technical Area		
Radar/Communications Operations	* 345 ft^2	1 Mod
o Radar		
o Communications		
o System Performance Monitoring		
o Weather Data		
o Navigational Aids		
o Security Monitoring		
Technical Supervisors Office	* 85 ft^2	1 Mod
Technical Library/Training Center	* 216 ft^2	
Electronics Maintenance Shop	* 345 ft^2	1 Mod
Calibration Room/Test Equipment Storage	* 345 ft^2	1 Mod
Technical Spares Storage	* 345 ft^2	1 Mod
* Space does not include corridor.		
Living Area (20 Site + 5 Transient Personnel)		
Dormitory	3140 ft^2	7 Mod
Lavatory/Laundry/Sanitary Waste	1800 ft^2	4 Mod
Kitchen/Food Storage	1350 ft^2	3 Mod
Mess Hall	900 ft^2	2 Mod
Recreational Area	1350 ft^2	3 Mod
Water Storage and Treatment	900 ft^2	2 Mod
Site Administration Office	450 ft^2	1 Mod
Total 16 x 28 Module Units Required		27 Mods
Power House/Furnace Room	(Existing Bldg. attached to or adjacent to Bldg. Train)	
Garage	(Existing Bldg. near Bldg. Train)	
Hangar	(Existing Bldg. at Air Strip)	

TABLE 3.4-2

Facility Space Requirements for

Logistic Nodes Located at

A DEW Line Auxiliary Station

Required Functional Areas in Building Train	Minimum Space Required Area	No. of 16'x28' Bldg. Train Units Req'd.
Technical Area		
Radar/Communications Operations	* 345 ft^2	1 Mod
o Radar		
o Communications		
o System Performance Monitoring		
o Weather Data		
o Navigational Aids		
o Security Monitoring		
Technical Supervisors Office	* 85 ft^2	1 Mod
Technical Library/Training Center	* 216 ft^2	
Electronics Maintenance Shop	* 345 ft^2	1 Mod
Calibration Room/Test Equipment Storage	* 345 ft^2	1 Mod
Technical Spares Storage	* 345 ft^2	1 Mod
* Space does not include corridor		
Living Area (16 Site + 2 Transient Personnel)		
Dormatory	2240 ft^2	5 Mods
Lavatory/Laundry/Sanitary Waste	900 ft^2	2 Mods
Kitchen/Food Storage	1350 ft^2	3 Mods
Mess Hall	900 ft^2	2 Mods
Recreational Area	450 ft^2	1 Mod
Water Storage and Treatment	450 ft^2	1 Mod
Site Administration Office/Storage	450 ft^2	1 Mod
Total 16 x 28 Module Units Required		20 Module Units

Required Functional Areas in Annex	Minimum Space Required in Annex
Living Area (4 Site + 3 Transient Personnel)	
Dormatory	900 ft^2
Lavatory/Laundry/Sanitary Waste	800 ft^2
Water Storage/Hot Water Heater	450 ft^2
Recreational	1000 ft^2
Furnace Room/Power Dist.	300 ft^2
	3450 ft^2 (For new Annex)
Powerhouse/Furnace Room	(Existing modules (3 units) attached to Bldg. Train)
Garage	(Existing Bldg. near Bldg. Train)
Hangar	(Existing Bldg. at Air Strip)

GE's inspection of the DEWLine facilities on an Air Force sponsored visit in August of 1977 revealed that while the DEWLine building trains are structurally sound and in good repair the interiors do show wear and are generally drab in appearance. Also site personnel, at least in one case, have observed frost accumulation and vapor trails at two building module interfaces during a cold spell.

Therefore, as a first step, in adapting the existing building trains for use as logistic nodes, it would seem prudent that these trains be carefully inspected for tightness at module interfaces. The exterior wall insulation should also be examined at selected locations to assure that its "U" value has not degraded over the years from moisture penetration.

At relatively little expense much could be done to improve the appearance and therefore livability of the building trains. New and attractive floor tiles and ceiling tiles could be installed. Colorful paint and even wall paper could be used to good advantage. Modern attractive lighting fixtures, washroom fixtures and furniture would greatly enhance the appearance of the trains rooms and corridors.

3.4.16.3 Garages

Each main and auxiliary station is provided with one garage which contains space for storing tools, equipment and spare parts for repairing and overhauling vehicles and other mechanical equipment. The garages have insulated metal wall panels on a steel frame. An emergency 60 KW diesel generator is also housed there and there is an oil fired heating plant for the heating of the garage. The diesel generator is operated on a rotational basis with other station generators. The garages on main stations have seven bays and can accommodate 5 to 7 vehicles. The garages at the auxiliary stations have five bays and can accommodate 4 to 5 vehicles.

These garages are in good condition and could be used directly in satisfying the logistic node requirements.

3.4.16.4 Warehouses

The warehouses are steel framed structures covered with insulated "Galbestos" wall panels. They are mounted on elevated concrete pedestals placed on fill. The warehouses are used for storing food stuffs, electronic equipment and spares as well as other materials for base support. Each warehouse contains an oil fired heating plant, supply offices, security crib and a receiving dock.

The typical main station has at least two 40' x 100' warehouses while the typical auxiliary station has one 40' x 100' warehouse.

The warehouses are in good condition and could be used directly in satisfying logistic node requirements.

3.4.16.5 Hangars

Hangars have been provided at all main stations and certain auxiliary sites. These structures are used to house aircraft, unload cargo aircraft in inclement weather and to provide heated work space for the repair and servicing of aircraft. The hangars are 120' x 134' with insulated metal wall panels on a steel frame. They contain two mechanical rooms which house oil fired heating plants, fuel storage and CO_2 fire protection system.

These hangars can be used directly to satisfy the logistic node requirements.

3.4.16.6 Powerhouse

The prime and survival electrical power for the DEWLine Stations is supplied by diesel engine generators. While these systems are now 20 years old most of the generators are still in good operating condition. They have been well cared for and most are operated well below their rated capacities. Also, there are standby units which are brought on line on a rotational basis so that the average operating hours per unit would be somewhat reduced. These factors, together with the fact that they are low RPM units, suggest a long service expectancy. It therefore appears economically justified to adopt or modify the power generating equipment on the main and auxiliary stations to supply the power needs of the logistic nodes.

A summary of the electrical power generating capacities for each of DEWLine Station is presented in Table 3.4-4. A tabulation of the logistic nodes power requirements is shown below:

Peak Demand Total	110 KW
Technical	15 KW
Utility	95 KW
Average Demand Total	100 KW
Technical	15 KW
Utility	85 KW

In discussing how the electric power requirements for a logistic node may be satisfied, it is advantageous to first consider how this may be accomplished if a node were located on a Canadian Auxiliary Station.

The typical Canadian Auxiliary Station utilizes five 60 KW GM generators, which are housed in the building train and one 60 KW unit in the garage. These power plants are referred to as up-graded because they provide automatic bus transfer and load shedding capabilities. Each bus in the two bus system provides power for both technical and utility power demands. The power plant is operated such that two engines power a single bus, requiring a total of four engines operating at all times. The station loads permit continued operation of all equipment assigned to a particular bus in the event of a single engine failure on that bus. Each generator is run at approximately 50% of maximum load which

TABLE 3.4-4

ELECTRICAL POWER GENERATING CAPACITIES OF DEW LINE STATIONS AND RECOMMENDED MODIFICATIONS FOR LOGISTIC NODE ADAPTATION

Station	Primary Units Each Station	Survival Units Each Station	Recommended Stations Modifications for Logistic Node
Main Stations POW Main	6 Ea. - General Motors 60 KW Units	1 Ea. - General Motors 60 KW Units	Adapt existing system or Install up-graded system from deactivated Canadian auxiliary station.
BAR Main	4 Ea. Chicago Pneumatic 350 KW Units 5 Ea. Chicago Pneumatic 175 KW Units	1 Ea. - General Motors 60 KW Units	Install up-graded system from deactivated Canadian auxiliary station.
PIN Main	5 Ea - Caterpillar 150 KW Units	1 Ea. - General Motors 60 KW Units	Install up-graded system from deactivated Canadian axuiliary station
CAM Main	5 Ea. - Caterpillar 150 KW Units	1 Ea. - General Motors 60 KW Units	Install up-graded system from deactivated Canadian auxiliary station.
FOX Main	6 Ea. - Chicago Pneumatic 500 KW Units	1 Ea. - General Motors 60 KW Units	Install up-graded system from deactivated Canadian auxiliary station
DYE Main - Upper Camp Lower Camp	5 Ea. - Chicago Pneumatic 500 KW Units 4 Ea. - General Motors 10 KW Units	1 Ea. - General Motors 60 KW Units	Install up-graded system from deactivated Canadian auxiliary station.
Alaskan Auxiliary Stations	3 Ea. - General Motors 60 KW Units	1 Ea. - General Motors 60 KW Units	Adapt existing system or install up-graded system from deactivated auxiliary station
Canadian Auxiliary Stations	5 Ea. - General Motors 60 KW Units	1 Ea. - General Motors 60 KW Units	Adapt existing system.

permits the entire bus load to be supported by a single generator. In the event an entire bus becomes unserviceable due to a fault in the bus or there is a loss of both engines on that bus, the technical load is transferred to the remaining active bus.

Comparing the logistic nodes power requirements against the Canadian Station's generating capacity and system configuration it appears that a good match can be achieved with little or no modification to the power system.

Because of the reduced power requirements for the logistic node the trip settings for certain of the load breakers may have to be adjusted downward or new breakers installed. (Also, the reduced load may necessitate placing only two 60 KW generators on one bus and one 60 KW on the other bus rather than having two on each bus as is now the case).

A typical Alaskan Auxiliary Station utilizes three 60 KW units. These three diesel generators are located in the building train with an additional survival 60 KW unit located in the garage. The switch gear and bus arrangements are designed to have the utility load on one bus and the technical load on another bus. The Alaskan Stations are considered non-up-graded power plants because the failure of one engine on a bus results in complete power loss to that bus.

The Alaskan Auxiliary Station generating capacity appears to provide a good match for satisfying the power requirements of a potential logistic node. Because of the relatively light technical load both the technical and utility loads should be put on one bus with two diesel generators feeding that bus.

An improvement over the above arrangement would be to up-grade the power generating system by installing the switchgear and bus from a deactivated Canadian Auxiliary Station.

POW Main's Power Generating System is similar to the Alaskan Auxiliary Station System. This power system differs primarily in that it has six 60 KW units instead of three units on line. The power systems description and comments for adapting it to Logistic Node requirements is covered in the discussion of the Alaskan Auxiliary Stations.

The electrical power system at BAR Main utilizes 175 KW units and 350 KW units. Utility power at this station is furnished by the 175 KW units while the technical power demand is satisfied by the 350 KW units. The switchgear utilized with the 350 KW units incorporates an automatic transfer feature which permits the transfer of the critical technical loads automatically from one bus to the other. This feature insures continuous prime power for critical loads.

PIN Main, CAM Main, FOX Main and DYE Main have a different switchgear and bus arrangement from that of the other DEWLine Stations. PIN Main and CAM Main each utilize five 150 KW diesel generating units. FOX Main is powered by six 500 KW generating units as is the Upper Camp at DYE Main. The lower camp at DYE Main employs four 100 KW diesel generating units to supply the air strip, hangars, dormatories and mess hall located there.

All main stations have one emergency 60 KW GMC generating units that is located in the garage.

The power plants at PIN Main, CAM Main, FOX Main and DYE Main Stations are protected by an arrangement of preliminary shutdown alarms and devices. These systems provide forewarning of impending faults within the engine, alternator and associated ancillary equipment.

The 175 KW units installed at BAR Main and the 150 KW units installed at PIN and CAM Main could probably be utilized for logistic node operation. One unit could be placed on line to feed the combined technical and utility loads off a common bus. They would be operated between 40 to 70 percent of their rated capacities which are acceptable limits. This arrangement, however, would probably not be a good situation because the loss of the engine generator would result in a complete loss of power on the site until another unit could be brought on line.

The four 100 KW units installed at DYE Main's Lower Camp could be used by putting two of these units on line. Inasmuch as there are only four 100 KW units they could only be used at one logistic node and the opportunity for commonality of equipment for all logistic nodes would be lost.

The 500 KW engine generators located at FOX Main and the Upper Camp of DYE Main are much too large to be considered for supplying the power needs of a logistic node.

Because of these factors the power generating systems located at BAR Main, PIN Main, CAM Main, FOX Main or DYE Main do not appear to be a good match for satisfying the electrical power requirements for a potential logistic node. These stations however, could be modified by sectioning off a portion of the existing power house and installing a salvaged up-graded power generating system from one of the deactivated Canadian Auxiliary Stations.

3.4.16.7 Heating Systems

Two types of heating systems are used to heat DEWLine buildings. They are forced circulation hot water systems and forced hot air systems.

The hot water system is a 2" pipe reverse return system and is utilized in heating the building trains. The primary heat source for the system is derived from the diesel generators cooling and exhaust systems. Also an auxiliary oil fired hot water boiler, located in the power house, is used to supplement the primary source when electric power demand is down or in cases of emergency.

Inasmuch as the electrical power generation required for a Logistic Node is less than that now generated for an operating main or auxiliary DEWLine Station, the waste heat from the diesels would likewise be reduced. Therefore greater utilization of the oil fired hot water boilers in the powerhouse would be required.

Inspection of these facilities at the DEWLine, during GE's visit, indicated that the heat exchangers and oil fire boilers associated with these heating systems were aging. It would therefore be desirable if these heating systems be carefully inspected and updated as required when a logistic node is deployed.

Buildings such as garages, hangars, dormitories and warehouse use oil fired forced hot air systems. There also should be inspected and updated as required.

3.4.16.8 POL Storage

Each main site is provided with steel tanks capable of storing a minimum of 1,250,000 gallons of fuel. BAR Main, FOX Main and DYE Main because of special requirements have additional capacity. A typical auxiliary site has at least four steel 65,000 gallon fuel storage tanks. The steel tanks and their pumping facilities appear to be in good condition and can be used directly in satisfying the logistic node fuel storage requirements.

Fort Chimo while not now a part of the DEWLine Chain should be considered as a possible logistic node candidate.

A breakdown of the various functional areas, their space requirements and how they will be accommodated at the Fort Chimo Logistic Node is shown in Table 3.4-3.

TABLE 3.4-3

Facility Space Requirements for

Logistic Node Located at

Fort Chimo

Functional Area	Space Required Area	No. of 10x30 Vans Needed
Technical Area		
Radar/Communications Operations	600 ft^2	2 Vans
o Radar		
o Communications		
o Systems Performance Monitoring		
o Weather Data		
o Navigational Aids		
o Security Monitoring		
Technical Supervisors Technical Library/Training Center	300 ft^2	1 Van
Electronic Maintenance Shop	600 ft^2	2 Vans
Calibration Room/Test Equipment Storage	300 ft^2	1 Van
Technical Spares Storage	600 ft^2	2 Vans
Living Area		
Day Room/Site Administration	300 ft^2	1 Van
Standby Power/Heating Unit	300 ft^2	1 Van

(All other facilities will be contracted for in the Town)

The appearance of this logistic node will differ somewhat from the DEWLine Nodes. First of all GE recommends contracting with the town for primary electrical power to the site. Food and lodging would also be similarly secured on the local economy along with services necessary for the operation of the helicopter and ground vehicles. The unattended radar station would not be located at this logistic node as is recommended for the DEWLine nodes.

The site complex would consist of one large building complex. This complex would be constructed of skid mounted portable buildings bolted together to form the desired configuration. Each building module would be factory built with all facility services and mission equipment pre-installed, checked out and operational.

Each portable building would have the following features built in:

- o Steel skids
- o Lifting points
- o Steel stacking racks for stacking units for shipment
- o Aluminum siding and roofing on plywood underlayment
- o R30 insulation on all walls
- o Interior lighting
- o Electrical and plumbing fixtures and services
- o Appropriate wall, floor and ceiling treatment for each area
- o All heating equipment would be preinstalled.

The site would be equipped with a 60 KW auxiliary power unit to provide emergency back up power.

This facility complex would become home base from which the maintenance crew would operate.

Because of the long distances that must be traversed along the eastern seaboard and the hazards of Arctic travel, GE recommends that unmanned auxiliary maintenance nodes be established at Frobisher Bay and Goose Bay. These towns are of sufficient size that they could provide for the refueling of the helicopter as well as limited maintenance services. Food and lodging for the small flight and maintenance crew could also be secured there.

Facilities for storing unattended radar spare parts and test equipment would be secured thru leasing of space in existing buildings believed to be available near the town's air strip.

Detailed planning would be required if the phase out of the current DEWLine to a new unattended radar system is to be accomplished successfully.

First off the overall mission of the current DEWLine must be re-evaluated. The primary mission of the DEWLine is to provide early warning of an impending enemy airborne attack on Canada or the United States. Since its inception, however, many other important secondary missions have developed around the DEWLine facilities.

These secondary activities include:

- Management, operation and maintenance of a long haul military communications system with subscribers all over the world.
- Operation and maintenance of navigational aids such as LF Beacons, TACAN and TVOR.
- Operation of HF/UHF/VHF short haul radio communication equipment.
- Maintenance of an aircraft advisory service providing weather and position data to both military and commercial aircraft in the vicinity.
- Weather data collection and reporting.

- o Maintenance and operation of air strips and airport facilities.
- o Maintenance of seaport facilities.
- o Maintenance of heavy equipment overhaul facilities.
- o Support of various geological and climatological research projects.

The present DEWLine is directly or indirectly involved in all of these secondary mission activities and may represent important services for the safety and well being of the total Arctic community. They should therefore be given proper consideration prior to the deployment of the new unattended radar system.

After the overall mission of the new unattended radar system has been established facility requirements over and above those required for the basic radar system must then be determined. The facility requirements for both the primary and any secondary missions can then be compared with facilities that currently exist.

Once the total facility requirements have been established a detailed inspection of the buildings and their facility elements which are to be used must then be accomplished to determine the extent of refurbishment.

It is GE's considered opinion that those facilities which are no longer required should be preserved and stored for future use for the following reasons:

- o Once a building, tank or structure has been properly sealed or protected against the elements they will last indefinitely in the Arctic.
- o The Arctic is growing and it is likely that military, commercial interest or the local community will have need of these facilities if not now, sometime in the future.
- o The cost of new construction far exceed the cost of storage.
- o The comdemnation and removal of structures in the Arctic is costly.

3.4.17 Recommendations

The construction planning process has been identified as an area requiring greater indepth study than provided by the scope of this report. The elements of site selection, land acquisition and ecological approval will take considerable time and should be started as early as possible in the program schedule cycle.

3.5 COMMUNICATIONS CONSIDERATION

3.5.1 Introduction

In order to determine the feasibility of implementing an unmanned radar station, it was necessary to investigate the communications requirements associated with these stations and to evaluate various methods of supporting the communications traffic within the unattended network. The general communications requirements for this network were identified in the document titled "A Preliminary Description of Unattended Radar Site Communications" dated 6 May 1977 which was supplied by ESD at the post bidder's briefing. The most significant requirements included in that document are summarized in Table 3.5-1

In addition to the requirements summarized in Table 3.5-1 it was recognized that there are other parameters which should be considered in the design of a communications approach to the unattended network. A listing of these additional considerations is included as Table 3.5-2.

The considerations shown in Table 3.5-2 are listed against the same outline as those shown in Table 3.5-1 and are presented as characteristics that are considered important to the basic design of a communications system without superseding the requirements previously established.

The circuit requirements for the unattended network are shown in Figure 3.5-1. Seven duplex circuits are required between each unmanned radar station and the primary logistics node associated with that segment of the radar line. These seven circuits are also required to be alternate routed to a secondary logistics node. For a segment with 16 unmanned stations, this amounts to 112 duplex circuits per segment. The alternate routing of these circuits is not rigid and should be distributed over the network. As shown in Figure 3.5-1, alternate routes are established to the nearest logistics node.

TABLE 3.5-1

COMMUNICATIONS REQUIREMENTS

- CIRCUITS
  - UNATTENDED RADAR STATIONS TO LOGISTICS NODE (7 PER SITE WITH ALTERNATE ROUTING)
  - LOGISTICS NODE TO LOGISTICS NODE (3 PER SITE TO A CIRCUIT SWITCH)
  - LOGISTICS NODE TO REAR ELEMENTS (6 PER NODE WITH ALTERNATE ROUTING)
- TRANSMISSION TECHNIQUES
  - LINE OF SIGHT MICROWAVE
  - SATELLITE
  - COMBINATION OF MICROWAVE AND SATELLITE
- TECHNOLOGY
  - SOLID STATE
  - LOW POWER
- COMMON ALARM AND CONTROL
  - REMOTED LOGISTICS NODES
  - REDUNDANT ROUTING
- RELIABILITY
  - NO SPECIFIC REQUIREMENT YET
  - FOR 3 MONTH MAINTENANCE INTERVAL - MTBF $>$ 30 MONTHS
  - MAY REQUIRE EQUIPMENT REDUNDANCY

TABLE 3.5-1 (cont.)

- POWER
  - DESIGN GOAL 500 WATTS
  - 24/48 VDC
- BUILT IN TEST EQUIPMENT
  - FAULT ISOLATION TO PLUG-IN MODULES
  - MINIMIZE TRANSPORTATION OF TEST EQUIPMENT
- ENVIRONMENTAL FACTORS
  - CONTROLLED: 0° TO 40°C, 90% RH
  - UNCONTROLLED: -70° TO 60°C, 0 TO 100% RH, WIND TO 150 MPH WITH 3" OF ICE
  - EARTHQUAKE CONDITIONS
    OPERATIONAL UP TO 0.25G
    SURVIVAL UP TO 0.5G
- SUBSYSTEM INTEGRATION
  - MINIMIZE STRUCTURES
  - STRESS COMMONALITY

TABLE 3.5-2

ADDITIONAL CONSIDERATIONS

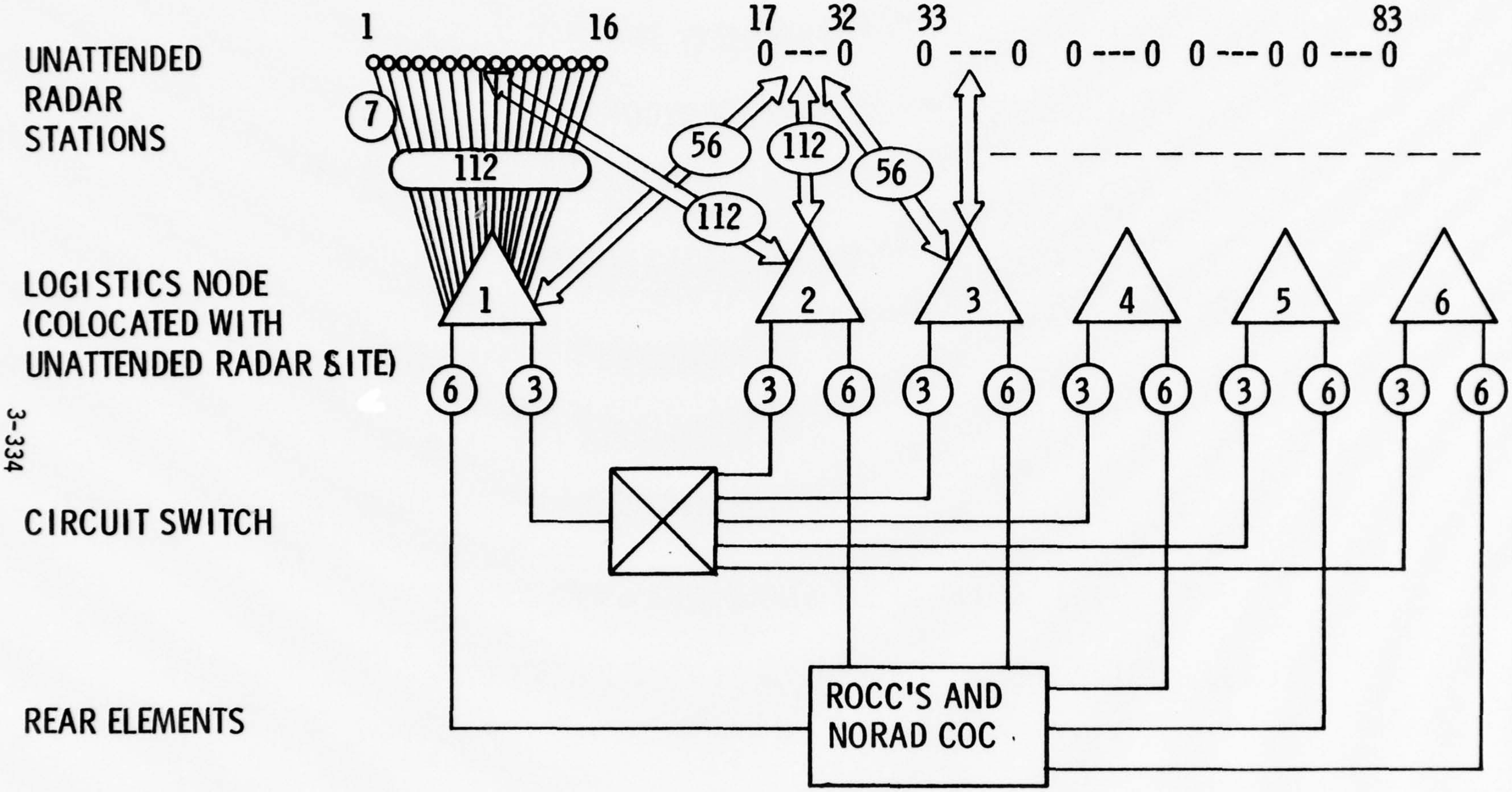
- CIRCUITS
  - TRAFFIC REQUIREMENTS MAY BE COMBINED IF IT IS ADVANTAGEOUS
  - CIRCUIT ROUTING IS NOT RIGID
  - DOUBLE HOPS BY SATELLITE LINKS SHOULD BE MINIMIZED
  - ONLY THE UNMANNED RADAR SITES AND LOGISTIC NODES ARE INCLUDED IN THIS STUDY
- TRANSMISSION TECHNIQUES
  - CONSIDER MORE THAN SATELLITE AND LOS MICROWAVE APPROACHES
  - DON'T USE TRACKING ANTENNAS
- TECHNOLOGY
  - USE OF TWTA'S IS DISCOURAGED
  - LOOK AT SOME INOVATIVE TECHNIQUES
  - DO NOT BE CONSTRAINED TO MIL-SPEC EQUIPMENT
- COMMON ALARM AND CONTROL
  - NOT RESTRICTED TO DEDICATED CHANNELS
  - EXCEPTION REPORTING IS PERMITTED
- RELIABILITY
  - FAIL SOFT EQUIPMENT SHOULD BE CONSIDERED
  - MAXIMIZE RECONFIGURATION CAPABILITY
  - MAXIMIZE ALTERNATE ROUTING OF INFORMATION

Table 3.5-2 (cont.)

- POWER
  - ADDITIONAL POWER IS AVAILABLE DURING MAINTENANCE VISITS
  - 25% OVERLOAD CONDITIONS ARE PERMITTED FOR UP TO 1 HOUR
- BUILT IN TEST EQUIPMENT
  - MAXIMIZE DISCRETE TESTING
  - MINIMIZE ANALOG TESTING
- ENVIRONMENTAL FACTORS
  - ONLY USE ANTENNA DEICING WHERE ABSOLUTELY REQUIRED
  - RECOGNIZE TALL TOWERS AS A MAJOR PROBLEM
  - RECOGNIZE BIG ANTENNAS AS A MAJOR PROBLEM
- SUBSYSTEM INTEGRATION
  - ATTEMPT TO HOUSE ALL COMMUNICATION EQUIPMENT IN A SINGLE RACK
  - KEEP WAVEGUIDE AND CABLE LENGTHS AS SHORT AS POSSIBLE

FIGURE 3.5-1

CIRCUIT REQUIREMENTS



Information collected at each logistics node is routed over six duplex circuits to the rear elements. Again these six circuits are to be routed over two paths to the rear elements. No specific interconnection requirement has been identified for these circuits as part of this study.

To support the communication traffic between the six manned logistics nodes, three duplex circuits are required between each site and a circuit switch. The circuit switch will permit the interconnection of any of these 18 circuits.

The circuit requirements for the unmanned stations were analyzed further to determine the volume of traffic involved. The results of this analysis are summarized in Figure 3.5-2. As shown the total traffic from the unmanned stations to the manned nodes is limited to 1100 bps of digital data plus a voice path during maintenance visits and the traffic from the manned node to the unmanned radar station is limited to 140 bps of digital data plus a voice path during maintenance visits.

Using either digital or analog techniques, it is possible to integrate the traffic requirements in both directions. As shown at the bottom of Figure 3.5-2, the traffic from each unmanned site can be multiplexed into one channel to include both the digital data and the voice requirements, and the traffic to a segment of unmanned sites can be multiplexed into one channel to be shared among the sites in either the frequency or time domain.

For this study, the communications requirements between the unmanned radar stations and the manned logistics nodes will be specifically addressed; whereas, the other communications requirements will only be considered in a general manner except where they impact the overall design of the network.

Figure 3.5-2

TRAFFIC REQUIREMENTS

	FROM UNMANNED STATIONS TO MANNED NODE	FROM MANNED NODE TO UNMANNED STATIONS
• RADAR DATA	800 BPS (INCLUDING IFF)	-
• RADAR STATUS AND CONTROL	100 BPS	10 BPS
• COMMON STATUS AND CONTROL	100 BPS	10 BPS
• G/A/G RADIO EMERGENCY/ MAINTENANCE	VOICE AS REQUIRED	10 BPS PLUS VOICE AS REQUIRED
• VOICE AND PUBLIC ADDRESS	VOICE AS REQUIRED	VOICE AS REQUIRED
• IFF	INCLUDED WITH RADAR DATA	100 BPS
• WEATHER AND NAVIGATION	100 BPS	10 BPS
TOTAL	1100 BPS PLUS VOICE AS REQUIRED	140 BPS PLUS VOICE AS REQUIRED
INTEGRATED TRAFFIC	ONE MULTIPLEXED CHANNEL PER SITE FOR DATA AND VOICE	ONE MULTIPLEXED CHANNEL PER SEGMENT FOR DATA AND VOICE

3.5.2 Identified Alternatives

Several approaches were considered as a means of meeting the communications requirements of the unattended network. A listing of the configurations considered most feasible is included as Table 3.5-3.

In order to select the configurations to be used in the unmanned station design study, the advantages and disadvantages of each configuration were tabulated. The results of this tabulation are included as Tables 3.5-4 through 3.5-12. It is recognized that there may be other feasible methods of providing communications to the unattended network and that the final configuration will most likely contain a combination of several techniques, but it was necessary to select a manageable number of alternatives which could be developed to the depth required for a facility feasibility determination.

TABLE 3.5-3

<u>CANDIDATE APPROACHES</u>

- Terrestrial
  - Line of Site Microwave
  - VHF Radio
  - Troposcatter
  - H.F. Radio
- Satellite
  - Commercial
  - Government
  - Advanced Techniques
- Innovative Techniques
  - Use Radar Equipment for Communications
  - Tethered Balloons

TABLE 3.5-4

LINE-OF-SIGHT MICROWAVE

Advantages

1) Proven in unmanned networks
2) Uses existing technologies
3) Ease of expansion
4) Low power consumption
5) Fairly immune to RF jamming and spoofing
6) Good message security

Disadvantages

1) Requires additional sites for repeaters
2) Still requires some satellite or tropo links
3) Maintenance costs
4) Requires towers for antennas
5) Cascaded transmission paths
6) Diversity techniques will be required .
7) Easily sabotaged

TABLE 3.5-5

VHF RADIO

Advantages

1) Slightly better than line of sight
2) Proven technologies
3) Availability of equipment
4) Simple antenna's
5) Low power consumption

Disadvantages

1) Requires some additional sites for repeaters
2) Still requires some satellite or tropo links
3) Limited number of channels
4) Maintenance costs
5) Cascaded transmission paths
6) Requires towers for antennas
7) Susceptible to jamming and spoofing
8) Poor transmission security
9) Easily sabotaged
10) Requires special design for this application

TABLE 3.5-6

TROPOSCATTER

Advantages

1) Good for long hops
2) Proven technology

Disadvantages

1) Power consumption
2) Dual to quad diversity required on each hop
3) Lack of significant new technology developments
4) Maintenance costs
5) Limited alternate routing capability
6) Cascaded transmission paths
7) Large antenna required
8) High initial cost

TABLE 3.5-7

H. F. RADIO

Advantages

1) Low cost equipment
2) Good for long ranges
3) No repeater sites required
4) Simple antenna
5) Proven technology

Disadvantages

1) Poor path predictability
2) Limited number of channels
3) Power consumption
4) Requires operator for frequency band selection
5) Poor resistance to jamming or spoofing
6) No transmission security
7) Poor channel availability

TABLE 3.5-8

COMMERCIAL SATELLITES

Advantages

1) Proven in unmanned stations
2) Uses existing technologies
3) Ease of expansion
4) Low power consumption
5) Doesn't require repeaters
6) Ease of establishing alternate routes
7) Availability of Back-up Satellites

Disadvantages

1) Sun outages - May require use of second satellite
2) Limited transmission security
3) Satellite may be jammed

TABLE 3.5-9

GOVERNMENT SATELLITES

Advantages

1) Uses existing technologies
2) Low power consumption
3) Doesn't require repeater sites
4) Ease of establishing alternate routes

Disadvantages

1) Limited number of satellites
2) Sun outages - May require use of second satellite

TABLE 3.5-10

ADVANCED SATELLITE APPROACHES

SUCH AS:
a) Ku Band
b) TDMA
c) Spot Beams - Time Assigned
d) VHF

Advantages

1) Low power consumption
2) Doesn't require repeater sites
3) Can be optimized for unattended network requirements
4) Ease of establishing alternate routes
5) Could simplify the earth station design
6) Ability to demand assign channels
7) Ability to do centralized maintenance

Disadvantages

1) Requires development
2) Limited number of satellites
3) Sun outages - May require use of second satellite

TABLE 3.5-11

USE OF RADAR FOR COMMUNICATIONS

Advantages

1) Reduces the equipment required at each site
2) Power consumption

Disadvantages

1) Requires development
2) Repeaters could be required
3) Some form of synchronization could be required between sites
4) Limited amount of redundancy
5) May cause "Holes" in the radar coverage
6) Would still require some satellite or tropospheric links
7) Data and voice transmissions could come in bursts
8) Transmission delays could be unacceptable
9) Complex maintenance procedures

TABLE 3.5-12

TETHERED BALLOONS

Advantages

1) Eliminates the need for repeater sites
2) Some possibility of alternate routing

Disadvantages

1) Questionable performance in unmanned arctic conditions
2) Power consumption
3) Requires development
4) Tethering could cause environmental problems
5) Complex maintenance procedures including circuit interruptions and associated high maintenance costs
6) Aircraft safety
7) Questionable system security

3.5.3 Selected Alternatives

Two communications configurations were selcted from those identified as being the most feasible to implement. Line of sight (LOS) microwave and commercial satellites were determined to have better characteristics than the other alternatives. Further details on these two configurations are presented in the following sections.

3.5.3.1 Terrestrial Radio Relay Configuration

3.5.3.1.1 System Description

Figure 3.5-3 shows a typical section of the Unattended Communication Network when configured with line-of-sight (LOS) terrestrial radio relay equipment. Fourteen unmanned radar sites are served by the two manned logistic nodes at the ends of the section. For the purpose of this study, all paths in this section are considered to be LOS; Section 3.5.2 of the study will assume that all paths are satellite paths. In reality, the final configuration may contain both approaches.

The figure illustrates the method of achieving system redundancy. The required seven traffic channels for Station 2 are shown being simultaneously sent to the two logistic nodes at both ends of the section. In a similar manner (but not shown), the other thirteen radar stations would handle their traffic.

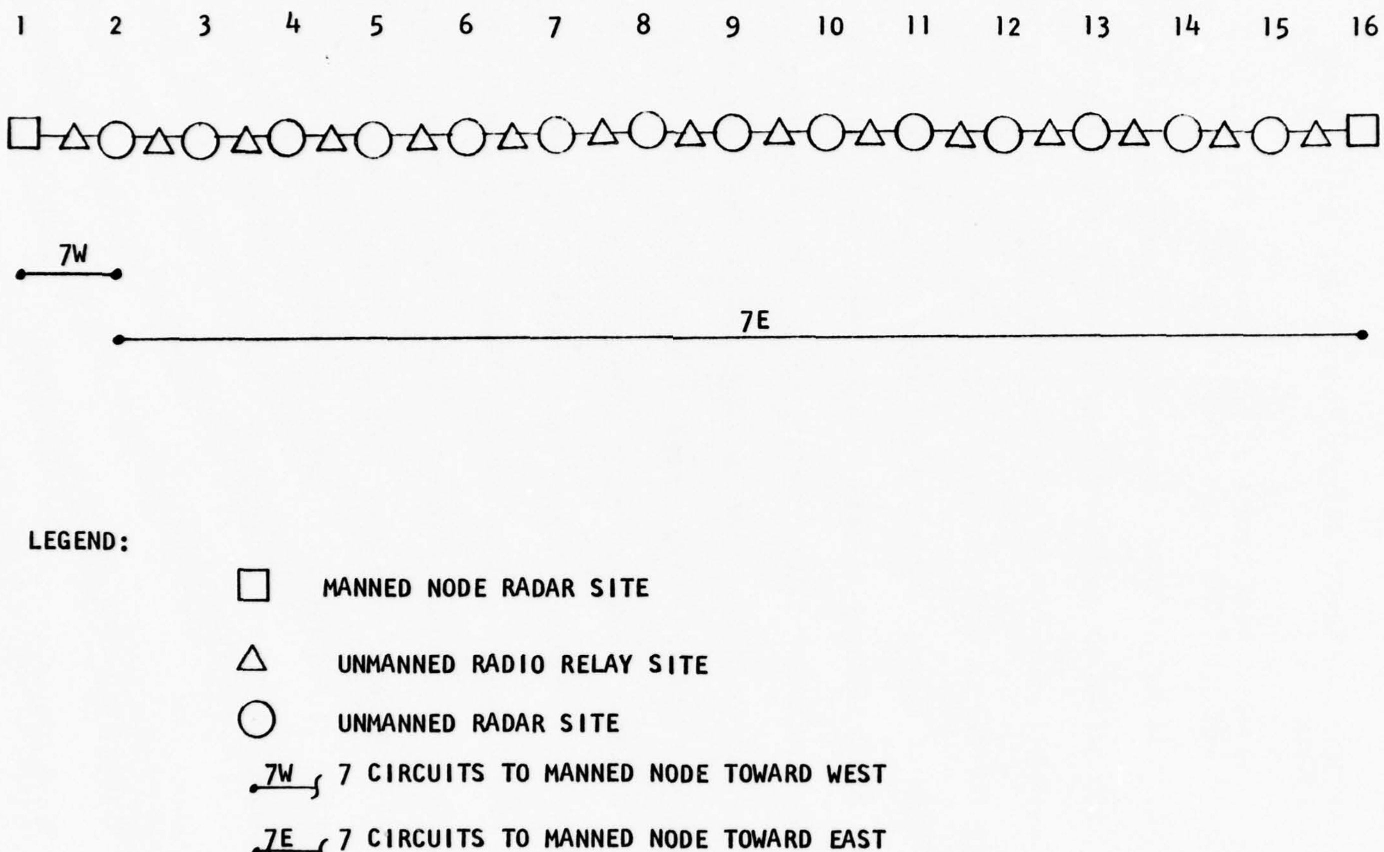
Note that Figure 3.5-3 shows the requirement for intermediate unamanned radio relay sites between the radar sites. These are required in order to keep the tower heights at the radar sites from becoming prohibitively large. The requirement is discussed in further detail in Paragraph 3.5.3.1.2.

3.5.3.1.2 Radio Relay Path Considerations

The detailed path design and the generation of path profiles is beyond the scope of this facilities study since these are subjects which will be addressed

FIGURE 3.5-3

TYPICAL LOS COMMUNICATION SECTION



in the communications study which is planned for the future. However, by review of the site data provided with the statement of work and examination of limited maps which were available, the following conclusions were established.

- The average path length between radar sites is just under fifty satute miles
- Many sites would need towers of approximately 500 ft. in order to support 2 GHz space diversity paths.

Since towers of this height should be avoided in these geographic areas, the preliminary path design assumed a worst-case condition of placing a radio relay repeater between all radar sites. The tower heights in this case will be approximately 200 ft. at both the radar sites and their intermediate radio relay stations. There is a great incentive to reduce the tower height at the intermediate radio relay stations to less than 150 feet. Doing so will avoid or reduce the requirement for tower lighting in many of the DEWLine geographic areas, and thereby reduce the power requirements for the intermediate radio relay stations to a minimum. The trade-off to achieve these 150 foot towers would involve the increase of the radar site towers to 285 feet. This alternative merits consideration and will be used as the baseline for the LOS configuration. It should be noted that this is only a typical tower arrangement, and each path will have to be designed using site terrain and path profiles to minimize overall life cycle costs. Based on existing information and operational equipment, it should be possible to implement LOS paths between unmanned radar stations while limiting the tower height at the repeater sites to 150 ft. or less.

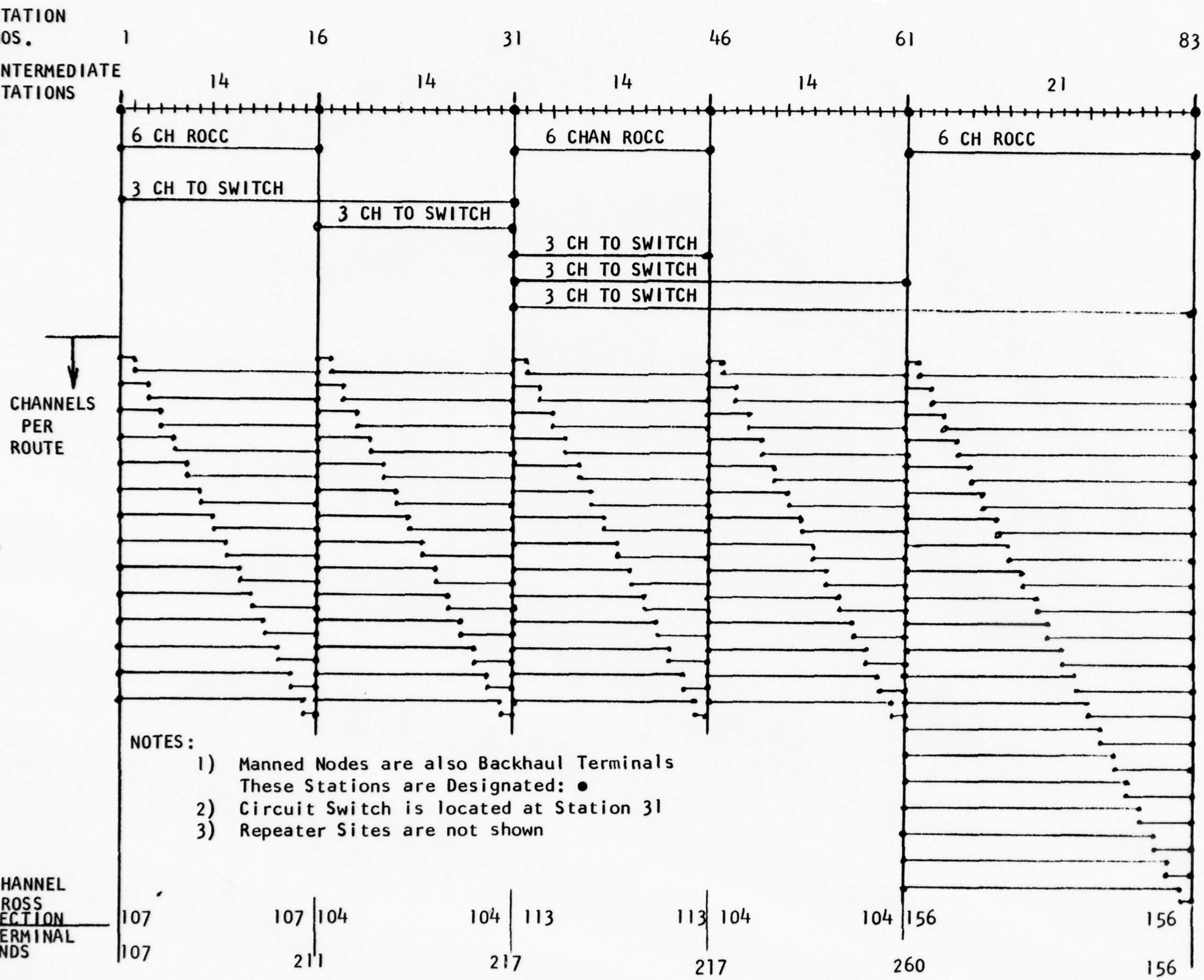
3.5.3.1.3 Channel Plan

3.5.3.1.3.1 General

Figure 3.5-4 summarizes the channel routing for the proposed LOS communication system. The channel plan is based on the traffic requirements outlined in the

FIGURE 3.5-4

DEW LINE CHANNEL ROUTING PLAN



Mitre Report "A Preliminary Description of Unattended Radar Site Communications", 6 May 1977, by Fred L. McDonald. The requirements are summarized below:

a. Manned nodes to Rear Elements
   6 point-to-point circuits with transmission redundancy.

b. Manned Node to Manned Node
   3 subscriber circuits from each manned node which are capable of being connected to any other manned node.

c. Manned Node to Unattended Radar Sites
   7 full duplex voice bandwidth channels with transmission redundancy.

Several assumptions are incorporated in the typical system configuration of Figure 3.5-4. These include the following:

1. Stations #1, 16, 31, 46, 61 and 83 (based on Requirement for Redundancy) are the radar stations designated as the manned nodes.

2. The manned nodes serve not only as logistic node stations but also as the backhaul gateway stations.

3. The manned node subscriber circuit switch is located at Station #31.

4. It is assumed that the lateral circuits to achieve transmission redundancy for the manned nodes to rear elements may be used in either direction, east or west.

The system terminal stations #1 and #82 have been designated as two of the six manned nodes. This is necessary in order to provide lateral redundancy for all the unmanned radar stations. For example, Station 2 communicates eastward to manned node Station 16. In the event of an equipment failure in eastbound equipment at Station 2, or a failure in any higher numbered station between Station 2 and 16, Station's 2 eastbound communication would be interrupted. In this case, the Station 2 traffic is carried by the westbound transmission to Station 1.

Fourteen unmanned stations are deployed between manned nodes Stations 1 and 16, Stations 16 and 31, Stations 31 and 46, and Stations 46 and 61. This deployment is in accordance with the stated requirement of a maximum of 14 radars reporting to a primary manned node. However, this assignment procedure falls down because six manned nodes are insufficient for meeting this criteria for 83 stations. Accordingly, 21 stations are shown between Stations 61 and 82. A more balanced configuration would be achieved by the use of three sections with 15 intervening radar stations and two sections with 16 intervening stations.

3.5.3.1.3.2 Backhaul Circuits

In order to achieve redundant transmission for the circuits from the manned nodes to the rear elements it is necessary to transmit the backhaul traffic laterally along the LOS backbone system. Figure 3.5-4 illustrates how this is achieved; for example, Station 1 has a primary transmission by means of the satellite station at its location; its backup transmission is via the six circuits which are sent laterally along the system to Station 16. The satellite subsystem at Station 16 is then used to complete the back haul to the rear elements.

The following chart summarizes the primary and backup satellite subsystems used to achieve transmission redundancy of the backhaul traffic.

Manned Node Traffic Station	Primary Satellite Backhaul	Backup Satellite Backhaul
Station 1	Station 1	Station 16
Station 16	Station 16	Station 1
Station 31	Station 31	Station 46
Station 46	Station 46	Station 31
Station 61	Station 61	Station 83
Station 83	Station 83	Station 61

Note that the above backup plan assumes that the three sets of lateral backup circuits (Station 1 to 16, Station 31 to 46, Station 61 to 83) can be manually patched at the manned nodes to accommodate the required backup connection, and that the backup transmission is not simultaneous with the primary transmission. If simultaneous transmission from manned sites to the rear elements is desired, this could be accomplished by the providing of three additional sets of lateral backup circuits as shown below:

- 6 CH ROCC STA. 16 to STA 1
- 6 CH ROCC STA 31 to STA 16
- 6 CH ROCC STA 61 to STA 46

3.5.3.1.3.3 Manned Node to Unattended Radar Site Circuits

The Mitre Report (previously referenced) summarizes the seven traffic elements which must be sent from the radar sites to the manned nodes. The report recognizes that several of these traffic elements are of lower bit rate than that of the full capability of a voice channel and that other elements may time share a voice channel. The report suggests that seven full duplex voice bandwidth channels be allocated to this service in order to allow system growth. Accordingly, the channel plan shows seven channels of redundant transmission for this service. It should be noted that by means of multiplexing and sharing, this number could be reduced substantially, based on the presently identified communication needs. A reduction in the quantity of channels would of course impact cost, physical size, and power requirements for the stations.

3.5.3.1.4 Path Calculations

The following criteria were used as a basis for the path calculations:

- Separation between unmanned radar site and adjacent repeater - 25 statute miles

- Tower height at unmanned radar site - 285 feet
- Radio equipment - Farinon FM 2000 (2GHz)
- Radio configuration - Space diversity with 2-watt hybrid transmitter
- Modulation - 132 Channels (3500 F9) with 126 KHz RMS deviation
- Transmission Line - 7/8" foam-filled Heliax

The following path calculation may be considered as typical:

Transmitter power (2 W)	33.0 dBm	
Transmitter antenna gain (8 ft.)	31.6 dB	
Transmission line loss (315 ft.)	9.8 dB	
Transmitted signal EIRP	54.8 dBm	
Path Loss	131.0 dB	
Receive antenna gain (8 ft.)	31.6 dB	
Receive transmission line loss (179 ft.)	5.5 dB	
Unfaded received signal	-50.1 dBm	
Unfaded noise	-21.5 dBrnC	(receiver threshold -91.5 dBm)
Fade margin	41.4 dB	

The fading margin of 41.4 dB plus the use of space diversity will insure a high path availability which will permit the required cascading of hops. The determination of the quantitative path availability is left for the communications study which will be performed later; however, the above calculation shows that no problem should result.

3.5.3.1.5 Terrestrial Radio Relay Equipment

3.5.3.1.5.1 General

For the purposes of this facilities study, the terrestrial radio relay system design was based on the use of analog radio and channeling equipment, rather than digital equipment. This was done based on the availability of data on proven designs, lower cost, and lower power demands. It should be recognized that the digital radio environment is dynamic and many new designs are being brought to the market - also new technologies and components are impacting designs to improve performance and reduce cost. The consideration of analog vs. digital for the terrestrial radio relay equipment is considered to be one of the prime tasks for the communications study to be performed at a later date.

The primary technical characteristics of the terrestrial radio relay equipment (also referred to as line of sight (LOS) equipment) are shown in Figure 3.5-5. The two classes of unmanned stations are identified in this figure. The primary communication equipment to be located at the unmanned radar stations is detailed. Also the reduced equipment requirement for the intervening LOS repeaters is identified.

3.5.3.1.5.2 Station Block Diagrams

Figures 3.5-6 and 3.5-7 are block diagrams of the LOS communications equipment for the unmanned radar sites and the intervening repeater sites. Figure 3.5-6 shows the space diversity arrangement utilized at the unmanned site. Outputs of two 1-watt transmitters are combined in a hybrid combiner which feeds two watts of output power to a duplexer. This a fail-soft configuration; loss of a transmitter drops the output power by 3 dB and the system will continue to operate with a 3 dB reduction in fading margin.

The top antenna is fed from the duplexer, thus making this antenna the transmitting antenna for best path clearance. The bottom antenna feeds only the diversity receiver. The non-correlated signal from the top antenna is fed to the other receiver and the output of the two receivers are combined in the diversity combiner. A 3-way, 4-wire bridge is used to cross-connect the basebands from the two sets of radio equipment and the local multiplex equipment.

FIGURE 3.5-5

LINE OF SIGHT MICROWAVE

EQUIPMENT CHARACTERISTICS

	UNMANNED RADAR STATIONS	LOS REPEATERS
TOWER	1 EACH - 285 FT	1 EACH - 149 FT
ANTENNAS	4 EACH - 8 FT PARABOLAS	4 EACH - 8 FT PARABOLAS
RADIO	2 GHZ FM REMODULATING REPEATERS WITH DROP AND INSERT	2 GHZ FM REMODULATING REPEATERS WITH ORDER WIRE
MULTIPLEX	7 CHANNEL - FREQ DIVISION	ORDER WIRE BELOW 12 KHZ
	12 TO 480 KHZ BASEBAND	
COMMON STATUS AND CONTROL	REMOTE STATION	REMOTE STATION
G/A/G RADIO	AN/GRC - 171	NOT PLANNED
INTERCOM AND PUBLIC ADDRESS	SPEAKER-PHONES AND SPEAKERS	NOT PLANNED

FIGURE 3.5-6

LINE OF SIGHT MICROWAVE UNMANNED STATIONS

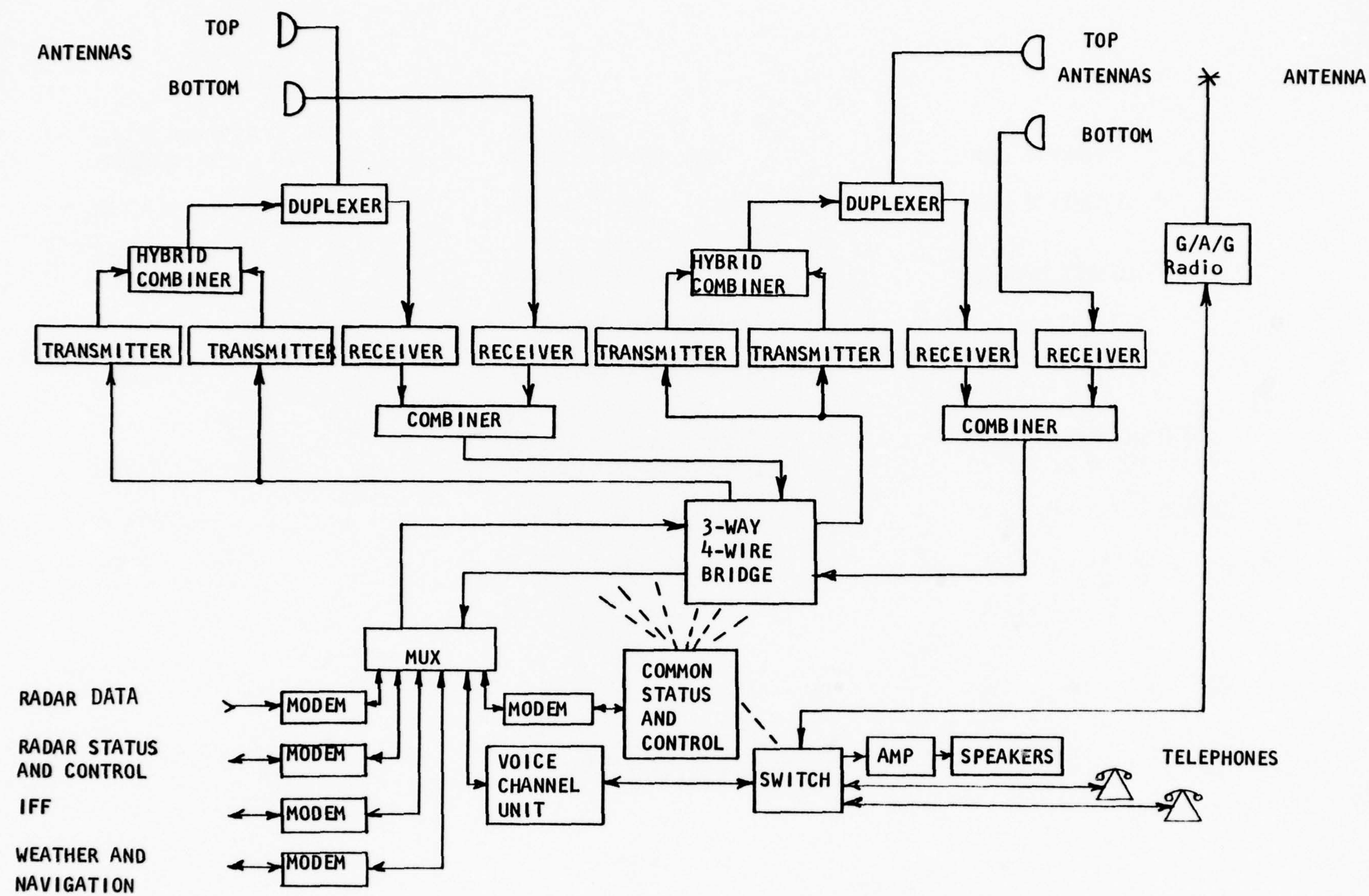
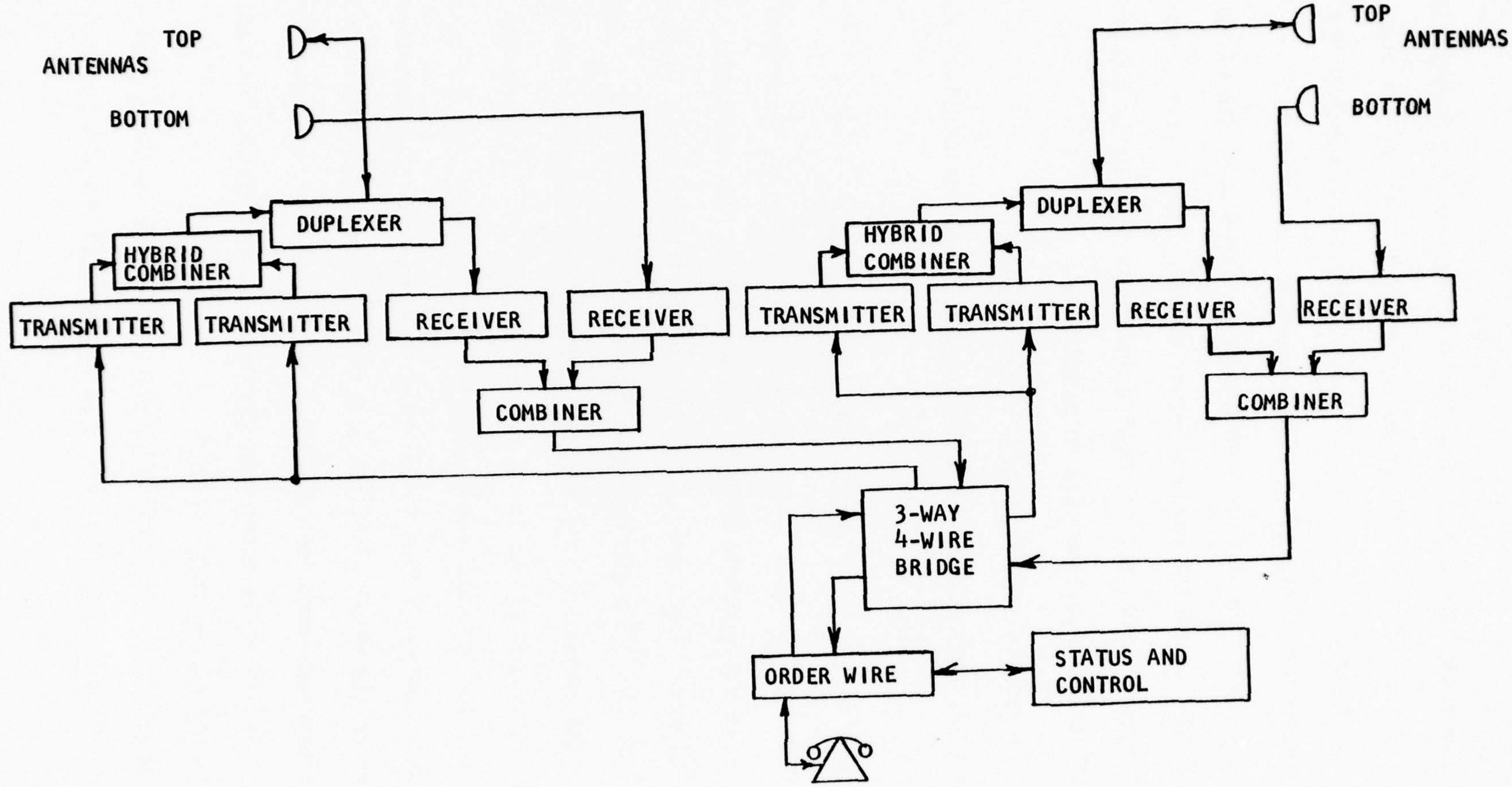


FIGURE 3.5-7

LINE OF SIGHT MICROWAVE

REPEATER SITES



Individual low speed modems are shown interfacing with the radar data, radar status and control, IFF, common status and control, and weather and navigation channels. As discussed in 3.5.3.1.3.2, an alternate arrangement would be to multiplex these signals and use a higher speed modem. Figure 3.5-7 which illustrates the configuration for the repeater site, shows that the rf equipment is identical to that of the unmanned radar sites. This station uses the same baseband bridge; however, the channeling equipment is greatly simplified since the repeated station requires only an order wire.

3.5.3.1.6 Line of Sight Environmental Considerations

Table 3.5-13 summarizes the environmental characteristics of the LOS equipment.

3.5.3.1.7 Line of Sight - Electrical Power Requirements

One of the major factors which impacts the design of the communications configuration is the electrical power consumption of the equipment. A summary of the electrical power requirements for the LOS configuration is included in Table 3.5-14. All of the LOS equipment would operate from 24 volts DC. The total power required for the communications equipment in the unmanned condition is 340 watts at the radar sites and 265 watts at the repeater sites. This assumes that the G/A/G radio and the intercom equipment will only be activated during maintenance visits or under emergency conditions. During the period when maintenance personnel are on the radar site, the electrical power requirements are 820 watts. Since the maintenance personnel will also require electrical power for their other activities, it is expected that additional power generation capability will be activated during this period.

The numbers given are considered to be conservative since they are based on actual hardware available today - they do not call for R & D programs. Since

TABLE 3.5-13

LINE OF SIGHT MICROWAVE

ENVIRONMENTAL CONSIDERATIONS

- INSIDE EQUIPMENT
  - EQUIPMENT MOUNTED IN TWO 19" RACKS
  - TOTAL RACK WEIGHT LESS THAN 600 LBS
  - OPERATIONAL UNDER THE FOLLOWING CONDITIONS:
    - a) TEMPERATURE — 0 TO +50° C
    - b) RELATIVE HUMIDITY — LESS THAN 90%
    - c) EARTHQUAKE-ACCELERATION — UP TO 0.25G
  - SURVIVE UNDER THE FOLLOWING CONDITIONS:
    - a) TEMPERATURE — - 70°C TO 60°C
    - b) RELATIVE HUMIDITY — 0 TO 100%
    - c) EARTHQUAKE-ACCELERATION — UP TO 0.5G
- OUTSIDE EQUIPMENT
  - FOUR 8 FT ANTENNAS MOUNTED ON A 285 FT GUYED TOWER (149 FT FOR REPEATERS)
  - OPERATIONAL UNDER THE FOLLOWING CONDITIONS:
    - a) TEMPERATURE — -70°C TO 60°C
    - b) RELATIVE HUMIDITY — 0 TO 100%
    - c) EARTHQUAKE-ACCELERATION — UP TO 0.25G
    - d) WIND LOADS — 100 MPH WITH 3" OF RADIAL RHIME ICE
  - SURVIVE UNDER THE FOLLOWING CONDITIONS:
    - a) EARTHQUAKE-ACCELERATION — UP TO 0.5G
    - b) WIND LOADS — 150 MPH WITH 3" OF RADIAL RHIME ICE

TABLE 3.5-14

LINE OF SIGHT MICROWAVE

ELECTRICAL POWER REQUIREMENTS - WATTS

	UNMANNED RADAR STATIONS	LOS REPEATERS
ANTENNA SYSTEM	0	0
RADIO (2W XMTR)	200	200
MULTIPLEX	50	25 (ORDER WIRE)
CHANNEL EQUIPMENT	50	0
COMMON STATUS AND CONTROL	40	40
G/A/G RADIO	450 TRANSMIT 150 RECEIVE	0
INTERCOM AND PUBLIC ADDRESS	30	0
TOTAL FOR UNMANNED CONDITION	340	265
MAXIMUM REQUIRED	820	265

power input is a characteristic that is currently being reduced due to new solid state technology, further reductions in these values may well be realized when the equipment is procured in the future.

3.5.3.1.8 LOS Configuration - Reliability Requirements

In order to determine the availability value for the LOS stations, it is necessary to calculate the Mean Time Between Failures (MTBF) and the Mean Time to Repair (MTTR) for the in-line components. As shown in Figure 3.5-8, the in-line components are defined to be the antennas, the radio equipment, the common multiplex equipment, the individual channel equipment, and the common status and control unit. The MTBF values for each piece of equipment is based on existing designs that are fabricated using high reliability industrial components in most circuits. The major commercial subsystems will be studied in depth to determine critical components which are the major constraints for increased MTBF's of the subsystem. Components with improved MTBF's will then be selected to bring about total subsystem improvements. Figure 3.5-9 illustrates the magnitude of improvement which may be realized in some instances.

In the case of the radio equipment, note that the MTBF of 20,000 hours applies to a transmitter-receiver-power supply combination. Because of the space diversity configuration utilized, full equipment redundancy is achieved. In addition, because the traffic is routed in both directions at the unmanned stations, those stations have transmission direction redundancy. All four transmitter-receiver-power supply combinations must fail before the station loses traffic-carrying capability. Because of this quadruple redundancy, the failure rate of the radio equipment becomes negligible when added to the other station failure rates.

FIGURE 3.5-8

LINE OF SIGHT MICROWAVE RELIABILITY DATA

	MTBF (HOURS)	FAILURE RATE (FAILURES/HR) UNMANNED STATIONS	FAILURE RATE (FAILURES/HR) REPEATER SITES
ANTENNAS	250,000	4×10^{-6}	4×10^{-6}
RADIO EQUIPMENT	20,000 IN QUAD	NEGL.	NEGL.
MUX EQUIPMENT (COMMON)	100,000	10×10^{-6}	10×10^{-6}
CHANNEL EQUIPMENT	100,000	10×10^{-6}	-
COMMON STATUS AND CONTROL	200,000	5×10^{-6}	5×10^{-6}
G/A/G RADIO	17,200	-	-
INTERCOM AND PUBLIC ADDRESS	100,000	-	-
TOTAL		29×10^{-6}	19×10^{-6}
• MTBF OF IN-LINE COMPONENTS		34,483 HRS	52,631 HRS
• WITH PROBABILITY OF SURVIVAL OF 0.9, REQUIRED MAINTENANCE LEVEL		> 4 MOS	> 7 MOS

FIGURE 3.5-9

MTBF IMPROVEMENTS

	COMMERCIAL PARTS	+	IC'S BURNED IN	+	LOWEST GRADE HI-REL COMPONENTS	+	IC'S LEAKAGE TESTED	+	MEDIUM GRADE HI-REL COMPONENTS	+	BEST GRADE HI-REL COMPONENTS AND MIL CLASS A IC'S
MTBF (HOURS)	2,000		6,300		14,800		20,600		46,500		96,700

Using these data, the MTBF at the unmanned stations is calculated to be 34,483 hours, and the MTBF for the repeaters is calculated to be 52,631 hours. To increase the confidence level to a 90% probability of survival, the projected MTBF is reduced to greater than four months for the unmanned stations, and greater than seven months for the repeater stations.

The MTTR data for the same equipment is shown in Table 3.5-15. By normalizing the failure rates to the antennas, the average site MTTR is shown to be 3.86 hours for the unmanned stations and 11.22 hours for the repeaters. For the availability calculation, it is assumed that 24 hours will be the average time required to get maintenance personnel to the site after a failure has been detected in the primary on-line equipment. Using these numbers, the availability of the unmanned earth station configuration is projected to be 0.9992 and the availability of the repeater station is projected to be 0.9993.

3.5.3.1.9 LOS Configuration - Cost Data

To compare the satellite configuration to the LOS microwave configuration, it was necessary to develop life cycle cost date for each approach. The cost elements and associated costs for the LOS configuration are listed in Table 3.5-16. It should be noted that this cost information is not the result of a detailed cost analysis, but rather it is a rough budgetary estimate. Further, in depth study of the communication system will permit the better definition of some of the factors which are the prime drivers of cost. Two specific factors which require further definition are the profiles between the unmanned radar sites and the soil bearing characteristics at the tower locations. Lacking this definition the present estimates have been based on almost worst case conditions, e.g., intermediate repeaters have been assumed between <u>all</u> unmanned radar sites. In addition comparitively high costs are included for tower footings at <u>all</u> locations.

TABLE 3.5-15

LINE OF SIGHT MICROWAVE

MAINTAINABILITY DATA

		MTTR HOURS	FREQUENCY OF FAILURES	REPAIR TIME
ANTENNAS		24.0	1	24.0
RADIO EQUIPMENT		1.0	NEGL.	NEGL.
MUX EQUIPMENT (COMMON)		0.6	2.5	1.5
CHANNEL EQUIPMENT		0.5	2.5	1.25
COMMON STATUS AND CONTROL		1.0	1.25	1.25
G/A/G RADIO		0.3	-	
INTERCOM AND PUBLIC ADDRESS		0.8	-	
	UNMANNED STATIONS		7.25	28.0
	REPEATER SITES		2.25	25.25

AVERAGE SITE MTTR:	UNMANNED STATIONS		3.86 HOURS
	REPEATER SITES		11.22 HOURS
ASSUMING 24 HOURS TO GET TO THE UNMANNED SITE - TOTAL MTTR:	UNMANNED STATIONS		27.9 HOURS
	REPEATER SITES		35.2 HOURS
AVAILABILITY:	UNMANNED STATIONS	0.9992	
	REPEATER SITES	0.9993	

TABLE 3.5-16

LINE OF SIGHT MICROWAVE

COST ELEMENTS

$ K - 1977 DOLLARS

	QTY.	NON-RECUR	INITIAL COST UNMANNED	INITIAL COST MANNED	INITIAL COST REPEATER	I & C/O WITH TRANSPORTATION UNMANNED	I & C/O WITH TRANSPORTATION MANNED	I & C/O WITH TRANSPORTATION REPEATER	ANNUAL COST
o ANTENNAS	4	10	20	20	20	4	4	4	2
o TOWER	1	25	43	43	23	57	57	30	3
o RADIO EQUIPMENT	4	200	50	50	50	10	10	10	2
o MUX COMMON EQUIP.	1	50	4	4	-	2	2	-	1
o CHANNEL EQUIPMENT	7	200	14	226	-	8	25	-	1
o COMMON STATUS & CONTROL	1	50	10	30	10	10	10	10	2
o G/A/G RADIO	1	100	5	5	-	10	10	-	2
o INTERCOM AND PUBLIC ADDRESS	1	20	10	10	-	10	10	-	3
TOTAL FOR EACH UNMANNED SITE		655	156	-	-	111	-	-	16
TOTAL FOR EACH MANNED SITE		-	-	388	-	-	128	-	26*
TOTAL FOR EACH REPEATER SITE		-	-	-	103	-	-	54	9

* INCLUDES COST OF MAINTAINING THE ADDITIONAL CHANNEL EQUIPMENT AT THE MANNED SITES.

As shown in Table 3.5-16 non-recurring costs were identified to cover the development of new capabilities such as remote tuning of the G/A/G radio and to identify high reliability components to assure the MTBF requirements of the unmanned stations.

During the development phase separate costs are identified for the initial cost of equipment and for the installation cost including the transportation of the equipment to the sites. It is recognized that there can be significant variations in these costs depending on such things as technical performance specifications, delivery schedules and method of installation and checkout. In general it was assumed that the existing technology was adequate for this application and could be fabricated using high quality components. The LOS equipment would be completely integrated and checked out prior to shipment to the site and would be installed by skilled field service personnel trained on the specific equipment.

The fourth cost category is the annual expense of maintenance of the equipment including replacement parts. The annual maintenance costs are based on the availability of skilled field service support at the logistics nodes with adequate spares to allow module replacement during corrective maintenance visits. Module repair would be accomplished at the logistics nodes.

As shown in Table 3.5-16, the cost elements are totaled separately for the unmanned, manned, and repeater sites. These data are then used to calculate the life cycle costs of the satellite configuration. A summary of this calculation is included as Figure 3.5-10. Based on a 20 year life cycle, it is estimated that the total cost of the LOS configuration is $79,704K. The majority of this cost ($42,520K) is related to the annual expense of maintenance.

This data is limited to the equipment cost.

FIGURE 3.5-10

LINE OF SIGHT MICROWAVE

COST DATA

		$K - 1977 DOLLARS		
	NON-RECUR.	INITIAL COST	I & C/O	ANNUAL COST
77 UNMANNED SITES	655	$12,012	$ 8,547	$1,232
6 MANNED SITES	-	2,328	768	156
82 REPEATER SITES	-	8,446	4,428	738
TOTAL	655	$22,786	$13,743	$2,126

FOR 20 YEAR LIFE CYCLE

NON-RECUR	655
INITIAL COST	22,786
INSTALLATION AND CHECKOUT	13,743
20 YEARS OF ANNUAL COST	42,520
TOTAL	79,704

3.5.3.1.10 LOS Configuration - Equipment Packaging and Mounting

The communications hardware for the LOS configuration consists of two racks of equipment, four 8-foot antennas with interconnecting coaxial cable and a guyed tower. The tower is 285 feet high at the radar sites and 149 feet high at the intervening repeater sites. Figure 3.5-11 shows the rack elevation of the equipment. The radio rack is a six foot high rack with a foot print of 24" x 24". The estimated weight of the rack is 250 lbs.

The antennas are Andrew high performance 8-foot antennas equipped with radomes to help protect against icing.

The two racks as shown in Figure 3.5-11 apply to the radar sites. At the intervening repeaters, however, only the radio rack is required. The order wire and common status and control equipment required at the repeater sites can be incorporated into the radio rack by increasing its height to seven feet.

3.5.3.1.11 LOS Configuration Vulnerability

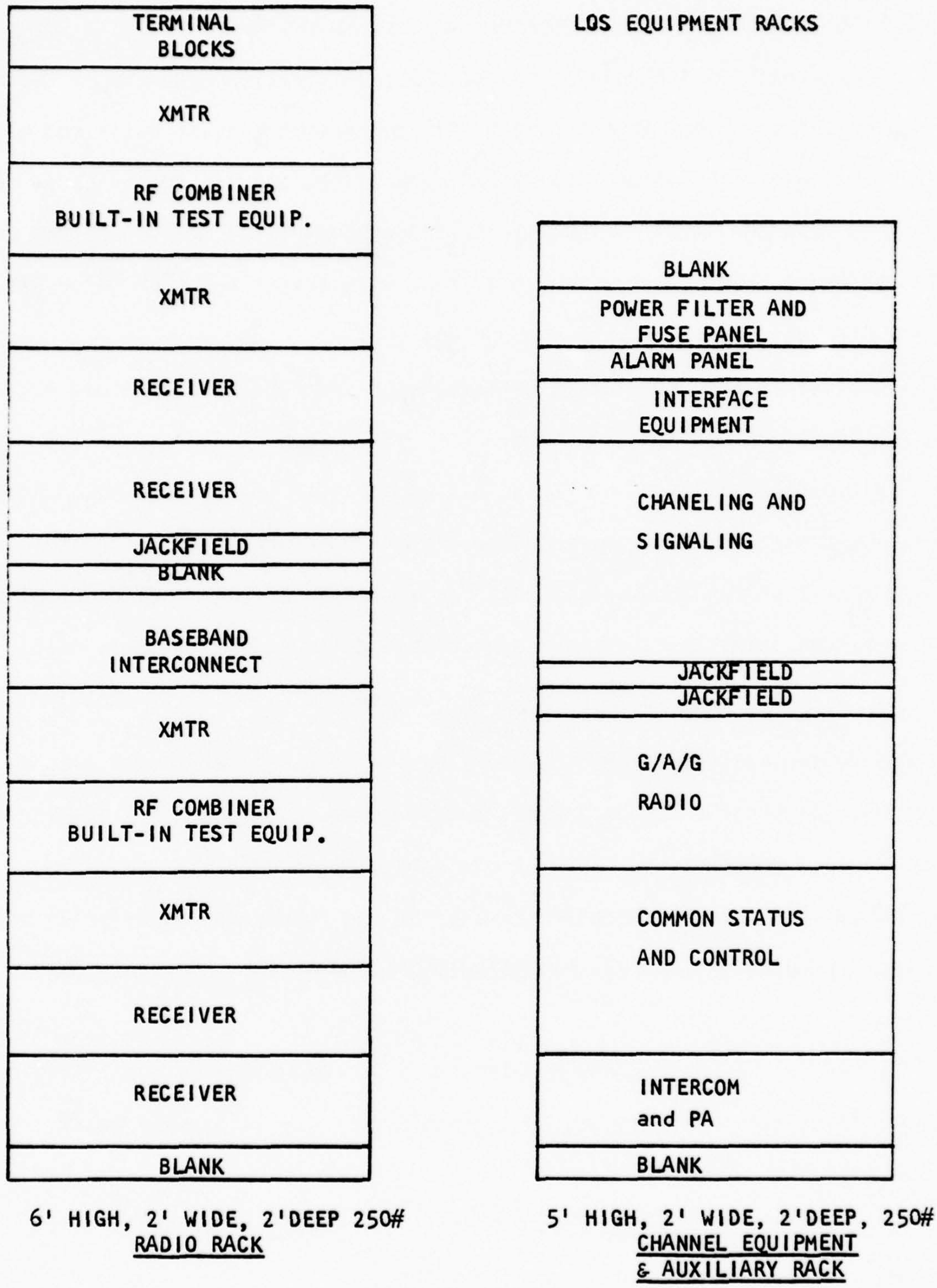
LOS terrestrial radio relay systems have a long and well-known history of operation. The systems can be jammed, but in general it requires a jammer either in close proximity to the stations or a very powerful jammer. The system offers additional protection because of the redundant transmission paths which would require jamming activity simultaneously at two separated geographic locations.

The use of spread spectrum modulation could reduce the vulnerability of the radio relay system to jamming but it would increase life cycle costs substantially.

Vulnerability to jamming should be considered in greater depth during the communications study planned for the future.

FIGURE 3.5-11

LOS EQUIPMENT RACKS



3.5.3.1.12 Telephone and Television Service for Local Communities

3.5.3.1.12.1 Telephone Service

Refer to Figure 3.5-4 the network of stations in conjunction with the intervening relay stations can easily be provided with the capability of carrying additional telephone channels for community service. This expandability is one of the attributes of an LOS system. In most cases the additional service is obtained by only the addition of multiplex channel units at the two stations closest to the communities desiring the service. The switch at Station 31 could be used (if desired) to offer switched service to several communities.

3.5.3.1.12.2 Television Service

The backhaul stations (1, 16, 31, 46, 61 and 83, Figure 3.5-4) are equipped with satellite stations in order to carry traffic to the rear elements. If these stations were modified to pick-up a television signal from a satellite transponder, then that signal could be sent laterally along the radio relay route to the designated community. Because of the wide baseband requirements of a television signal, an additional set of radio equipment is required for each intervening station on the route between the closest backhaul station and the closest station to the designated community. The antennas, transmission line and the rest of the facilities are not impacted, however, the cost increase of the parallel radio equipment will be substantial unless the community is very close to the satellite station making the TV pick-up.

3.5.3.2 Satellite Configuration

3.5.3.2.1 System Description

A satellite configuration was developed to meet the basic communications requirements of the unattended network. A system diagram of this configuration is shown in Figure 3.5-12. As shown, each unmanned station would be interconnected to a manned logistics node by a communications satellite. The odd numbered sites would use another satellite. This would minimize the impact of satellite problems caused by either natural occurances or induced by offensive forces. Each site would be equipped with two fixed antennas (one for each satellite). Switchover to the alternate satellite can be accomplished by either command from the manned node or through automatic detection circuitry at the unmanned station.

The feasibility of using commercial satellites was investigated for this application. A list of domestic communications satellites is included in Table 3.5-17. Each of these satellites is positioned to permit coverage for the unattended network. Figure 3.5-13 shows the satellite coverage for earth stations with 5^{o} of elevation look angle or greater for the satellites in the extreme east and west positions as well as the satellite located at 119^{o}E. It is obvious from this figure that any earth station in the unattended network will have visibility to at least four satellites. The ability to communicate through a specific satellite will depend on the unique characteristics of each satellite and the associated earth stations. The link calculations in the following section are based on the typical characteristics of existing domestic satellites.

3.5.3.2.2 Link Calculations

In order to size the RF components required at the various sites in the unattended netowrk, a link analysis was performed based on the use of domestic communications satellites. The nominal characteristics used in the link calculations are as follows:

FIGURE 3.5-12

SATELLITE CONFIGURATION

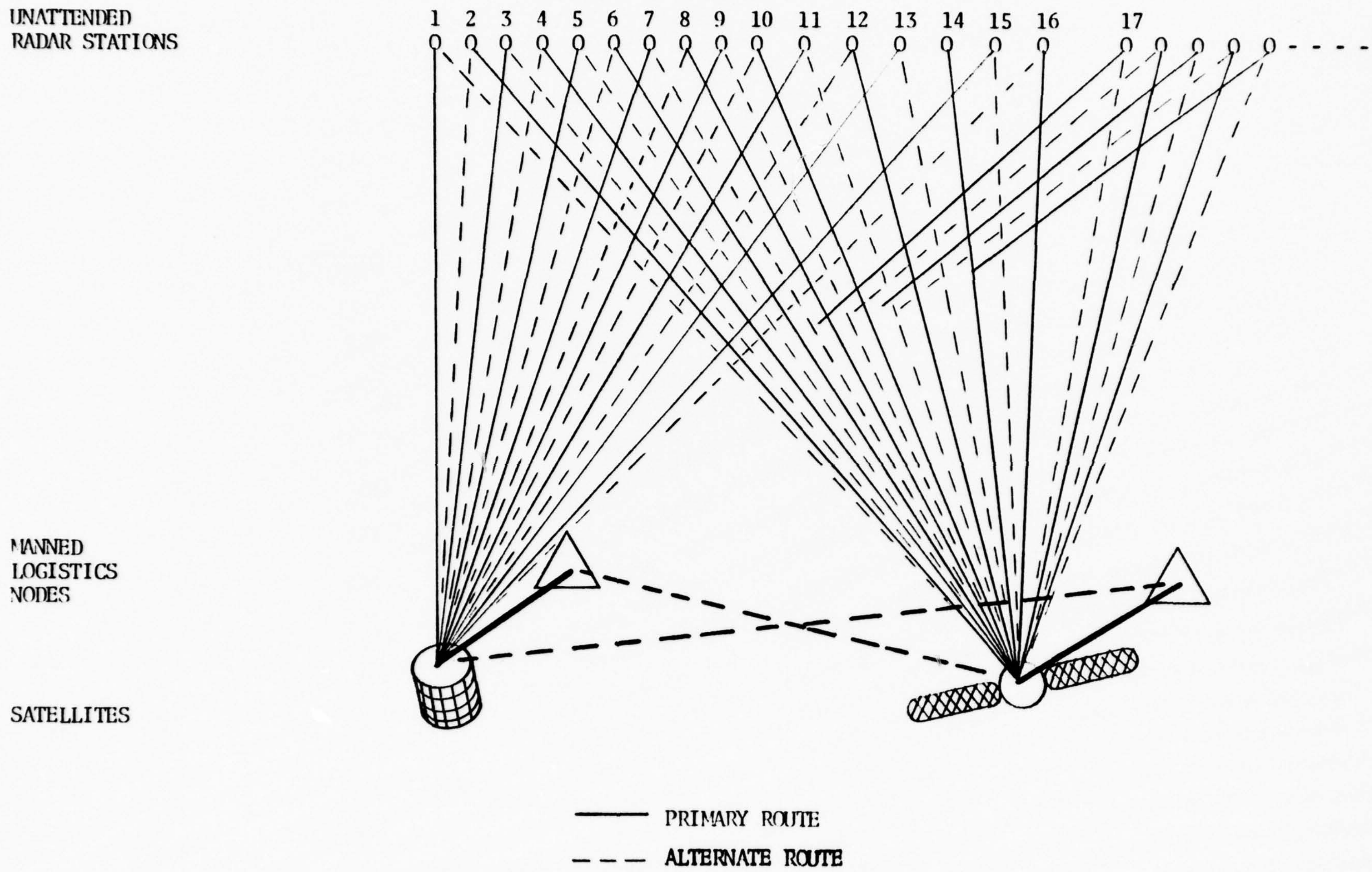


TABLE 3.5-17

DOMESTIC SATELLITES

EXISTING

EAST LONGITUDE

95°	COMSTAR II
99°	WESTAR I
104°	ANIK III
109°	ANIK II
114°	ANIK I
119°	RCA SATCOM I
123.5°	WESTAR II
128°	COMSTAR I
135°	RCA SATCOM II

PLANNED

COMSTAR III - MAY 1978

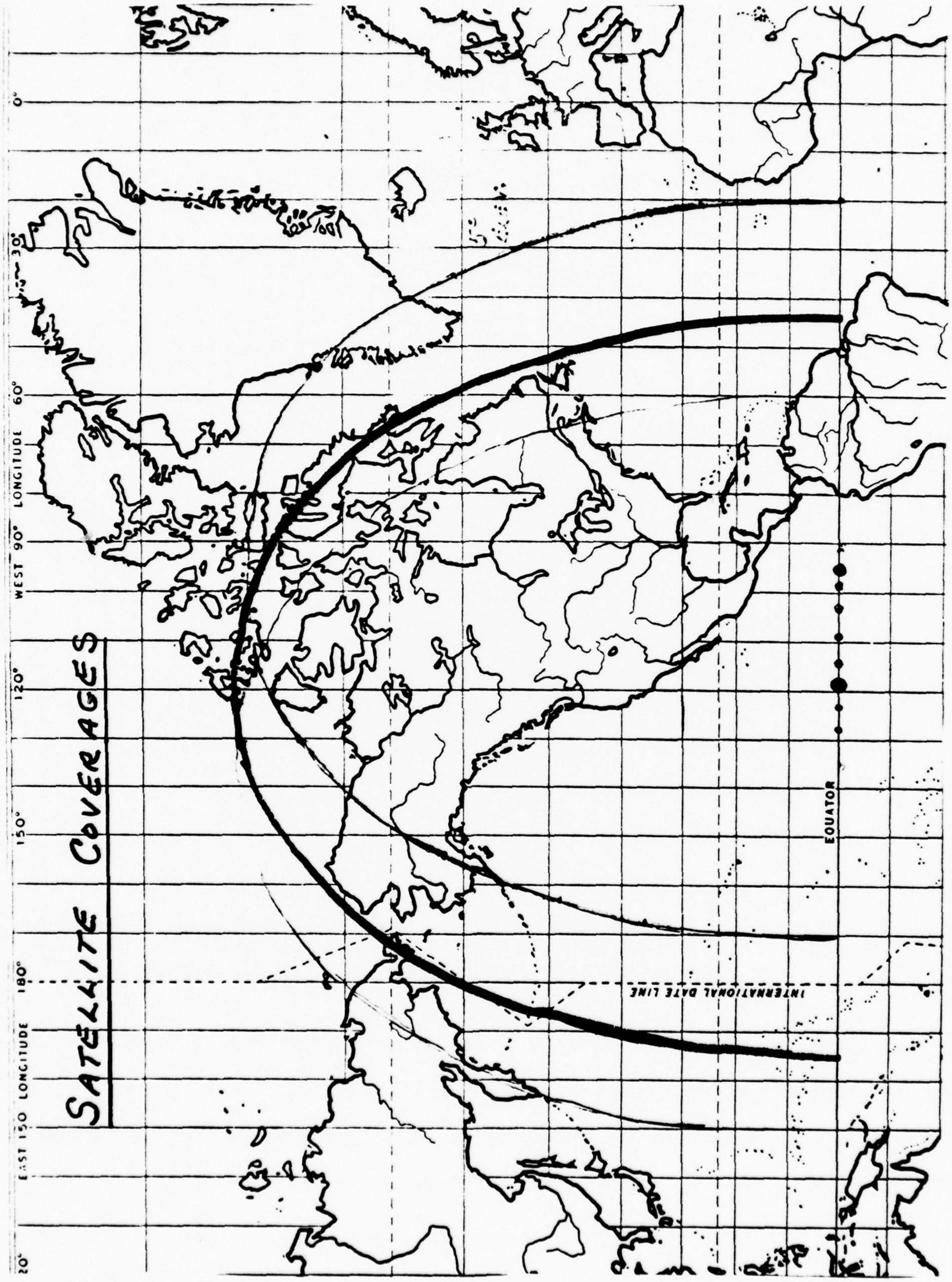

SATELLITE COVERAGES
EAST 150 LONGITUDE
180°
150°
120°
WEST 90° LONGITUDE
60°
30°
0°
EQUATOR
INTERNATIONAL DATE LINE

FIGURE 3.5-13

Satellite EIRP (3dB Contour)	33 dBw
Satellite G/T	-7 dB/^{0}K
Bandwidth (BW) of integrated carrier (64 Kbps)	48 dB
k- Boltzmann's constant	228.6 dB
C/N Required for BPSK	9.3 dB

The link from the unmanned sites to the logistics nodes is summarized below:

C/N Thermal Uplink (Table 5-18)	22.4 dB
C/N Thermal Downlink (Table 5-19)	12.5 dB
C/N Intermodes	22.0 dB
C/N Interference (Allocation)	19.0 dB
C/N Total*	10.8 dB
C/N Required for BPSK	9.3 dB
Link Margin	1.5 dB

The link from the logistics nodes to the unmanned sites is summarized below:

C/N Thermal Uplink (Table 5-18)	32.4 dB
C/N Thermal Downlink (Table 5-19)	17.5 dB
C/N Intermodes	22.0 dB
C/N Interference (Allocation)	19.0 dB
C/N Total*	14.2 dB
C/N Required for BPSK	9.3 dB
Link Margin	4.9 dB

$$*C/N\ Total = 10\ Log \left[\frac{1}{\frac{1}{Log^{-1} C/N(TU)} + \frac{1}{Log^{-1} C/N(DL)} + \frac{1}{Log^{-1} C/N(IM)} + \frac{1}{Log^{-1} C/N(Int)}} \right]$$

From the downlink calculations, it was dtermined that a G/T of 20 dB/ok was required at the unmanned radar stations and a G/T of 25 dB/ok was required at the manned logistics nodes. At the present time, 4.5 meter antennas are considered to be the smallest size that will be authorized by the FCC for use with C band domestic satellites. The gain of this size antenna at 4 GHz is 42.5 dB; therefore,

TABLE 3.5-18

UPLINKS

	FROM UNMANNED SITES	FROM LOGISTICS NODES	
FLUX DENSITY AT SATELLITE TO SATURATE TRANSPONDER	-80.0	-80.0	dBW/M²
INPUT BACKOFF FOR - 6.1 DB BACKOFF	-11.2	-11.2	dB
% OF TRANSPONDER POWER	-3.0	-3.0	dB
NUMBER OF CHANNELS	-20.0	-10.0	dB
ABSORPTION AREA OF ISOTROPIC ANTENNA	-37.0	-37.0	dB
POWER REQUIRED AT SATELLITE	-151.2	-141.2	dBW
LOSSES	-201	-201	dB
-SPACE LOSS (-199.1)			
-POLARIZATION (-0.1)			
-WEATHER & ATMOSPHERICS (-0.1)			
-TRANSMIT ANT. POINTING ERROR (-0.2)			
-5° ANT ELEVATION ANGLE (-1.5)			
GROUND STATION EIRP/CHANNEL (UNSATURATED) REQUIRED	49.8	59.8	dBW
C/N THERMAL = EIRP/CHAN - LOSSES + G/T (SAT)+k-BW	22.4	32.4	dB

TABLE 3.5-19

DOWNLINKS

	TO LOGISTIC NODES	TO UNMANNED SITES	
SATELLITE EIRP (3dB CONTOUR)	33.0	33.0	dBW
OUTPUT BACKOFF	-6.1	-6.1	dB
% OF TRANSPONDER POWER	-3.0	-3.0	dB
NUMBER OF CHANNELS	-20.0	-10.0	
AVERAGE EIRP/CHAN	3.9	13.9	dBW
LOSSES	-197.0	-197.0	dB
-SPACE LOSS (-195.6)			
-POLARIZATION (-0.1)			
-WEATHER AND ATMOSPHERICS (-0.1)			
-RECEIVE ANT. POINTING ERROR (-0.2)			
-5° ANT. ELEVATION ANGLE (-1.1)			
k	228.6	228.6	dB
BW	-48.0	-48.0	dB
G/T (EARTH STATION)	25.0	20.0	dB/OK
C/N THERMAL	12.5	17.5	dB

the system noise temperature of the unmanned site must be less than 42.5-20= 22.5 dB (178^{o}k). At 5^{o} elevation, the antenna noise temperature is 46^{o}k. Based on existing technology, solid state amplifiers are available with 100^{o}k noise temperature which allows adequate margin for transmission line losses between the antenna and the low noise amplifier. A similar analysis of the manned nodes establishes the requirement for an uncooled parametric amplifier with a noise temperature of 40^{o}k.

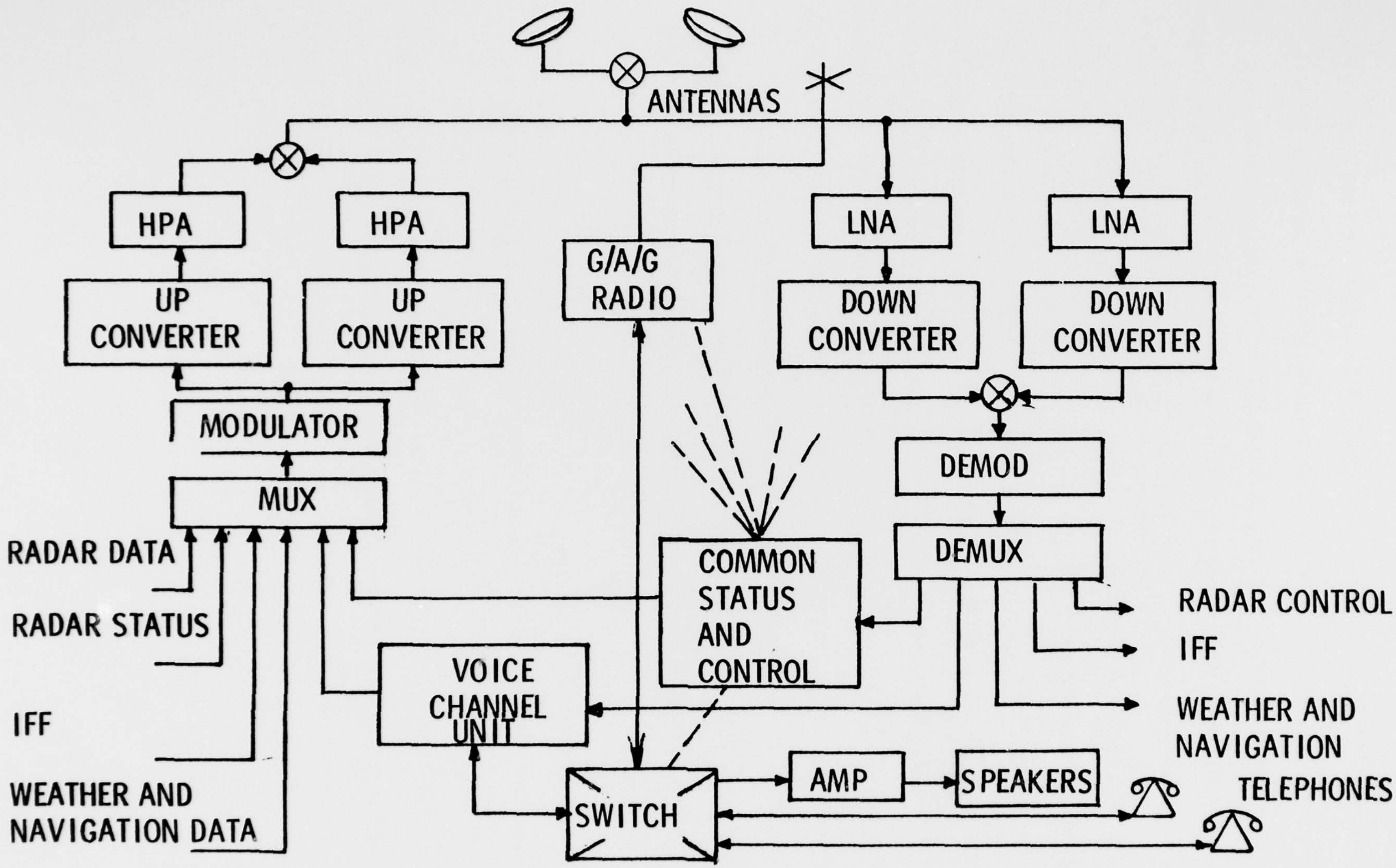
On the transmit side, it was determined from the uplink calculations that the EIRP required at the unmanned stations was 49.8 dBW and at the manned nodes 59.8 dBW. The gain of the 4.5 meter antenna at 6 GHZ is 45.2 dB. With an allowance of 1 dB for transmission line loss, the transmitter requirement at the unmanned radar stations is 49.8-45.2+1.0=5.6 dBW (3.6W). This can be implemented using solid state amplifiers with 10 watts of output power. A similar calculation for the manned sites establishes the requirement for a 15.6 dBW transmitter which can be implemented using 400 watt traveling wave tube amplifiers.

3.5.3.2.3 Earth Station Equipment

Based on the communications requirements and the link analysis, a block diagram for an earth station configuration was developed. As shown in Figure 3.5-14, this configuration includes two antennas, redundant high power amplifiers, redundant u/down converters, seven channel digital multiplex equipment, a voice channel unit to be shared between the G/A/G radio and the local maintenance circuit, common status and control equipment, and the G/A/G radio with its associated antenna.

FIGURE 3.5-14

UNMANNED STATIONS SATELLITE CONFIGURATION



The characteristics of each unit in this configuration are included in Figures 3.5-15 through 3.5-26. The information included in these tables should be based on a more detailed study and should include many parameters that are not addressed in these tables.

3.5.3.2.4 Satellite Configuration - Electrical Power Requirements

One of the major factors which impacts the design of the communications configuration is the electrical power consumption of the equipment. A summary of the electrical power requirements for the satellite configuration is included in Table 3.5-20. All the earth station equipment would operate from either 24 or 48 volts DC. The total power required for the communications equipment in the unmanned condition is 470 watts. This assumes that the G/A/G radio and the intercom equipment will only be activated during maintenance visits or under emergency conditions. During the period when maintenance personnel are on the site, the electrical power requirements are 950 watts. Since the maintenance personnel will also require electrical power for their other activities, it is expected that additional power generation capability will be activated during this period.

3.5.3.2.5 Satellite Configuration - Reliability Requirements

In order to determine the availability value for the satellite configuration it is necessary to calculate the Mean Time Between Failures (MTBF) and the Mean Time to Repair (MTTR) for the in-line components. As shown in Table 3.5-21, the in-line components are defined to be the antennas, the high power amplifiers, the low noise receivers, the u/down converters, the channel equipment, and the common status and control unit. The MTBF values for each piece of equipment is based on existing designs that are fabricated using the best

FIGURE 3.5-15

ANTENNA

• SIZE	4.5 METER
• FREQUENCY	
TRANSMIT	5.925 TO 6.425 GHZ
RECEIVE	3.7 TO 4.2 GHZ
• GAIN	
@ 6 GHZ	45.2 DB
@ 4 GHZ	42.5 DB
WITH WINDS TO 87 MPH AND STATIC LOAD OF 1/2" RADIAL ICE OR 6" OF SNOW ON NON-RADIATING SURFACES OF THE ANTENNA.	
• POWER HANDLING CAPABILITY	
@ 6 GHZ	2 KW
• VSWR MAXIMUM	1.3
• POLARIZATION	TRANSMIT AND RECEIVE PORTS LINEAR AND ORTHOGONAL TO EACH OTHER.
• POLARIZATION ADJUSTMENT	360° BY FEED ROTATION
• BEAMWIDTH - HALF POWER POINTS	
@ 4 GHZ	1.2°
@ 6 GHZ	0.9°
• NOISE TEMPERATURE - AT 5° ELEVATION	50°K MAX.
• PATTERN ENVELOPE	PER 25.209(a) OF FCC RULES AND REGULATIONS.
• TEMPERATURE	-60 TO +125°F
• PRESSURIZATION	WAVEGUIDE AND FEEDHORN PRESSURIZED USING DRY NITROGEN.
• WEIGHT	2300 LBS.
• RADOME	EITHER HYPALON OR FIBERGLASS
• MOUNTING	CAN BE MOUNTED ON THE GROUND OR ON THE RADAR TOWER.
• MTBF	250,000 HOURS
• MTTR	24 HOURS

FIGURE 3.5-16

HIGH POWER AMPLIFIER

UNMANNED RADAR STATION

• CONFIGURATION	REDUNDANT WITH AUTOMATIC SWITCHOVER TO THE SECOND UNIT.
• TRANSMIT FREQUENCY	5.925 TO 6.425 GHZ
• POWER OUTPUT	10 W
• BANDWIDTH	500 MHZ
• GAIN	50 DB
• SPURIOUS OUTPUTS	80 DB BELOW RATED OUTPUT
• OPERATING TEMPERATURE RANGE	0 TO 40°C
• ELECTRICAL POWER-MAX.	200 W AT 24/48 VDC
• DIMENSIONS	19" X 7" X 20"
• WEIGHT-MAX.	20 LBS.
• MTBF	100,000 HOURS
• MTTR-AFTER ARRIVAL AT SITE	0.5 HOURS

FIGURE 3.5-17

HIGH POWER AMPLIFIER

MANNED LOGISTICS NODE

• CONFIGURATION	REDUNDANT WITH AUTOMATIC SWITCHOVER TO THE SECOND UNIT.
• TRANSMIT FREQUENCY	5.925 TO 6.425 GHZ
• POWER OUTPUT	400 W
• BANDWIDTH	500 MHZ
• GAIN	60 DB
• SPURIOUS OUTPUTS	65 DB BELOW RATED OUTPUT.
• OPERATING TEMPERATURE RANGE	0 TO 40°C
• ELECTRICAL POWER-MAX.	3000 W AT 24/48 VDC
• DIMENSIONS	19" X 24" X 24"
• WEIGHT-MAX.	200 LBS
• MTBF	20,000 HOURS
• MTTR	1 HOUR

FIGURE 3.5-18

LOW NOISE RECEIVER

UNMANNED RADAR STATIONS

• CONFIGURATION	REDUNDANT WITH AUTOMATIC SWITCHOVER TO THE SECOND UNIT.
• NOISE TEMPERATURE (MAX.)	100°K
• FREQUENCY	3.7 TO 4.2 GHZ
• GAIN	50 DB
• BANDWIDTH (MINIMUM)	500 MHZ AT THE 1 DB POINTS
• INTERMODULATION	IM PRODUCTS SHALL BE AT LEAST 50 DB BELOW EACH OF TWO EQUAL SIGNALS WHOSE OUTPUT ARE -5 DBM.
• OPERATING TEMPERATURE RANGE	0 TO 40°C
• ELECTRICAL POWER-MAX.	10 W MAX. @ 24/48 VDC
• DIMENSIONS	19" X 5 1/4" X 20"
• WEIGHT-MAX.	10 LBS.
• MTBF	150,000 HOURS
• MTTR - AFTER ARRIVAL ON-SITE	0.5 HOURS

FIGURE 3.5-19

LOW NOISE RECEIVER

MANNED LOGISTICS NODE

• CONFIGURATION	REDUNDANT WITH AUTOMATIC SWITCHOVER TO THE SECOND UNIT.
• NOISE TEMPERATURE (MAX.)	40°K
• FREQUENCY	3.7 TO 4.2 GHZ
• GAIN	50 DB
• BANDWIDTH (MINIMUM)	500 MHZ AT THE 1 DB POINTS
• INTERMODULATION	IM PRODUCTS SHALL BE AT LEAST 50 DB BELOW EACH OF TWO EQUAL SIGNALS WHOSE OUTPUT ARE -5 DBM
• OPERATING TEMPERATURE RANGE	0 TO 40°C
• ELECTRICAL POWER - MAX.	600 W MAX. @ 24/48 VDC
• DIMENSIONS - WALL MOUNTING	12" X 15" X 36"
• WEIGHT - MAX.	80 LBS.
• MTBF	25,000 HOURS
• MTTR	0.9 HOURS

FIGURE 3.5-20

CONVERTER AND COMMON EQUIPMENT

• TECHNICAL PERFORMANCE	AS FOLLOWS
• OPERATING TEMPERATURE RANGE	0 TO 40°C
• ELECTRICAL POWER-MAX.	140 W @ 24/48 VDC
• DIMENSIONS	19" X 33" X 12"
• WEIGHT - MAX.	50 LBS.
• MTBF	120,000 HOURS
• MTTR	1 HOUR

FIGURE 3.5-21

UP CONVERTER

• CONFIGURATION	REDUNDANT WITH AUTOMATIC SWITCHOVER TO THE SECOND UNIT.
• OUTPUT FREQUENCY	5.925 TO 6.425 GHZ
• OUTPUT POWER	
- SINGLE CHANNEL	0 DBM
- MULTI-CHANNEL	-10 DBM COMPOSITE
• OUTPUT CHANNEL BANDWIDTH	36 MHZ
• OUTPUT CENTER FREQUENCY SELECTION CONTROL	24 STEPS OF 20 MHZ
• GAIN	20 DB
• INPUT FREQUENCY	70 $\pm$ 18 MHZ
• TWO CARRIER IM PRODUCTS (EACH CARRIER AT -13 DBM)	$<$ -40 DB FROM CARRIER

FIGURE 3.5-22

DOWN CONVERTER

• CONFIGURATION	REDUNDANT WITH AUTOMATIC SWITCHOVER TO THE SECOND UNIT.
• INPUT FREQUENCY	3.7 TO 4.2 GHZ
• INPUT CENTER FREQUENCY SELECTION CONTROL	24 STEPS OF 20 MHZ
• NOISE FIGURE	$<$ 14 DB
• INPUT SIGNAL LEVEL	-85 DBM
• OUTPUT FREQUENCY RANGE	70 $\pm$ 18 MHZ
• OUTPUT POWER-MAX.	+9 DBM COMPOSITE
• GAIN-NOMINAL	65 DB
• THIRD ORDER IM PRODUCTS (2 CARRIERS EACH AT +6 DBM OUTPUT)	$>$ 40 DB BELOW CARRIER

FIGURE 3.5-23

CHANNEL EQUIPMENT

• IF INTERFACE	
- OUTPUT POWER	-20 DBM
- INPUT POWER-MIN.	-50 DBM PER CARRIER
- OUTPUT FREQUENCY	70 ± 18 MHZ
- INPUT FREQUENCY	70 ± 18 MHZ
• DIGITAL INTERFACE	
- NUMBER OF INPUTS	UP TO 7
- NUMBER OF OUTPUTS	UP TO 7
- INPUT DATA RATE	UP TO 1200 BPS
- OUTPUT DATA RATE	UP TO 1200 BPS
• VOICE INTERFACE	
- OUTPUT LEVEL	+7 DBM
- INPUT LEVEL	-16 DBM
- OUTPUT IMPEDANCE	600 OHMS, BALANCED
- INPUT IMPEDANCE	600 OHMS, BALANCED
- FREQUENCY RESPONSE - 300 TO 3200 HZ	+0.8 TO -1.5 DB
• MODULATION TECHNIQUE	PSK
• OPERATING TEMPERATURE RANGE	0 TO 40°C
• ELECTRICAL POWER-MAX.	80 W
• DIMENSIONS	19" X 9" X 12"
• WEIGHT-MAX.	40 LBS.
• MTBF	100,000 HOURS
• MTTR - AFTER ARRIVAL AT SITE	1 HOUR

FIGURE 3.5-24

COMMON STATUS AND CONTROL

• STATUS	
- NUMBER OF INPUTS - MIN.	120
- INPUT FORMAT	LOGIC LEVELS OR RELAY CLOSURES
- OUTPUT FORMAT	DIGITAL - UP TO 100 BPS
- RESPONSE TIME	OUTPUT STATUS MESSAGE WITHIN 2 SECONDS OF CHANGED INPUT.
• CONTROL	
- NUMBER OF OUTPUTS - MIN.	50
- INPUT FORMAT	DIGITAL - UP TO 10 BPS
- OUTPUT FORMAT	LOGIC LEVELS OR RELAY CLOSURES
• ERROR RATE ON COMMAND AND STATUS MESSAGES	BER $< 1 \times 10^{-9}$
• OPERATIONAL TEMPERATURE RANGE	0 TO 40°C
• ELECTRICAL POWER - MAX.	50 W @ 24/48 VDC
• DIMENSIONS	19" X 10" X 20"
• WEIGHT - MAX.	50 LBS.
• MTBF	200,000 HOURS
• MTTR - AFTER ARRIVAL ON SITE	1 HOUR

FIGURE 3.5-25

GROUND/AIR/GROUND RADIO

• MODEL	AN/GRC-171
• TYPE	AM TRANSCEIVER
• FREQUENCY BAND	225 TO 400 MHZ
• OUTPUT POWER	10 TO 20 WATTS
• CHANNEL SELECTION	ANY ONE OF 7000
• REMOTE CONTROLS	POWER - ON/OFF-RECEIVER SQUELCH TRANSMITTER - KEYING TUNING - TO SINGLE CHANNEL
• OPERATING TEMPERATURE RANGE	-29 TO +65°C
• ELECTRICAL POWER - MAX.	400 W TRANSMIT 185 W RECEIVE
• DIMENSIONS	19" x 8-3/4" x 20.5"
• WEIGHT - MAX.	75 LBS.
• MTBF	17,200 HOURS
• MTTR	15 MIN. MAX.

FIGURE 3.5-26

INTERCOM AND PUBLIC ADDRESS

• INTERSTATION COMMUNICATIONS	
- TRANSMISSION MEDIA	DUPLEX VOICE GRADE CHANNEL
- TERMINATION EQUIPMENT	TELEPHONE INSTRUMENTS
• INTRASTATION COMMUNICATIONS	
- TRANSMISSION MEDIA	STATION WIRING
- TERMINATION EQUIPMENT	SPEAKER-PHONE WITH HEADSET CAPABILITY
• PUBLIC ADDRESS	
- TRANSMISSION MEDIA	SIMPLEX VOICE GRADE CHANNEL
- TERMINATION EQUIPMENT	INSIDE AND OUTSIDE SPEAKERS
• OPERATING TEMPERATURE RANGE	
- INSIDE EQUIPMENT	0 TO 40°C
- OUTSIDE EQUIPMENT	-70 TO 60°C
• ELECTRICAL POWER - MAX.	30 W
• DIMENSIONS	TBD
• WEIGHT	TBD
• MTBF	100,000 HOURS
• MTTR	1 HOUR

TABLE 3.5-20

SATELLITE CONFIGURATION

ELECTRICAL POWER REQUIREMENTS

	WATTS AT 24/48 VDC
ANTENNA	0
HIGH POWER AMPLIFIER	200
LOW NOISE RECEIVER	10
UP/DOWN CONVERTER	140
CHANNEL EQUIPMENT	80
COMMON STATUS AND CONTROL	40
G/A/G RADIO	450 - TRANSMIT 150 - RECEIVE
INTERCOM AND PUBLIC ADDRESS	30
TOTAL FOR UNMANNED CONDITION	470 WATTS
MAXIMUM REQUIRED	950 WATTS

TABLE 3.5-21

SATELLITE CONFIGURATION

RELIABILITY DATA

	MTBF (HOURS)	FAILURE RATE (FAILURES/HR)
ANTENNA	250,000	4×10^{-6}
HIGH POWER AMPLIFIER	100,000	10×10^{-6}
LOW NOISE RECEIVER	150,000	6.7×10^{-6}
UP/DOWN CONVERTERS	120,000	8.3×10^{-6}
CHANNEL EQUIPMENT	100,000	10×10^{-6}
COMMON STATUS AND CONTROL	200,000	5×10^{-6}
G/A/G RADIO	17,200	-
INTERCOM AND PUBLIC ADDRESS	100,000	-
TOTAL		44×10^{-6}

- MTBF OF IN-LINE COMPONENTS $= \frac{10^6}{44} = 22,727$ HRS
- WITH PROBABILITY OF SURVIVAL OF 0.9 REQUIRED MAINTENANCE INTERVAL = 2273 HRS = 3.1 MONTHS

grade, high reliability components and MIL Class A integrated circuits. Figure 3.5-9 shows the MTBF improvements that were calculated for a typical commercial design that is implemented by various quality components. The MTBF values shown in Table 3.5-21 were established using this approach and should be realizable through proper component selection.

Using this data, the earth station MTBF at the unmanned stations is calculated to be 22,727 hours. To increase the confidence level to a 90% probability of survival, the projected MTBF is reduced to 2,273 hours which corresponds to 3.1 months.

The MTTR data for the same equipment is shown in Table 3.5-22. By normalizing the failure rates to the antennas, the average site MTTR is shown to be 3.32 hours. For the availability calculation, it is assumed that 24 hours will be the average time required to get maintenance personnel to the unmanned site after a failure has been detected in the primary on-line equipment. Using these numbers, the availability of the unmanned earth station configuration is projected to be 0.9988.

3.5.3.2.6 Satellite Configuration - Cost Data

To compare the satellite configuration to the LOS microwave configuration, it was necessary to develop life cycle cost data for each approach. The cost elements and associated costs for the satellite configuration are listed in Table 3.5-23. It should be noted that this cost information is not the result of a detailed cost analysis, but reflects an understanding of the costs associated with the development, fabrication, implementation and operation of satellite systems based on information developed by several years of experience and kept current through continued involvement in large communications programs.

TABLE 3.5-22

SATELLITE CONFIGURATION

MAINTAINABILITY DATA

	MTTR (HOURS)	FREQUENCY OF FAILURES	REPAIR TIME
ANTENNA	24.0	1	24.0
HIGH POWER AMPLIFIER	0.5	2.5	1.25
LOW NOISE RECEIVER	0.5	1.7	0.85
UP/DOWN CONVERTER	1.0	2.1	2.1
CHANNEL EQUIPMENT	1.0	2.5	2.5
COMMON STATUS AND CONTROL	1.0	1.25	1.25
G/A/G RADIO	0.3	---	---
INTERCOM AND PUBLIC ADDRESS	0.8	---	---
TOTAL		11.05	36.70

- AVERAGE SITE MTTR = 36.70/11.05 = 3.32 HOURS
- ASSUMING 24 HOURS TO GET TO THE UNMANNED SITE - TOTAL MTTR = 27.3 HOURS
- AVAILABILITY = MTBF/MTBF + MTTR = 22,727/22,754.3 = 0.9988

SATELLITE CONFIGURATION
COST ELEMENTS

		$ K - 1977		
	NON-RECUR.*	INITIAL COST	I & C/O WITH TRANS.	ANNUAL COST
• ANTENNA WITH RADOME				
4.5M EACH	50	15	10	2
• HIGH POWER AMPLIFIER				
10W REDUNDANT	100	10	10	2
400W REDUNDANT	100	60	20	10
• LOW NOISE RECEIVER				
100°K REDUNDANT	10	10	10	1
40°K REDUNDANT	10	50	20	5
• UP/DOWN CONVERTER-REDUNDANT	10	70	10	2
• CHANNEL EQUIPMENT	100	20	10	2
• COMMON STATUS AND CONTROL				
REMOTE	50	10	10	2
MASTER	50	30	20	3
• G/A/G RADIO	100	5	10	2
• INTERCOM AND PUBLIC ADDRESS	20	10	10	3
• SATELLITE-ONE TRANSPONDER	-	-	-	800
TOTAL FOR EACH UNMANNED SITE	440	165	90	18
TOTAL FOR EACH MANNED SITE	160	275	120	31

* This is a system cost rather than a per site cost

As shown in Table 3.5-23, non-recurring costs were identified to cover the development of new capabilities such as remote tuning of the G/A/G radio and to identify high reliability components to assure the MTBF requirements of the unmanned stations.

During the development phase separate costs are identified for the initial cost of equipment and for the installation cost including the transportation of the equipment to the sites. It is recognized that there can be significant variations in these costs depending on such things as technical performance specifications, delivery schedules and method of installation and checkout. In general it was assumed that the existing technology was adequate for this application and could be fabricated using high quality components. The earth station equipment would be completely integrated and checked out prior to shipment to the site and would be installed by skilled field service personnel trained on the specific equipment.

The fourth cost category is the annual expense of maintenance of the equipment including replacement parts and the lease of satellite resources which are adequate for the entire unattended network. The annual maintenance costs are based on the availability of skilled field service support at the logistics nodes with adequate spares to allow module replacement during corrective maintenance visits to the unmanned stations. Module repair would be accomplished at the logistics nodes. Based on current practice, satellite transponder bandwidth and power is available in whatever amount the customer required down to individual voice grade circuits. The annual estimate for the satellite resources is based on a summation of the entire network requirement which amounts to one 36 MHZ transponder as available on existing commercial satellites.

As shown in Table 3.5-23, the cost elements are totaled separately for the unmanned and manned sites. This data is then used to calculate the life cycle costs of the satellite configuration. A summary of this calculation is included as Table 3.5-24. Based on a 20 year life cycle, it is estimated that the total cost of the satellite configuration is $70,045M. The majority of this cost ($47.44M) is related to the annual expense of maintenance and satellite leasing.

This data is limited to equipment cost.

3.5.3.2.7 Satellite Configuration - Performance Monitor and Control

To assure maximum performance from theunmanned radar stations, monitor and control capability must be considered over the communications equipment.

To collect information from the unmanned sites, a time share channel is suggested for each segment (approximately 16 stations) of the unattended network. At the unmanned station, status and alarm signals would be collected and formatted by a remote monitor and control unit. This unit would accumulate performance indications from all the equipment located at a given station. The performance indicators would be provided by the equipment to be monitored. Alarm conditions would also be collected by this unit. One other category of indicators would be included with the data to be transmitted from the unmanned stations, and these are all of the configuration signals which provide primary/standby, on/off and open/closed type information to the manned node. The remote monitor and control unit would integrate all of this status information into messages that can be requested from the manned nodes. Three types of status signals, manual selection of data, and change of state signals. Using microprocessor based technology, all three types should be implemented to provide complete operational flexibility.

TABLE 3.5-24

SATELLITE CONFIGURATION

COST DATA

	$ K - 1977 DOLLARS			
	NON-RECUR.	INITIAL COST	I & C/O	ANNUAL COST
77 UNMANNED SITES	440	12,705	6,930	1,386
6 MANNED SITES	160	1,650	720	186
SATELLITE LEASE				800
TOTAL	600	14,355	7,650	2,372

FOR 20 YEAR LIFE CYCLE

NON-RECUR.	$ 600K
INITIAL COST	14,355
INSTALLATION & CHECKOUT	7,650
20 YRS. OF ANNUAL COST	47,440
TOTAL	$70,045

To control the equipment at the unmanned stations from the logistics nodes, a time shared channel is also suggested for each segment. This channel would be multiplexed with control messages from the master monitor and control unit located at the manned node. Messages would be addressed and formated for the specific site requiring action. Typical control messages would select a new active unit, turn on specific equipment, change G/A/G radio frequencies, activate test sequences or request selected status indicators. The remote monitor and control unit at a given unmanned stations would decode the control messages addressed to it, but would ignore all other messages. Control commands would be generated by this remote unit and the circuitry required to execute these commands would be included in the equipment to be controlled.

3.5.3.2.8 Satellite Configuration - Equipment Packaging and Mounting

The communications hardware for the satellite configuration consists of one rack of equipment and two 4.5 meter antennas with interconnecting waveguide. Figure 3.5-27 shows a rack elevation of the communication equipment. It is a seven foot high rack with a foot print of 24" x 24". The estimated weight of the rack is 450 lbs.

Several antenna manufacturers have 4.5 meter antennas available which could be mounted on the radar towers below the level of the radar equipment. The elevation angle of the antennas will be between 5 and 10 degrees at most of the unattended sites; therefore, the antennas can be mounted rigidly along the vertical supports in order to survive the extreme wind conditions of the artic. The antennas will weigh approximately 2,300 lbs. each which shouldn't cause major structural problems.

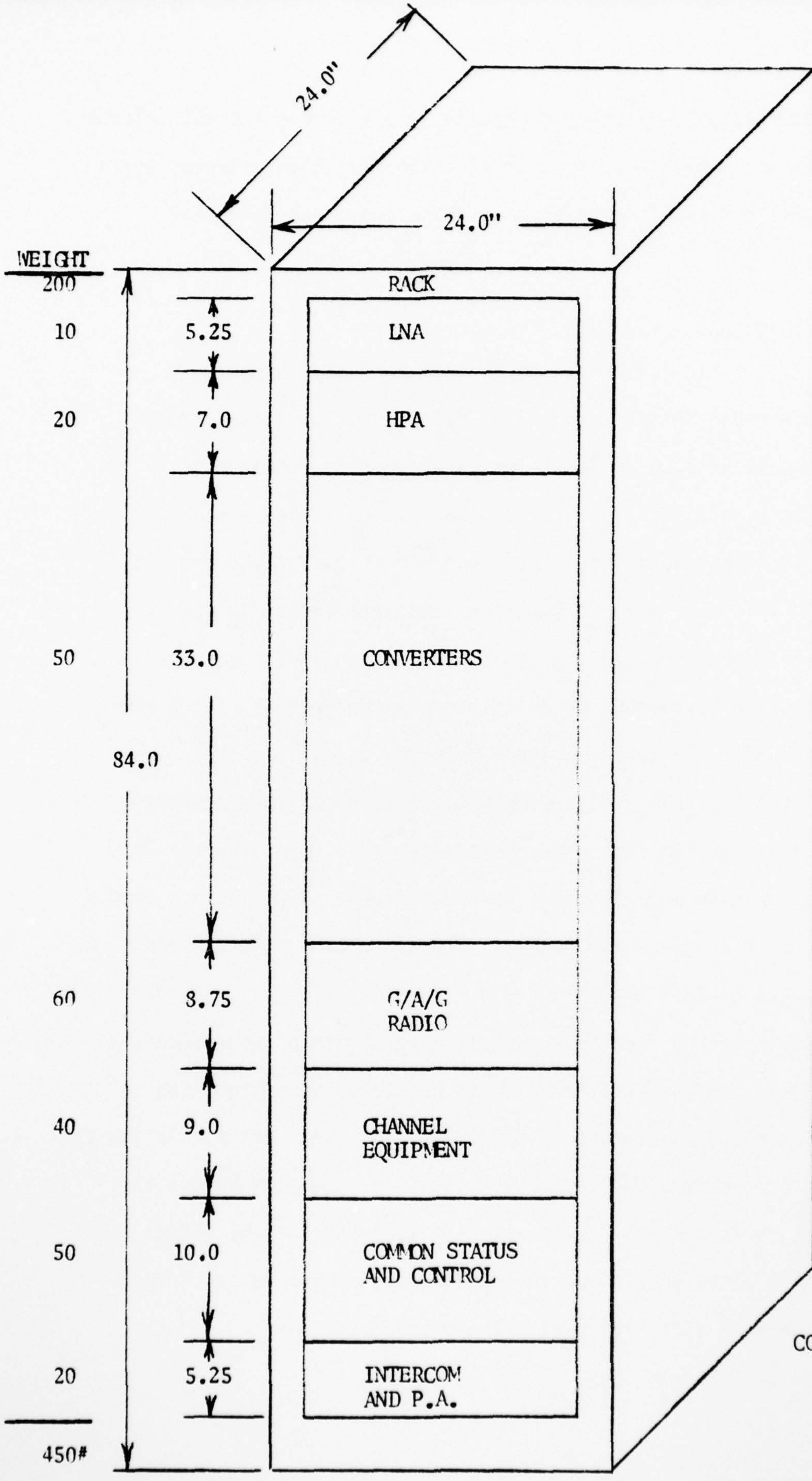


FIGURE 3.5-27

COMMUNICATIONS

RACK

Similar antennas are currently operating in the Arctic without deicing equipment; but if icing becomes a problem at a specific site, radomes are available that will minimize the effects of icing due to slippery and flexible surfaces.

3.5.3.2.9. Satellite Configuration - Vulnerability

The satellite configuration can be implemented using commercial satellites (as described in this report) or military satellites. Either implementation should utilize at least two satellites to permit a total network outage due to a satellite failure or enemy action. With two satellites the possibility of simultaneous failures is highly unlikely; therefore if communications is lost from all sites through two satellites, it can be assumed that some aggressive activity has caused the outage. Two satellites are also useful during normal operation to prevent sun outages. At a given earth station site when the sun is aligned with the satellite, the noise generated by the sun is usually high enough to overcome any fade margin included in the transmission link and a communication outage occurs. This happens near the equinoxs and lasts for several minutes (usually less than 5 minutes) per day over a 3 or 4 day period. Therefore at a specific site, the annual outage should be less than 2 x 5 x 4 = 40 minutes. This outage is on a site by site basis moving from West to East at the rate of approximately 100 miles per minute. Since it is a geometry problem, sun outages can be accurately predicted (within seconds), but this also points out a solution to the problem. By switching to the alternate satellite sometime before the predicted outage, it is possible to prevent the occurance of the outage. Depending on the relative spacing of the satellites, it may be feasible to switch to the alternate satellite during the preceeding night.

If the enemy wants to spoof or jam the satellite configuration, it would have to be accomplished on all satellites in use. Jamming could probably be accomplished with little effort but would be easily recognizable as an aggressive action. Spoofing would require greater effort. If the traffic from the satellite were analyzed over long periods of time, it might be possible to send commands to deactivate the unmanned radar stations and simulate the station by generating artificial radar data. As a preventative measure, it might be possible to include some variables in the design of the radar returns or in station addresses which would significantly reduce the possibility of being spoofed. Carrier hopping is another way of adding a variable to the communications traffic which has been proven to be a useful tool for secure transmissions.

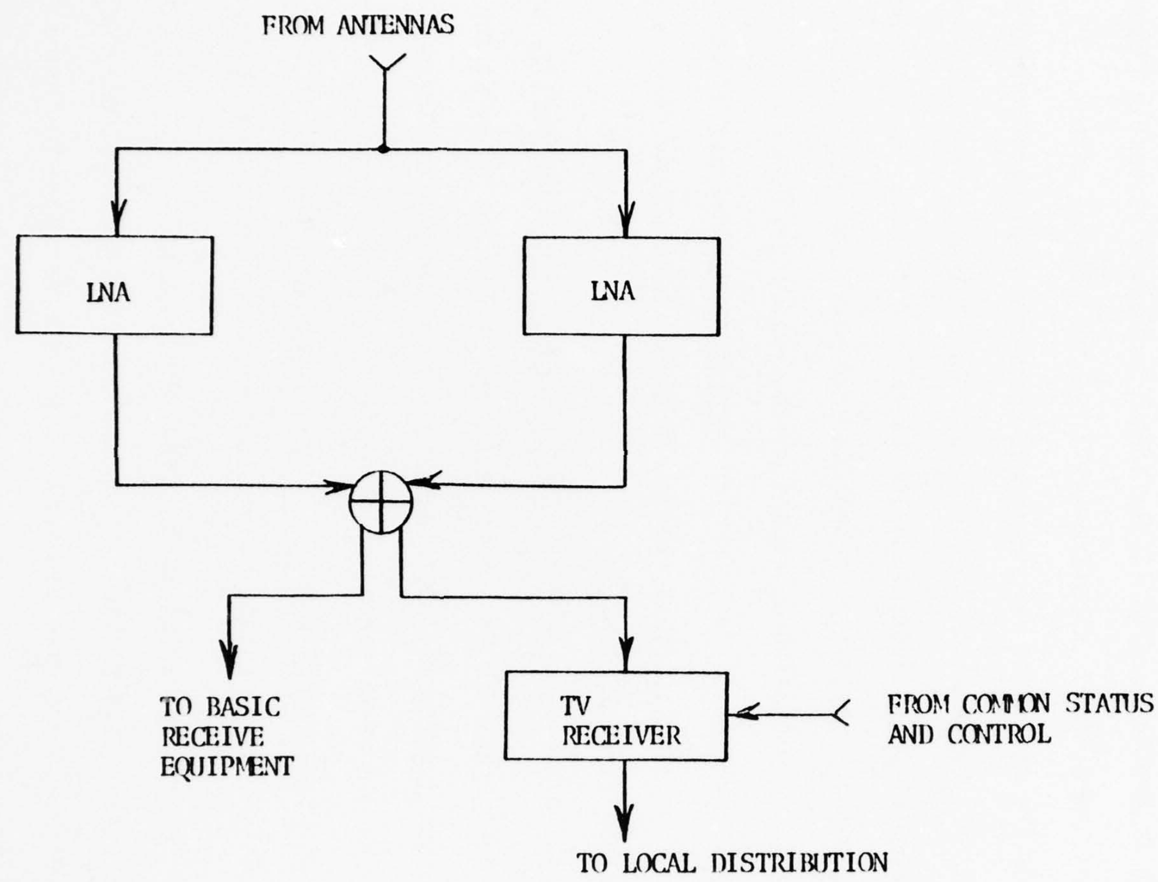
The use of military satellites could reduce the vulnerability of the satellite configuration. Satellite technology exists to minimize the effects of spoofing and jamming while at the same time increasing the transmission security. The use of this type of satellite would increase the life cycle costs, but might be a good solution (depending on the mission of the unattended network). This concept should be the subject of an additional study.

3.5.3.2.10 Television Reception for Local Communities

The earth station configuration developed for the unattended network is readily adaptable to receive television signals. As shown in Figure 3.5-28, the television receiver would be connected to one of the low noise receivers (LNA). The LNA receives and amplifies all transponder signals of the satellite that is in the beam of the antenna; therefore the TV receiver can demodulate the program information on any of the 12 or 24 transponders of existing

FIGURE 3.5-28

TV RECEIVER ADDITION



satellites. The TV receiver is tuneable by remote control to the program channel to be used at a specific location. The output of the TV receiver is compatible with cable distribution systems or similar techniques for distributing TV signals to individual TV sets like used for home reception.

Video programs are currently being transmitted on several domestic satellites. The Canadian Broadcasting Network signals are available on the ANIK satellites. In the United States, the PBS Network is implementing a satellite network to distribute their program and these will be transmitted by domestic satellites. There are also special video programs being transmitted via satellite to cable vision companies to be used for local distribution. Based upon the resale of the programming information to the cable customers, each cablevision operator pays for the use of the satellite signal. This programming information is currently being received by non-paying earth stations where the signal is not being sold but only being used. This is an area that needs further clarification; but in general, there appears to be an abundance of TV signals available from the same satellites which could be used in the unattended network.

The local distribution of the television signal will depend on the specific characterisitics of the sites involved. For short distances cable transmission has advantages and would not require much additional electrical power; whereas for the more remote communities, other transmission techniques should be considered.

The quality of the color video signal should be very good by home viewing standards. With the earth station components used in this analysis (4.5 meter antenna and 100^{o}k LNA), the video signal to noise ratio should be 47 dB which is better than the majority of home viewers are getting in the USA today.

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UNATTENDED RADAR STATION DESIGN FOR DEWLINE APPLICATION.(U)
JAN 78 W E ABRIEL, S E BELL, J R GOLDEN F19628-77-C-0212

UNCLASSIFIED ESD-TR-78-176-VOL-3 NL

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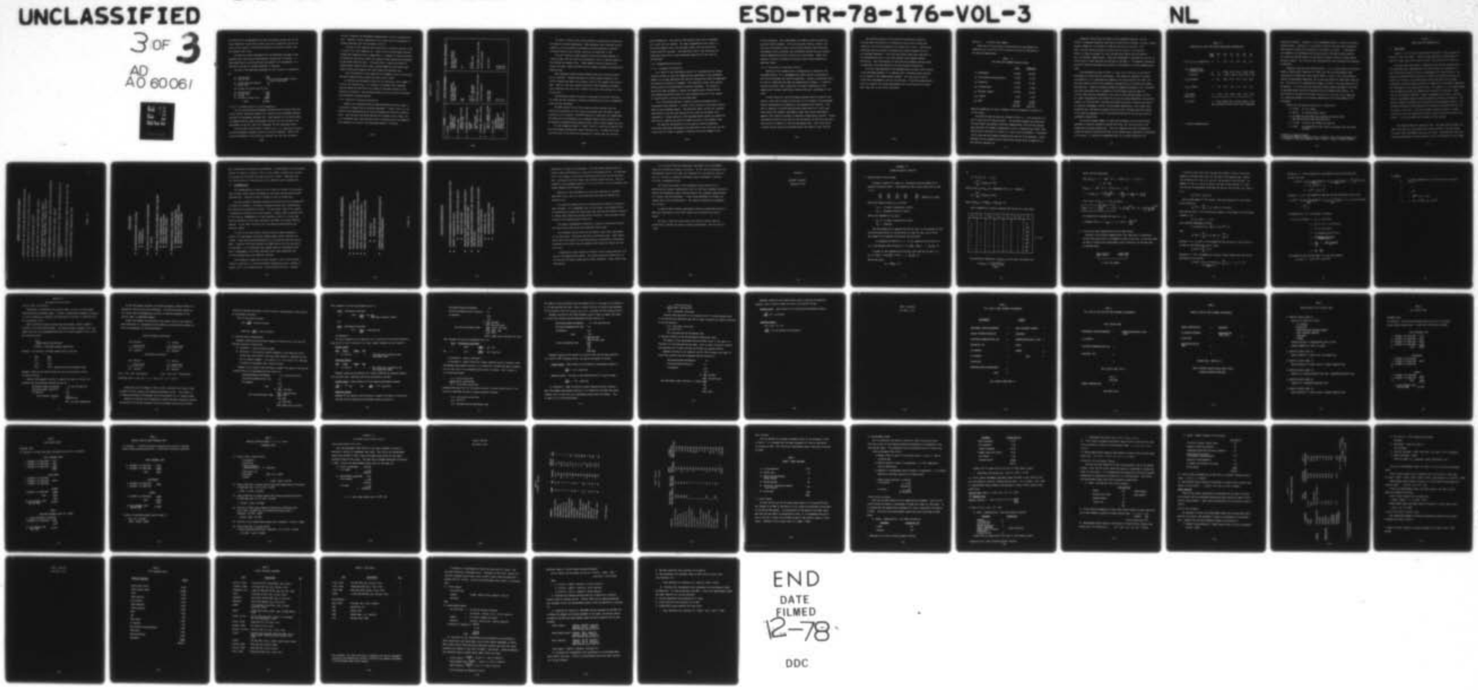

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This quality will be degraded by any local distribution system, but for the local communities of the arctic region, this will be excellent service and should be very helpful in minimizing vandalism by the local residents near the numanned radar sites.

The electrical power requirements for the additional equipment at the unmanned radar sites would be approximately 50 watts per TV receiver. If some communities can justify more than one channel of TV programming, it is technically feasible to include additional TV receivers.

The cost of the additional equipment for the TV service is estimate to be:

a)	Non-recurring	$40K	
b)	Initial Cost	10K	per site per channel without local distribution
c)	Installation and Checkout	5K	
d)	Annual Cost	1K	

For 20 year life cycle with 83 sites:

a)	Non-recurring	$ 40K
b)	Initial Cost	830K
c)	I & C/O	415K
d)	20 Years of Annual Cost	1,660K
	TOTAL	$2,945K

3.5.3.2.11 Telephone Service for Local Communities

The link calculations and equipment configurations previously described in this section include the capability of having 10 active telephone channels available for maintenance personnel use. These channels will be shared among the unmanned stations based on maintenance activity and are included in the requirement for one full satellite transponder for the unattended network.

Using the audio switch shown in Figure 3.5-14, it is technically feasible to provide emergency telephone service to the local community. Most of the time the maintenance circuits would be available for local use; but when a circuit is required for maintenance communications, it has to be made available. Therefore, traffic generated by local users should be preemptable or handled separately from the maintenance circuits.

One way to offer separate service would be to allocate a portion of the 10 circuits for local community use. These circuits could be made available through each unmanned site on a demand basis. A request for service could be initiated over the status channel and a queue of users maintained and managed by the manned logistics nodes. This would offer a significant amount of communications capabilities to these isolated communities and should again create a positive attitude by the locals toward the unmanned sites.

Local distribution of this capability will depend on the site conditions and would probably be best routed the same as the TV signal.

By sharing the maintenance circuits or by allocating a small number of circuits for contested use, it is feasible to implement local telephone service without any significant cost impact to the earth stations or the satellite utilization. From the manned nodes the circuits could be extended into the general telephone network.

3.5.4 Comparison of Selected Alternatives

Based on the information that has been developed during this study, it is possible to compare the two selected approaches. Figure 3.5-29 is a comparison of the characteristics of the LOS microwave and satellite configurations. Only the most significant features are included in this figure, and it is recognized that a more detailed study is required before the communications approach to be used in the unattended network is finalized.

FIGURE 3.5-29

COMPARISON

FEATURES	LINE OF SIGHT MICROWAVE	SATELLITE CONFIGURATION
• TECHNICAL		
- EQUIPMENT STATUS	EXISTING TECHNOLOGY	EXISTING TECHNOLOGY
- TRANSMISSION	TWO TERRESTRIAL PATHS	TWO SATELLITE PATHS
- CHANNELIZATION	FREQUENCY DOMAIN	TIME DOMAIN
• ELECTRICAL POWER		
- UNMANNED RADAR STATIONS	340	470
- REPEATER SITES	265	-
• ENVIRONMENTAL CONSIDERATIONS		
- ANTENNAS	4-8 FT.	2-15 FT.
- TOWERS	285 FT. UNATTENDED, 149 FT. REPEATER	ON RADAR TOWER
- EQUIPMENT RACKS	2	1
- TEMP., HUMIDITY, WINDS	QUESTIONABLE ON 150 MPH WINDS	QUESTIONABLE ON 150 MPH WINDS
• PERFORMANCE MONITOR & CONTROL	EXISTING TECHNIQUES	EXISTING TECHNIQUES
• RELIABILITY		
- MTBF AT UNMANNED STATIONS	34,400 HOURS	22,700 HOURS
- MTBF AT REPEATER SITES	52,600 HOURS	-
• RELATIVE COSTS		
- DEVELOPMENT	1.0	0.92
- INITIAL EQUIPMENT	1.0	0.63
- INSTALLATION	1.0	0.56
- ANNUAL COSTS	1.0	1.12
- 20 YEAR LIFE CYCLE	1.0	0.88

As shown in Figure 3.5-29, both approaches are technically feasible and are based on existing technologies. Both approaches offer alternate routing capability, but the satellite configuration allows essentially unlimited alternate routing to any location visible by the satellites in use.

The total electrical power required by the LOS microwave approach is slightly higher than the satellite configuration since it requires power at the unmanned and repeater sites. These repeater sites also require real estate, buildings, towers and other facility support equipment associated with unmanned sites.

Both approaches require outside antennas which must survive the harsh Arctic conditions. Antenna mountings will require special attention, but similar antennas and towers are currently in use in this general type environment. Specific sites could require additional effort depending on extreme local conditions, but this level of detail will have to be resolved on a site-by-site basis.

The performance monitor and control techniques are basically the same for either the LOS microwave or satellite configuration and can be implemented using existing techniques.

The MTBF figures for the LOS microwave are more favorable than the satellite configuration, but this does not guarantee that the overall network reliability will be better. The MTBF figures are a good basis for determining the annual cost of maintenance, but a complete network failure analysis will be required to determine which approach yields a more reliable network solution.

The cost comparison shown in Figure 3.5-29 is a relative evaluation with the LOS microwave configuration used as the base line. As shown the 20 year life cycle cost of the satellite configuration is better than the LOS microwave configuration. The satellite configuration costs less to implement, but is more costly to operate. The lower implementation costs relate to not having repeater sites, and the higher annual costs are caused from leasing satellite resources. With additional study it may be possible to reduce the annual costs of both approaches especially for the satellite configuration.

3.5.5 Recommendations/Conclusions

3.5.5.1 Assessment of Feasibility

As a result of this preliminary analysis of the communications configurations available to solve the communications requirements of the unattended network, it has been determined that both LOS microwave and satellite approaches are technically feasible to implement. With additional study, other configurations might also be established as feasible candidates. The concept of sharing the radar equipment to support the communication's function offers some interesting possibilities; but a more thorough analysis of this concept is required before a position can be established.

The LOS microwave approach is based on existing technology which is continuously being improved. It offers a solid solution to the severe requirements of the unattended network. The electrical power, reliability, technical characteristics and cost data derived by this study are considered to be conservative. Further analysis of this approach should improve its feasibility especially in reducing the electrical power and costs of the repeater sites.

The satellite configuration is also based on existing technology. Significant technology improvements have been made in this field over the last 5 years and this trend is expected to continue in both the commercial and military equipment. These improvements are impacting both the satellite and earth station hardware. Of the two solutions studies in detail, the satellite configuration offers a more flexible approach where additional requirements can be considered, new technologies applied and costs reduced without compromising the basic feasibility of the concept. Agains this approach is based on a conservative analysis which can be enhanced with additional study.

3.5.5.2 Requirement for Additional Analysis

Before any final communication's configuration is selected for the unattended netowrk, it is recommended the further details be developed on both the LOS microwave and satellite approaches. Further consideration should be given to integrating the radar and communications hardware. It might be possible to design a radar system that will permit troposcatter or LOS communications without significantly reducing the basic requirements of the radar.

Further analysis of the LOS microwave approach should be based on the specific sites that are known to exist and will be included in the unattended network supplemented by information on the projected site locations. This data is necessary to perform detailed path studies which will yield actual tower heights and repeater requirements rather than average requirements. Repeater sites should be analyzed to determine minimum power solutions. Further consideration should also be given to the distribution of television and telephone service to communities near the unattended sites. Local distribution of these services should be considered against the specific sites involved.

More detailed analysis of the satellite configuration should be directed toward the question of vulnerability which should include both commercial and military equipment on the ground and in orbit. Earth station technology should be studies to determine the radeoffs between fail-soft and redundant components. This could precipitate significant reductions in the implementation costs if fail-soft concepts yield adequate netowrk reliability. Local distribution of television and telephone services should be addressed in the same fashion as the LOS microwave configuration.

With the large magnitude of the implementation and annual costs involved in the unattended program, it is important that a thorough analysis be made of all aspects of the communications segment. This type analysis should include the requirements as well as the solutions. A detailed communication's study on a network with unique requirements this size should pay for itself many times over in the life of the system.

Section 4 Life Cycle Cost Summary

Twenty year life cycle costs of the baseline six node network are summarized for line-of-site (LOS) microwave and satellite approaches to the network communications.

TABLE 4-1

LIFE CYCLE COST SUMMARY BASELINE SYSTEM

	LOS	SATELLITE
C_1, Development	\$19.43M	\$19.27M
C_2, Site Preparation/Construction	46.87M	35.70M
C_3, Production	119.43M	111.73M
C_4, Transportation	14.31M	11.69M
C_5, Personnel Support	102.00M	102.00M
$C_{6,7}$, Spares	7.86M	8.14M
C_8, Power	20.03M	19.67M
	\$329.93M	\$308.20M

Detailed assumptions for each of the above costs are presented in Section 3.2 of this report.

No satellite leasing costs are included in Table 4-1. Both approaches will entail some satellite leasing charges. The satellite approach uses satellites for both lateral and backhaul (vertical) communications, while the LOS approach uses satellites for backhaul communcations, and as a standby backup lateral path node-to-node in the event of failure of a link in the LOS equipment. A groundrule of this study was that backhaul communications were not to be addressed. Strict adherence to this groundrule would require that leasing costs be added only to the satellite approach LCC.

Commercial leasing costs are based on total bandwidth required. For the 36 MHz of information bandwidth associated with data from 83 stations, an annual leasing charge of $800K will be incurred, or $16M for the 20 year life cycle. This would raise the satellite system life cycle cost to $324.2M. As a practical matter, it might be necessary to incur the additional $16M on the LOS system as well, for backhaul communications. Since only maintenance is performed on the line, it follows that all radar data must be available at the ROCC's. The beamwidth required to relay this data and associated costs should be investigated in a future communications study.

The transportation costs in Table 4-1 apply to Air Force S61 (or equivalent) helicopters and crews used for maintenance. Even though this approach is the most cost-effective, it is recognized that demands on Air Force aircraft are great, and that many complex political and strategical considerations are involved with commitment decisions. Based on estimates provided by Okanagan Helicopters, Ltd., transportation costs associated with six commercial S76 helicopters (one per node) and civilian crews used for maintenance on the same six node baseline network, results in a total transportation cost of $90.11M for the LOS system ($88.37M for the satellite network), of which $65.76M is overhead cost beyond crew costs, covering such factors as insurance, management, profits, and helicopter depreciation. With these transportation costs, the baseline network life cycle costs (including satellite leasing in the satellite approach) rise to $405.73M and $400.88M for the LOS and satellite approaches, respectively.

By utilizing reduced numbers of nodes and helicopters, and by taking maximal advantage of existing non-DEWLine related facilities, the life cycle cost of the network may be reduced dramatically. Table 4-2 summarizes the cost differentials (satellite network) associated with the various network nodal alternatives investigated in this study. It should be re-emphasized that all of these alternatives are

TABLE 4-2

BASELINE LIFE CYCLE COST DELTAS VERSUS NODAL ALTERNATIVES*

	BASE-LINE	ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6
Δ (C_1 + C_2 + C_3), Acquisition	0	-.3	-1.8	-1.6	-5.5	-2.6	-5.4
Δ C_4, Transportation Commercial S76's	0	0	+2.86	+5.14	+5.14	-27.61	-20.46
(AF S61's)	(0)	(0)	(-.89)	(-.54)	(-.54)	(+.35)	(-.35)
Δ C_5, Personnel	0	-29	-64.0	-57.0	-77.0	-51.0	-82.0
Δ $C_{6,7}$, Spares	0	-.61	-.82	-.82	-1.2	-.75	-1.5
Δ C_8, Power	0	-1.12	-3.10	-2.45	-3.50	-3.10	-5.33
Δ C_T, Total	0	-31.03	-66.86	-56.73	-82.06	-85.06	-114.69
	(0)	(-31.03)	(-70.61)	(-62.41)	(-87.74)	(-57.10)	(-94.58)

* Satellite Communications

technically feasible. Alternate 2 is not recommended because it ignores the Alaskan-Canadian border. Alternate 3 is a practical version of the same roving maintenance team approach allowing for sovereignty of the respective regions. If implemented with commercial S76 maintenance and roving aircraft, alternate 3 would produce a net savings of $56.73M relative to the baseline network, primarily through reduced personnel support. The life cycle cost associated with this alternate would therefore be $344.95M.

Alternate 6 provides much further savings. It is a 4 node network configuration (nodes at POW-M, BAR-3, CAM-M and Ft. Chimo) with two roving maintenance teams operating out of CAM-M and a fixed team at POW-M. A total of five S76 helicopters support the maintenance operations, one at each node except for CAM-M where there are two. The entire line is supported by 31 people, of which 11 are associated with the helicopters. It is felt that this alternative takes maximum advantage of the orders of magnitude better reliability designed into this proposed radar network. The cost savings so realized are $114.69M, resulting in a life cycle cost of $286.19M. for a satellite approach to the network communications and using commercial S76 helicopters.

Further LCC cost deltas* which may be of interest are:

- + $19.0M All 125' towers.
- + $22.2M All secure heliport towers
- + $74.94M** AF radar RDT&E and production per project E259
  + $39.27M***"Typical Radar Characteristics"
- + $ 2.95M TV service for Eskimos via satellite
- \- 5-30% of transportation costs return on secondary user helicopter charters.

* Referred to baseline network
** Assuming AF RDT&E and production costs include all radar related equipments only
*** Assuming AF RDT&E and production costs include all station related equipment.

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Figure 5-1 list the major accomplishments described in this document and detailed in the final report. There were many additional accomplishments in support of those shown which helped to lead to the conclusions of Figure 5-2.

We believe that this study, in conjunction with previous studies such as the Unattended Radar, Communications, and Power studies, has addressed the major feasibility concerns relative to Unattended Arctic Radar Stations. The analyses accomplished during the past five months are conservative and do not address the savings to be accrued based on policy decisions such as border sovereignty, continued support obligations (communications and weather reporting), and requirements to use existing facilities. For example, it is our understanding that the DEWLine provides the communications services for Pelly Bay. These could be eliminated or modified. However, agreements are involved. Similarly, there is considerable weather reporting presently provided by the DEWLine. This would be reduced in substance to that coming from the unattended stations. The personnel observations would essentially be reduced to the manned airstrips (6). The impact of this loss in view of new weather reporting systems is unknown. In addition, there are communication traffic routes utilizing the present tropo systems. This study assumes the retirement of these systems.

The remaining technical concerns are few. The radar station designs and radars were based on a given model which may be modified in the near future. The actual radar requirements are yet to be firmed. Technologically those that have been conjectured do not add technical risk to the program but could change

<u>SUMMARY OF MAJOR STUDY ACCOMPLISHMENTS</u>

- IDENTIFIED MAJOR COST DRIVERS AND DEVELOPED REDUCTION OPTIONS
- ESTABLISHED FEASIBILITY OF ARCTIC HELICOPTER UTILIZATION
- DEVELOPED MINIMUM MANNED NODE CONCEPTS
- ESTABLISHED FEASIBILITY OF UNATTENDED RADAR STATION
- DEVELOPED STATION DESIGNS AND STRUCTURAL CONCEPTS (SECURE, ADAPTIVE, TRANSPORTABLE, MODULAR, UNITIZED)
- DETERMINED UNMANNED STATION EQUIPMENT CONFIGURATIONS AND REQUIREMENTS
- BASED STATION DESIGN ON TOTAL ENERGY CONCEPT
- INTRODUCED INTERLEAVED SATELLITE CONCEPTS AND ESTABLISHED SATTELITE SUPERIORITY
- COMPLETED RELIABILITY/MAINTAINABILITY ANALYSIS AND LIFE CYCLE COST
- ACCOMPLISHED PRELIMINARY COMMUNICATIONS STUDY

FIGURE 5-1

CONCLUSIONS

- AN UNATTENDED NETWORK IS FEASIBLE
  - TECHNICALLY
  - ECONOMICALLY
- THE ANALYSES PRESENTED ARE CONSERVATIVE
  - POLICY
- REMAINING CONCERNS ARE PRIMARILY POLICY RELATED
  - ARCTIC COMMUNICATIONS
  - HOURLY WEATHER REPORTING
  - EXISTING TRAFFIC ROUTES
- REMAINING TECHNICAL CONCERNS ARE:
  - FIRMING OF RADAR REQUIREMENTS
  - DEVELOPMENT OF UNATTENDED STATION
  - DEVELOP BACK-UP COMM LINK

FIGURE 5-2

power requirements and processing requirements. The development of the unattended station is primarily a concern in that it still remains to empirically validate the analyses which resulted from these analytical studies. Additional comm link backup should be a consideration and is addressed under recommendations.

5.2 RECOMMENDATIONS

The recommendations to come out of this study are divided into two groups, those directed toward system implementation, and those directed toward program considerations. These are listed in Figures 5-3 and 5-4 respectively.

The study primarily addressed concerns and alternatives, and the generation of feasibility concepts. The choice of concept may have other considerations than those used to establish the study. For that reason, none of the concepts is addressed as being the only viable approach. However, under the ground rules of the study our recommendation is that Alternate 6, which is a roving team satellite approach with all data returning to the ROCC; as the most effective approach. It has least life-cycle cost, and requires minimum manning and logistics support.

In light of the significantly reduced logistics support compared to present line requirements, multi-year reduced supply options should be considered. These would be governed primarily by QC storage and testing requirements. There are facilities available at communities on the line that should be considered. It is conceivable that reduced logistics requirements might make it advantageous to co-locate personnel within these communities and utilize purchased power, and community resources.

The existence of communities and the increase in Arctic activity make it feasible, technically, to utilize helicopter transportation only, although, at present, that is not without concern. Most helicopter activity is located

UNATTENDED RADAR STATION - RECOMMENDATIONS

- IMPLEMENT ROVING TEAM SATELLITE CONCEPT
- CONSIDER MULTIYEAR REDUCED SUPPLY OPTION
- UTILIZE AVAILABLE COMMUNITY AND AGENCY RESOURCES
- UTILIZE HELICOPTER TRANSPORTATION ONLY
- REDUCE NUMBER OF PACER OPERATIONS TO TWO
  - PACER MACK
  - PACER DEW BASIN
- OPTIMIZE UNATTENDED SITE LOCATIONS RELATIVE TO RADAR SYSTEM REQUIREMENTS

FIGURE 5-3

PROGRAM RECOMMENDATIONS

- ESTABLISH REQUIREMENTS FOR UNATTENDED DEW RADAR SYSTEM
- INITIATE COMMUNICATION STUDY
    - CONSIDER VLF BEACONS FOR DATA BACKUP
    - RADAR AS DATA LINK
- INITIATE RADAR/IFF STATION DEVELOPMENT PROGRAM IN PARALLEL WITH COMMUNICATION STUDY
- DETERMINE INTERFACE REQUIREMENTS AND SPECIFICATIONS WITH THE ROCC
- ESTABLISH A PANEL TO REVIEW AND EVALUATE APPLICABLE TECHNOLOGY ADVANCES AND IMPACT
    - METHANOL FUEL CELL
    - UNATTENDED WEATHER STATION
    - COMM GEAR DEVELOPMENT

FIGURE 5-4

around the oil fields of the Northwest. This area offers possibilities for charter trade considerations as a function of maintenance policy. The remainder of the line, however, would require dedicated service which can be made available. Helicopter facilities become less available toward the east. What will eventually be the greatest concern will not be the Arctic, but the Laborador Coast between Hopedale and Frobisher Bay.

Reduction in POL requirements will alter the reduction of the PACER operations to two, and it is even conveivable that they can eventually be reduced to one.

This study did nothing relative to evaluating site selection relative to radar coverage. It is recommended that, in the future, site analyses should be accomplished to locate the radars where they could be most affective relative to minimum tower height and maximum terrain elevation. Every advantage should be made of the expected system reliability.

The program recommendations detailed in Figure 5-4 come about primarily from observations made during the unattended station study.

The unattended station study did not address future radar requirements for the DEW system. These were specified as previously shown. These requirements should now be made firm and tested against the conceptual alternatives presented by the station study to determine their impact on concept and life cycle cost.

A communication study should be initiated in which backup modes are to be used for the communications system. This should include the possibility for utilizing the VLF Beacon system and the radars themselves. These require some investigation.

It is not envisioned that operational requirements for an unattended radar would undergo any changes in principle. On this basis and because of the developmental nature of the radar and integrated IFF, consideration should be given to initiating a prototype unattended station development in parallel with other recommended actions.

The reliability aspects of the unattended station have yet to be demonstrated by hardware implementation short of individual component evaluation. Whereas the mathematical models indicate feasibility, acceptable demonstrations will require time and development. Timely system deployment at minimum risk suggest early station implementation. The required technology and components are available.

In addition ROCC interface requirements should be established relative to ROCC data requirements so that their impact can be factored into station design.

And last, a technical review panel with industry liaison should be established to consider the impact of merging developments, some of which are listed.

SECTION 6

EQUIPMENT (DELETED)

INCLUDED IN TEXT

APPENDIX 7.1

NETWORK RELIABILITY ANALYSIS

A. Adjacent Radar Failure Problem

Consider a network of N radars, as illustrated, and the probability of adjacent failures by time t. The probability that a given radar fails by time t is R.

Network of N radars

Define the random variables X_K as follows:

$X_K = 1$ if radar K operational at time t

$X_K = 0$ otherwise (failed at time t)

Define the complement of X_K, $\overline{X}_K$ by

$\overline{X}_K = 0$ if radar K operational at time t

$\overline{X}_K = 1$ otherwise

Then the probability of adjacent failures by time t is the probability that one and two have failed, or two and three, or three and four, and so forth. The probability of adjacent failures may thus be written:

$$P_r \text{ (Adjacent Failures by t)} = 1 - P_r \text{ (no adjacent pairs failed by t)}$$

$$P_o = P \text{ (No Adjacent Pairs Failed by t)} = P_r (\overline{X}_1\overline{X}_2 + \overline{X}_2\overline{X}_3 + \ldots + \overline{X}_{N-1}\overline{X}_N = 0)$$

In order for the indicated sum to be zero, each term must be zero, i.e.,

$$P_D = P_r (\overline{X}_1\overline{X}_2 = 0 \text{ and } \overline{X}_2\overline{X}_3 = 0 \text{ and } \ldots\ldots\ldots \overline{X}_{N-1}\overline{X}_N = 0)$$

Define the events

$$A_K = \{\overline{X}_K\overline{X}_{K+1} = 0\}$$

so

$$P_o = P_r(A_1, A_2, \ldots, A_{N-1})$$

$$= \left(\prod_{K=2}^{N-1} P(A_K/A_{K-1})\right) P(A_1)$$

Notice that A_K and A_{K-n} are independent for $n \geq 2$. Therefore:

$$P_o = \left(\prod_{K=2}^{N-1} P(A_K/A_{K-1})\right) P(A_1)$$

where $P(A_K/A_{K-1}) = P(\overline{X}_K\overline{X}_{K+1} = 0/\overline{X}_{K-1}\overline{X}_K = 0)$

Such a probability is easily evaluated with the aid of a truth table.

X_{K-1}	X_K	X_{K+1}	A_{K-1}	A_K	$A_K\ A_{K-1}$	P_3
0	0	0	1	1	1	R^3
0	0	1	1	1	1	R^2Q
0	1	0	1	1	1	R^2Q
0	1	1	1	0	0	RQ^2
1	0	0	1	1	1	R^2Q
1	0	1	1	1	1	RQ^2
1	1	0	0	1	0	RQ^2
1	1	1	0	0	0	Q^3

$Q = 1-R$

The conditional probability $P(A_K/A_{K-1})$ can be found from Bayes rule:

$$P(A_K/A_{K-1}) = \frac{P(A_K \text{ and } A_{K-1})}{P(A_{K-1})}$$

where, from the truth table

$$P(A_K \text{ and } A_{K-1}) = 1 - 2RQ^2 - Q^3 = 1 - Q^2(2R + Q) = 1 - Q^2 (R + 1)$$

$$= 1 - Q^2 - Q^2R$$

$$P(A_{K-1}) = 1 - RQ^2 - Q^3 = 1 - Q^2 (R + Q) = 1 - Q^2$$

$$\therefore \quad P (A_K/A_{K-1}) = \frac{1 - Q^2 - Q^2R}{1 - Q^2} = 1 - \frac{Q^2R}{1-Q^2} = R + \frac{R-1}{R-2} = R + \frac{1 - R}{2 - R}$$

Also $P (A_1) = P (A_{K-1}) = 1 - Q^2$, so finally

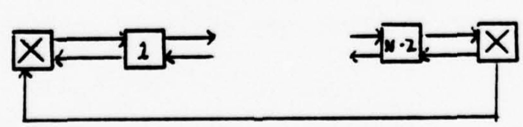
$$\boxed{R_{NET} = P_o = \left(1 - \frac{Q^2R}{1-Q^2}\right)^{N-2} (1 - Q^2)} = \left(R + \frac{1 - R}{2 - R}\right)^{N-2} R(2 - R) = R \frac{(1 + R - R^2)^{N-2}}{(2 - R)^{N-3}}$$

The probability of adjacent failures is $1 - P_o$.

$$P \text{ (adjacent fails)} = 1 - R_{NET} = 1 - (1 - Q^2) \left(1 - \frac{Q^2R}{1-Q^2}\right)^{N-2}$$

B. Line-of-Site (LOS) Communications Failure Span Problem

Consider a LOS microwave communications line, where data is transmitted serially both ways along a line segment to nodes at each end. At the east nodes, the data is relayed (with approximately unity reliability) to the west node, as sketched below.



N link line segment

A failure in one link of the line does not produce a failure in the line, because an alternate path exists for the data to the adjacent node. Denote the reliability of a link as C, and let n be the span of link failures. For example if links 2, 5 and 9 are failed, the span of the failures is 8 links. The line will be considered failed when the span of link failures is at least m, i.e.,

$$P_m \text{ (fail)} = P_r(n \geq m)$$

Let K be the number of links failed. Then the probability of line failure can be written as:

$$P_m \text{ (fail)} = \sum_{K=0}^{N-1} P_r \text{ } (n \geq m/K) \text{ } P_r \text{ (K failed)}$$

Note that the span of link failures must exceed m if the number of link failures exceeds m, i.e.,

$$P_r \text{ } (n \geq m/K) = 1 \quad K \geq m$$

Also, assuming independent failures,

$$P \text{ (K failed of N)} = \binom{N}{K} (1 - C^K)^* \text{ } C^{N-K} = P_K$$

Then:

$$P_m \text{ (fail)} = \sum_{K=0}^{m-1} P \text{ } (n \geq m/K) \text{ } P_K + \sum_{K=m}^{N-1} P_K$$

Consider m = 0. P_o (fail) is the probability that the span of link failures is at least 0, which should be, and is, unity.

$$P_o \text{ (fail)} = \sum_{K=0}^{N-1} P_K = 1$$

Consider m = 1. This corresponds to a failure criteria wherein one link failure constitutes a line failure.

$$P_1 \text{ (fail)} = \underbrace{P(n \geq 1/0 \text{ fails})}_{\text{zero}} P_o + \sum_{K=1}^{N-1} P_K = 1 - P_o = 1 - C^N$$

Consider m = 2. This corresponds to the probability that the failures span at least two links.

$$P_2\text{ (fail)} = \underbrace{P_r\text{ (n} \geq 2/0\text{ failed)}}_{\text{zero}}\; P_0 + \underbrace{P_r\text{ (n} \geq 2/1\text{ failed)}}_{\text{zero}}\; P_1 + \sum_{2}^{N-1} \binom{N}{K} C^{N-K} (1-C)^K$$

$$= 1 - C^N - N\, C^{N-1}\, (1 - C)$$

$$= 1 - N\, C^{N-1} + (N-1)\, C^N$$

Consider m = 3, ie., the probability that the failures span three or more links.

$$P_3\text{ (fail)} = \underbrace{P_r\text{ (n} \geq 3/0\text{ failed)}}_{\text{zero}}\; P_0 + \underbrace{P_r\text{ (n} \geq 3/1\text{ failed)}}_{\text{zero}}\; P_1 + P_r\text{ (n} \geq 3/2\text{ failed)} P_2$$

$$+ \sum_{3}^{N-1} P_K$$

The probability P_r (n $\geq$ 3/2 failed) is non-zero.

$$P_r\text{ (n} \geq 3/2\text{ failed)} = 1 - P_r\text{ (n} < 3/2\text{ fails)}$$

$$= 1 - P_r\text{ (n = 0 or 1 or 2/2 fails)}$$

$$= 1 - P_r\text{ (n = 2/2 fails)}$$

$$= 1 - P_r\text{ (adjacent fails/2 fails)}$$

$$= 1 - \frac{\text{\# adjacent pairs in N}}{\text{\# pairs in N}}$$

$$= 1 - \frac{N-1}{\binom{N}{2}} = 1 - \frac{(N-1)\ (N-2)!2!}{N!}$$

$$= 1 - \frac{2}{N} = \frac{N-2}{N}$$

The probability that failures span 3 or more links becomes:

$$P_3\text{ (fail)} = 1 - (N-1)\, C^{N-2} + (N-2)\, C^{N-1}$$

In summary,

m	P_m (fail) (probability of a failure span of at least m)
0	1
1	$1 - C^N$
2	$1 - NC^{N-1} + (N - 1) C^N$
3	$1 - (N - 1) C^{N-2} + (N - 2) C^{N-1}$

Appendix 7.2

Maintenance Loading Analysis

Baseline Nodel Configuration

Maintenance is performed at the logistic nodes, in part, by the personnel constituting the maintenance teams. In order to determine the manpower utilization it is first necessary to determine the percentage of time that is associated with site maintenance visits.

Nodal reliability figures indicate mean time between network (segment) failures is 6/3.4 MO (Satellite/LOS). Including the yearly resupply visit, this equals one visit to an unattended station per 4/2.7 month average or 3/4.5 visits per station per year.

∴ 3/4.5
  13.83 (average stations/node)

41.5/62.2 Trips/nodal network segment/year

Assuming: Two days/trip (includes weather delay of one day)

∴	Sat.	LOS	
	41.5	62.2	
	x 2	x 2	
	83.0	124.4	days/year/two man maintenance team

Manpower loading at the logistic nodes can now be calculated as follows:

a) Station Failures

Logistic node manpower available to support the repair of failed LRI's returned from the unattended stations consist of:

Maintenance Supervisor/Manager	.75	(75% availability)
Electronics/Comm. Technician	2.0	
P/V Mechanic	1.0	
Total Manpower Available	3.75	
at	365	days/year
	1369	Available mandays/year

Of the 1369 mandays available to perform maintenance, 166/249 mandays are required for travel and on-site maintenance. (Two-man maintenance team/trip.) This leaves 1203/1120 mandays/year available to perform maintenance at the logistic nodes, or 9624/8960 manhours.

Assume four manhours are required for each repair action at the logistic nodes (excluding 11.1 maintenance actions (MA)/year associated with overhaul of the 4.4 KW generators (at 20 hours/overhaul).

Satellite Network Calculations

153.9 MA/Year*	11.1 MA/Year
x 4 Manhours/MA	x 20 Manhours/MA
616 Manhours	222 Manhours

LOS Network Calculations

160.9 MA/Year *	11.1 MA/Year
x 4 Manhours/MA	x 20 Manhours/MA
644 Manhours	222 Manhours

Total = 616 + 222 = 838 Manhours   Total = 644 + 222 = 866 Manhours

*Reference Table 3.2-24 (165 - 11.1 = 153.9; 172 - 11.1 = 160.9)

Assume that the 18.25 MA/year (Table 3.2-25), associated with logistic node equipment failures, require four manhours/maintenance action. This results in 73 manhours/year/node of maintenance load or 438 manhours for six logistic nodes.

Manpower utilization can be determined by adding the hours required to perform maintenance on failed LRIs returned from the unattended stations plus the hours required to perform maintenance of failed logistic node equipment; then dividing by the manhours available.

Thus for the baseline system:

$$\text{LOS} = \frac{939}{8960} = 10.5\% \text{ utilization}$$

$$\text{Satellite} = \frac{911}{9624} = 9.5\% \text{ utilization}$$

b) Alternate Nodal Configurations

Manpower loading and the resultant manpower utilization will vary from the alternate concepts as shown below:

a) Alternate 1 = same as baseline system

b) Alternate 2 = the baseline concept assumption of two days/site visit/ two-man team and 41.5/62.2 trips each nodal network is expanded to cover the six network segments. This equals 2 x 2 x 41.5 (62.2) x 6 = 996 days to respond to unattended radar station failures.

Manpower at the logsitic node available to support the repair of failed LRIs returned from all 83 unattended stations consist of:

Maintenance/Supervisor/Manager	.75	(75% availability)
Electronics/Communications Tech	4.0	
P/V Mechanic	1.0	
Total	5.75	
at	365	Days/year
	2099	Available days
Two 2-man maintenance teams	- 996 (1493)	
	1103 (606)	
	8	Hours/day
	8824 (4848)	Hours available

Then, manpower utilization (maintenance only) is:

Nodes	Maintenance Hours/Node		
6	(939)	$\frac{5634}{4848}$ = 116%	LOS Additional personnel needed

and

Nodes	Maintenance Hours/Node		
6	(911)	$\frac{5466}{8824}$ =	62% Satellite

c) Alternate 3

The basic assumption of two days/site visit required by the two-man maintenance teams and 41.5 (62.2) trips/each (six) nodal network segments per year requires:

Alaskan Sector

Days	Trips	Nodes	Men		
2	41.5 (62.2)	1	2	=	166 (249) days required by the maintenance team

Remaining Sectors

Days	Trips	Nodes	Men		
2	41.5 (62.2)	5	2	=	830 (1244) days required by the two maintenance teams

Manpower loading at the Alaskan Full Logistic Node and the remaining sectors (full-logistic node - modified) can now be calculated as follows:

Alaskan Sector - Same loading as for the baseline maintenance concept

$\frac{939}{8960}$ = 11% LOS and $\frac{911}{9624}$ = 9.% Satellite

Remaining Sectors

Manpower at the logistics node available to support the repair of failed LRIs returned from the remaining 69 unattended stations consists of:

Maintenance/Supervisor/Manager	.75	
Electronics/Communications Technician	4.0	
P/V Mechanic	1.0	
	5.75	
at	365	Day/year
	2099	Available days
Two 2-man maintenance teams	-830	(1244) SAT (LOS)
	1269	(855) Days
	x 8	Hours
	10152	(6840) Hours available SAT (LOS)

Then, manpower utilization (maintenance only) is:

	Nodes	Maintenance Hours/Node			
	5	(939)	$\frac{4695}{6840}$ =	69%	LOS
and	5	(911)	$\frac{4555}{10152}$ =	45%	Satellite

d) Alternate 4 - Same as Alternate 3

e) Alternate 5 - Nodal reliability figures (Canadian Sectors) indicate a mean time between node network failures is 4.7 (satellite) including the yearly resupply visit or one visit to an unattended station every 3.4 months. This is equal to 3.5 visits/station/year.

$\therefore$ 3.5 visits/station/year
x 20.75 (83/4) stations/node
72.6 visits/nodal sector/year

Assuming three days/visit for the Canadian Sectors (includes weather delay of one day and an additional day due to longer distances involved):

$\therefore$ 72.6 visits/nodal sector/year
x 3 days/trip
218 days/year/two man maintenance team

The number of trips associated with the Alaskan Sector is the same as in Alternate 3 or 166 days/year/two man team. Hours to repair failures on logistic node equipment for the Alaskan Sector are 73 hours and 73 (3) = 219 hours for the Canadian Sectors.

Manpower available at the three Canadian Logistic Nodes to support the repair of failed LRIs returned from 69 unattended stations consists of:

Maintenance/Supervisor/Manager	.75	(75% availability)
Electronics/Communication Tech.	2.0	
P/V Mechanic	1.0	
Total	3.75	
	at 365	days/year
	1369	available days
Two man maintenance team	-436	
	933	
	x 8	
	7464	Hours

Manpower loading at the Alaskan Full Logistic Node and the three Modified Full Logistic Nodes (Canadian Sector) can now be calculated as follows:

<u>Alaskan sector</u> - Same loading as the Alternate 3 maintenance concept or:

$$\frac{911}{9624} = 9.4\% \text{ Satellite}$$

Canadian Sectors - For each of the three Modified Full Logistic Nodes:

$$\frac{911}{7464} = 12\% \text{ Satellite}$$

f) Alternate 6 - Nodal reliability figures (Canadian Sectors indicate a mean time between node network failures is 4.7 (Satellite) including the yearly resupply visit or one visit to an unattended station every 3.4 months). This is equal to 3.5 visits/station/year.

$\therefore$ 3.5 visits/station/year
x 20.75 (83/4) stations/node

72.6 trips/nodal sector/year

Assuming three days/trip for the Canadian Sectors (includes weather delay of one day plus two additional days due to longer distances and refueling required by the heliocpters):

72.6 trips/nodal sector/year
x 3 days/trip

218 days/year/two man maintenance team

or 436 days required by the two maintenance teams/nodal sector.

The number of trips associated with the Alaskan Sector is the same as in Alternate 3 or 166 days/year/two man team. Hours to repair failure on logistic node equipment are 73 hours for both the Alaskan and Canadian Sectors.

Manpower available at the Canadian Logistic Node to support the repair of failed LRIs returned from 69 unattended stations consists of:

Maintenance/Supervisor/Manager	.75	
Electronics/Comm Technician	4.0	
P/V Mechanic	1.0	
	5.75	
at	365	day/year
	2099	available days
(two maintenance teams @ 436 days x 3 nodes)	1308	
	791	
	x 8	
	6328	hours

Manpower loading at the Alaskan Sector Logistic Node and the remaining Canadian Sector's Logistic Nodes can now be calculated as follows:

<u>Alaskan Sector</u> - same loading as for the baseline maintenance concept:

$$\frac{911}{9624} = 9\% \text{ utilization}$$

<u>Remaining Sectors</u>

616 + 222 + 73 = 911

$$\frac{3177}{6328} = 14\% \text{ utilization for Alternate 6}$$

TABLE A (DELETED)

SEE TABLE 3.2-23

TABLE B

FULL LOGISTIC NODE PERSONNEL REQUIREMENTS

MAINTENANCE		SUPPORT	
MAINTENANCE SUPERVISOR/MANAGER	1	HEAVY EQUIPMENT OPERATOR	1
CONSOLE OPERATOR/TECHNICIAN	3	COOK/BAKER	1
ELECTRONICS/COMMUNICATIONS TECH	2	TRANSPORTATION/SUPPLY SPECS	2
MECHANICAL TECH	1	CLERKS	1
V/E MECHANIC	1	LABORER	1
P/V MECHANIC	1	TOTAL	6
ELECTRICIAN	1		
POWER/SANITATION OPERATOR/MECH	1		
TOTAL	11		

FULL LOGISTIC NODE TOTAL 17

TABLE C

MINI LOGISTIC NODE AND DATA NODE PERSONNEL REQUIREMENTS

MINI LOGISTIC NODE

MAINTENANCE SUPERVISOR/MANAGER	1	TRANSPORTATION/SUPPLY SPEC/ CLERK	1
P/V MECHANIC	1		
ELECTRONIC/COMMUNICATIONS TECH	2		
MECHANICAL TECH	1		
	5		

MINI LOGISTIC NODE TOTAL 6

TABLE D

DATA NODE

CONSOLE OPERATOR/TECH	3

DATA NODE TOTAL 3

TABLE E

REDUCED LOGISTICS NODE PERSONNEL REQUIREMENTS

CONSOLE OPERATOR/TECH	3	COOK/BAKER	1
V/E MECHANIC/OPERATOR	1	TRANSPORTATION/ SUPPLY SPEC	1
ELECTRICIAN	1		
			2
POWER/SANITATION OP/ MECH	1		
	6		

REDUCED NODE - MODIFIED (1)

SAME AS REDUCED LOGISTICS NODE EXCEPT DELETE

3 CONSOLE OPERATOR/TECHNICIANS

TABLE F

MODIFICATIONS OF FULL LOGISTIC NODE

- MODIFIED LOGISTIC NODE (1)

  SAME AS FULL NODE EXCEPT DELETE:

  1 V/E MECHANIC
  1 ELECTRICIAN
  1 POWER/SANITATION OPERATOR MECHANIC
  1 HEAVY EQUIPMENT OPERATOR
  1 COOK/BAKER
  1 LABORER

  CANADIAN MINISTRY OF TRANSPORTATION (MOT) OR USAF

  ALASKAN COMMAND WILL SUPPLY THE ABOVE

- MODIFIED LOGISTIC NODE (2)

  SAME AS MODIFIED (1) EXCEPT ADD 2 ELEC/COMM TECHS

- MODIFIED LOGISTIC NODE (3)

  SAME AS MODIFIED (2) EXCEPT DELETE 3 CONSOLE OPERATOR TECHS

- MODIFIED LOGISTIC NODE (4)

  CONSISTS OF 3 CONSOLE OPERATOR TECHS AND 1 TRANSPORTATION/SUPPLY SPEC

- MODIFIED LOGISTIC NODE (5)

  CONSISTS OF 1 TRANSPORTATION/SUPPLY SPEC

- MODIFIED LOGISTIC NODE (6)

  SAME AS MODIFIED (1) EXCEPT DELETE 3 CONSOLE OPERATOR TECHS

TABLE G

FULL LOGISTIC NODE

PERSONNEL COSTS

All personnel 1 shift/8 hours/day/7 days/week plus on-call as required.

Except console operator/tech - 3 eight hour shifts/day/7 days/week.

TOTAL PERSONNEL COSTS

1	CATEGORY A AT $74K/YEAR =	$74K
5	CATEGORY B AT $54K/YEAR =	$270K
10	CATEGORY C AT $46K/YEAR =	$460K
1	CATEGORY D AT $46K/YEAR =	$46K
17	TOTAL	$850K

MAINTENANCE

1	CATEGORY A AT $74K/YEAR	
5	CATEGORY B AT $54K/YEAR	$574K
5	CATEGORY C AT $46K/YEAR	
11		

SUPPORT

5	CATEGORY C AT $46K/YEAR	
1	CATEGORY D AT $46K/YEAR	$276K
6	TOTAL	$850K

20 YEAR PERSONNEL COSTS PER FULL NODE	$17,000K

TABLE H

MINI-LOGISTIC NODE

PERSONNEL COSTS

All Personnel 1 shift/8 hours/day/7 days/week plus on-call as required.

TOTAL PERSONNEL COSTS

1 CATEGORY A AT $74K/YEAR	= $74K
3 CATEGORY B AT $54K/YEAR	= $162K
2 CATEGORY C AT $46K/YEAR	= $92K
	$328K

MAINTENANCE

1 CATEGORY A AT $74K/YEAR	
3 CATEGORY B AT $54K/YEAR	$282K
1 CATEGORY C AT $46K/YEAR	

SUPPORT

1 CATEGORY C AT $46K/YEAR	$46K
TOTAL	$328K
	x20
20 YEAR PERSONNEL COSTS PER MINI NODE	$6,560K

TABLE I

DATA NODE PERSONNEL COSTS (FT. CHIMO)

3 - 8 HOUR SHIFTS/DAY/7 DAYS/WEEK

3 CATEGORY B AT $54K/YEAR =	$162K
	x 20
20 YEAR PERSONNEL COST DATA NODE	$3,240K

TABLE J

REDUCED LOGISTICS NODE PERSONNEL COSTS

All Personnel - 1 shift/8 hours/day/7 days/week plus on-call as required.
Except console operator/technician - 3 eight hour shifts/day/7 days/week.

TOTAL PERSONNEL COSTS

*3	CATEGORY B AT $54K/YEAR	=	$162K
5	CATEGORY C AT $46K/YEAR	=	$230K
	TOTAL		$392K

MAINTENANCE

3	CATEGORY B AT $54K/YEAR	$300K
3	CATEGORY C AT $46K/YEAR	

SUPPORT

2	CATEGORY C AT $46K/YEAR	$ 92K
	TOTAL	$392K
		x 20
20	YEAR PERSONNEL COSTS REDUCED NODE	$7,840K

* Delete for modified-reduced logistic node (1)

∴ 162 x 20 = ($3,240)

$7840 - $3240 = $4600K

TABLE K

MODIFIED LOGISTICS NODES 1, 2, 3, 4, 5 and 6

PERSONNEL COSTS

(1) Same as Table H except delete:

1 V/E mechanic

1 Electrician

1 Power/Sanitation
Operator/Mechanic at $276K/year

1 Heavy Equip. Op

1 Cook/Baker $276 x 20 = (5520)

1 Laborer

∴ 17,000 - 5520 = $11,480

(2) Same as Modified (1) except add two Electronic/Communications Technicians at $54K/year each = 54 (2) (20) = 2,160K

∴ $2160 + 11,480 = $13,640K

(3) Same as Modified (2) except delete three Console Operator/Technicians at $54K/year each = 54 (3) (20) = $3,240K

∴ $13,640 - 3,240 = $10,400K

(4) Consists of three Console Operator/Technicians at $54K/year each = 54 (3) (20) = $3,240K Plus one transportation/supply spec @ $46K/year = 46 (20) = $920K

∴ $3,240 + $920 = $4,160K

(5) Consists of one transportation/supply spec @ $46K/year = 46 (20) = $920K

(6) Same as modified (1) except delete:
3 Console Operator/Technicians @ $54K/year = 54 (3) (20) = $3,240K

∴ $11,480K = 3,240 = $8,240K

Appendix 7.3

Unattended Station Spares Analysis

Radar Spares/Repair Parts Costs

The line-replaceable items (LRIs) for the radar equipment are those as described in the GE 2-D unattended radar study. The initial and replenishment spares costs defined in Table B were calculated using the AF LCC cost model provided as part of this study. The radar has an assumed operational utilization of 100%. Initial and replenishment spares costs for the radar are:

1)	Initial spares/node	=	$33,010
	x six nodes		6
		1	$198,060
2)	Replenishment spares/URS		1,014
	x 83 stations		83
			$ 84,162
	x 19 years		19
		2	$1,599,078

1 + 2 = Total radar spares cost = $1,797,138

TABLE A DELETED

SEE TABLE 3.2-26

TABLE B
SPARES - RADAR*

Catagory	NSRF	Qty	Cost ($)	Failures/ 10^6 Hrs	% Cond
Large Digital Boards	24	35	1,375	6.0	1
Analog Boards	12	12	900	1.58	1
Equipment Plate	2	2	10,000	23.49	1
Low Current P.S.	9	18	500	3.0	1
High Current P.S.	2	2	4,700	30.0	1
Receiver Protect/Keyer	1	1	955	2.29	100
Transceiver Module	30	32	1,000	12.0	5
SPDT Switch	30	32	300	1.7	100
Circulator	1	1	200	0.5	100
64-Way Power Divider	1	1	500	0.1	100
Column Assembly	125	128	825	.01	100
Driver Amplifier	1	1	6,500	26.0	1
Attenuator Controller	30	32	300	1.56	100
Delay Driver	30	32	300	4.2	100
HIC Circuit	2	2	4,500	14.16	1
VCC Supply Control	30	32	155	2.29	100

*100% Utilization

TABLE B (CONT'D)

SPARES - RADAR*

Catagory	Log Node Repair Time (Per Quarter)	Depot Repair Cycle (Days)	Initial Spares Per Node ($)	83 Sites Replenishment Spares (20 Yrs) ($)
Large Digital Boards	.002	60	1,375	27,000
Analog Boards	.002	60	900	2,000
Equipment Plate	.022	90	10,000	65,000
Low Current P.S.	.002	60	500	2,000
High Current P.S.	.002	60	4,700	39,000
Receiver Protect/Keyer	0	0	955	30,000
Transceiver Module	0	0	1,000	265,000
SPDT Switch	0	0	300	225,000
Circulator	0	0	200	5,500
64-Way Power Divider	0	0	500	1,000
Column Assembly	0	0	825	14,600
Driver Amplifier	.002	60	6,500	900
Attenuator Controller	0	0	300	207,000
Delay Driver	0	0	300	557,000
HIC Circuit	.002	60	4,500	1,200
VCC Supply Control	0	0	155	157,000
			33,010	1,599,200

*100% Utilization

Power Equipment

The LRIs defined for the power equipment consist of the equipments listed in Table C. It is assumed that the power equipment will have an operational utilization of 100%. The initial and replenishment spares costs were calculated as shown.

TABLE C

SPARES - POWER EQUIPMENT

1) 4.2 KW Generator	$ 5K
2) Control unit	5K
3) Starter Battery/Charger Energy Storage	1K
4) Battery/Charger	5K
5) Controller (including telemetry and inverter)	10K
6) Switch Gear	2K
	$28K

1) Initial Spares

The base failure rate of the diesel power system is 17 failures/10^6 hours. This equates to an MTBF of 708 hours or 12.37 corrective maintenance actions/year for the entire URS network. In consideration of the weight of the power equipment LRIs and the affect on transportation costs, it is recommended that one of each of the LRIs in Table C be provided at each of the logistic nodes as initial spares. Therefore initial spares costs at 6 ($28K) = $168K.

2) Replenishment Spares

This is essentially the material required to repair failed LRIs and/or that used as part of the proposed preventive maintenance (as recommended in the Power System study). The maintenance plan and associated costs are shown below:

Yearly maintenance (two visits):

1) Replace filter in each 4.2 KW generator twice = 2 x 20 x 2 = $80.00 at $20.00 each
2) Replace injector in each 4.2 KW generator = 2 x 100 = $200.00 one time at $100.00 each
3) Overhaul 3.1 KW generator every 30 months (.4 times/year) = .4 x 2(1000) = $800.00 of continuous operation at $1,000.00 each

∴ Station total cost/year =	$1,080.00
x 83 stations	83
	$ 89,640.00
x 20 years	20
	$1,792,800.00

Communications Equipment

LRIs have not been defined for the communications equipment. Costs for LRI initial spares are based on a percentage of system cost (same % as the radar). It is assumed that the communication equipment will have an operational utilization of 100%. The initial and replenishment spares costs were calculated as shown below.

1) Spares - Communications - LOS (100% utilization)

Equipment	System Cost ($)
* Tower	15K
* Antenna	15K

* Required at all sites including repeater stations.

Equipment	System Cost ($)
* Radio Equipment	37.5K
Mux Equipment	4.0K
Channel Equipment	46.3K
* Common Status and Control	16.6K
G/A/G Radio	5.0K
Intercom and PA	10.0K
	149.4K

Assume ratio of system cost to LRI cost is 7.25% (same as radar).

∴ replaceable item spares cost = $149.4K (.0725) = 10.83K

a) Initial Spares--Recommend replaceable items ($10.83K) at each logistic node plus one antenna at centrally located logistic node ∴ (6 x $10.83K) + $15K = $80K.

b) Replenishment Spares--Based on 3%/site/year of single initial logistic node spares cost.

Logistic node $80K/6 = 13.33K (.03) x 83 x 19 = $631K

and Unmanned Sites

Repeater Stations = ($6.1K) (.03) x 74 x 19 = $257K

$888K

7.25% of (37.5 + 16.6 + 15 + 15K)

2) Spare - Communications - Satellite (100% utilization)

Equipment	System Cost
Antennas High Power Amp Low Noise Rec Up/Down Converters Channel Equipment Common Status & Control G/A/G Radio Intercom and PA	$275K ($15K Ant)

Assume ratio of system cost to LRI cost is 7.25% (same as radar)

* Required at all sites including repeater stations.

∴ Replaceable item spares cost = $275K (.0725) = $19.9K

a) Initial Spares--Recommend replaceable items ($19.9K) at each logistic node plus one antenna at centrally located logistic node. ∴ (6x $19.9K) + $15K = $134.4K.

b) Replenishment Spares--Based on 3%/site/year of single initial logistic node spares cost ∴ $134.4K/6 = $22.4K (.03 x 83 x 19 = $1,060K

Navigational Aids and Weather Package

LRIs have not been defined for either the navigational aids or the weather package. Costs for LRI initial spares are based on a percentage of system cost (same % as the radar). It is assumed that the navigational aids and the weather package have an operational utilization of 1% (≈ 88 hours/year). The initial and replenishment spares costs were calculated as shown below.

1) Spares - Navigational Aids (1% utilization)

	Unit Cost ($)	
Beacon	10K	(3500 antenna)
Ground-to-Air Radio	3K	(500 antenna)
Rotating Beacon	1K	
Lights, etc.	1K	
	15K	

a) Initial Spares--Recommend all above items except antennas at three nodes plus one of each antenna at centrally located logistic node ∴ 3 x $11K) = 33K

Antenna $ 4K

Initial Spares Cost $37K

b) Replenishment Spares--Based on 3%/site/year of single initial logistic node spares costs (1% utilization) ∴ $11K (.03) x 83 x 19 (.01) = $5,204.

2) Spares - Weather Package (1% utilization)

	Unit Cost $
Visibility (forward scatter meter)	4K
Pressure (vibrating diaphram)	4K
Temperature/(platinum resistance) Dewpoint	3K
Wind Direction and Speed (differential pressure sensor)	3.5K
Controller (microcomputer)	1K
TV Camera (solid-state, slow scan)	1.5K
Miscellaneous	2.5K
	$19.5K

a) Initial Spares--Recommend one of each unit at 3 centrally located logistic nodes ∴($19.5K x 3) = $58.5K

b) Replenishment Spares--Based on 3%/site/year of single initial logistic node spares (1% utilization) ∴ $19.5K x .03 x 83 x 19 (.01) = $9,225.

Repair Material

These are the repair parts/material associated with the repair of failed LRIs returned from the unattended stations and those required to repair failed logistic node equipment. These repair parts/material are calculated as shown in Table D.

Logistic Node Equipment

The estimate of initial and replenishment spares and the associated repair material for logistic node equipment is based on a percentage of the hardware cost. Hardware cost for each equipment category are estimated as:

1) Computer (and peripherals) - $250K (vendor quotes on typical equipment)
   Display - $350K

TABLE D

REPAIR MATERIAL CALCULATIONS

	EQUIPMENT	MA/YR. PER NODE	AVE MATERIAL COST/REPAIR $	COST $ 20 YEARS/NODE	
	POWER	*13.14	150.00	6,240	
	RADAR	138.6	60.00	166,320	
		10.79 (SATELLITE)	60.00	12,948	
STATION	COMMUNICATIONS	17.84 (105 + REPEATERS)	60.00	21,408	
	NAV AIDS	.4	60.00	480	
	WEATHER	1.21	60.00	1,452	
LOGISTIC NODE	COMPUTER	4.38	60.00	5,256	
	DISPLAY	4.38	60.00	5,256	
	A/C FACILITY EQUIPMENT	2.92	60.00	3,504	
	MAINTENANCE TEST EQUIPMENT	6.57	60.00	7,884	
			SAT $	209,340	$217,800 LOS
				X 6 NODES	X 6 NODES
			$	1,256,040	$ 1,306,800

* 11.06 MA INCLUDED IN REPLENISHMENT SPARES FOR OVERHAUL OF 4.4 KW GENERATOR

2) A/C facility - $125K (engineering estimate)

Equipment

3) Maintenance - $94K (see Table F)

Test Equipment

4) Vehicular equipment - $541K (see Table G for typical list of equipment)

* 5) Support Equipment - $490K

(facility items, e.g., generators, power distribution, etc.)

Initial and replenishment spares for items 1), 2) and 3) above are estimated below:

Initial Spares--Assume ratio of hardware cost to LRI costs is 7.25% (same as radar) ∴ ($250K + $350K + $125K + $94K) (.0725) = $59.37K/node or (6) $59.37K = $356K.

Replenishment Spares--Based on 3%/year of a single logistic node spares cost (same as radar) ∴ $59.37K (.03) (19) = $34K

Initial and replenishment spares and repair material for items 4) and 5) above are estimated as follows:

Initial Spares--Assume 10% of hardware cost

∴ ($541K + $490K) (.1) (6 nodes) = $691K

Replenishment Spares and Repair Material--Assume 5% x initial spares costs

∴ $619K (.05) 19 = $588K

Alternate Maintenance Concepts Impact

Cost comparisons between the baseline maintenance concept and the proposed alternates are shown in Table E.

* Based on current inventory of support equipment of $15.3M/31 sites = $494K average.

TABLE E (DELETED)

SEE TABLE 3.2-27

TABLE F

TEST EQUIPMENT COSTS

REQUIRED EQUIPMENT	COST $
Analog Board Tester	8,200
Digital Board Tester	46,500
Tools	4,400
Power Supplies	4,000
Oscilloscope	5,700
Sweep Generator	5,000
Signal Generator	6,400
VTVM	2,700
VOM	200
Power Meter	3,000
RF Couplers	600
Miscellaenous Cables/Adapters	1,000
VSWR Meter	1,200
Spectrum Analyzer	3,500
Attenuator	1,400
	$93,800

TABLE G

TYPICAL VEHICULAR EQUIPMENT

TYPE	DESCRIPTION	NO.
Carrier, Cargo	Thiokol Mod 601 (Trackmaster), gas 10-pass	1
Cleanter, Steam	Littleford Mod 155, gas, 180 gph, tires	1
Compressor, Air	Ingersoll-Rand Mod DR-315, gas, 315 cfm, tires	1
Crane	Threw Mod TL-25-K, gas, 10-ton, tracks	1
Generator	Penn Boiler Mod PE-75AF, gas, 2.5 KW, skid	1
Generator	Reiner Mod GGG10AC, gas, 10 KW, skid	1
Grader	Allis-Chalmers, Mod M-100, sixe 3, diesel scarifier, tires	1
Heater	Herman Nelson Mod BT-400-1, gas, 416,000 BTU/hr, tires	4
Loader, Fr End	Yale & Towne Mod 124-A, diesel, 1.5-yd bucket and fork attachments, tires	1
Roller, Towed	Tampo Mod R-13, 84" wide, tires	1
Scraper, Towed	Cat, Mod 70, 9-cy, tires	1
Starter, Aircraft	ACF Brill Mod A-1, gas, 7.5 KW, tires	1
Tractor	International Harvester (IHC) mod TD20, size 4, diesel, dozer blade/winch/cable control unit, track	1
Tractor	IHC Mod TD20, size 4, diesel, dozer blade, tracks	1
Trailer, Stake	Athey Mod 7EU, 20-ton, tracks	1
Trailer, Stake	Athey Mod 7CU, 10-ton, tracks	1
Truck, Cargo	Dodge Mod W-200, gas, 1-ton, tires	1

TABLE G (Continued)

TYPE	DESCRIPTION	NO.
Truck, Cargo	IHC Mod 1600, gas, 2.5-ton, tires	1
Truck, Cargo	Dodge Mod W-200, gas, 1-ton, tires	1
Truck, Dump	Mack Mod LRXID, diesel, 10-cy, tires	1
Welder	Lincoln Mod SAE-300, gas, 300 amp, tires	1
Miscellaneous:		
Boat, Motor	Evinrude, gas, 10-hp, outboard	1
Boat	Watercraft, 18'	1
Pump	Barnes, GED	2
Pump	Gorman Rupp, 2 in., Mod 802	2
Sled	Mitchler Mod 9 EXHY	1

This equipment list (PIN-4 auxiliary) is assumed as the typical complement required at the proposed main stations, reflecting the reduced requirements of the unattended radar station network.

1) Alternate (1)--Replacement of DYE-M with data node (Ft. Chimo). Add mini-node (Goose Bay, maintenance only). Eliminate A/C facilities, support and vehicular equipment spares/repair parts at BAR-3, CAM-M, FOX-M and Goose Bay--Canadian MOT will provide. Initial and replenishment spares impact is calculated thus:

a) Initial Spares

A/C facilities

Support 6 Node = \$673K initial spares/6 = \$112.2K

Vehicular

then:

b) Replenishment Spares

A/C facilities	=	3% (initial spares) (19 years)
	=	.03 (\$54.4K - \$36.4K) (19) = (10.3K) reduction
Support	=	5% (initial spares) (19 years)
Vehicular	=	.05 (619 - 412.4) (19) = \$196.3K reduction

Alternate (1) Reduction =	\$448.8K
	10.3K
	196.3K
Total	\$655.4K

2) Alternate (2)--All intermediate level maintenance to be performed at CAM-M; delete mini node (Goose Bay), stock initial spares complements at POW-M, BAR-3, BAR-M, CAM-M, FOX-M and Chimo (additional analysis may allow this spares stockage to be reduced to less than six nodes). (see below) Delete maintenance test equipment spares at POW-M, BAR-3, BAR-M, FOX-M, and Chimo.

∴ Initial Spares = $\frac{\$40.9K}{6}$ = \$6.82K x 5 = \$34.1K reduction

Replenishment Spare $\frac{\$23.3K}{6}$ = \$3.88 x 5 = \$19.4K reduction

Repair Material $\frac{\$68.3K}{6}$ = 11.4K x 5 = \$56.9K reduction

Total Alternate (2) Reduction \$110.4K

Additional Impact of Initial Spares Stockage Alternates

Initial spares cost (Alternate (1) and (2) = \$151.6K - \$459K - \$34K =

\$1023.6K/6 = \$170.6K/Node

Nodes

∴ 5 x \$170.6K = -\$853K + \$1023.6K = \$170.6K reduction

4 x \$170.6K = -\$682.4 + \$1023.6K = \$341K reduction

3 x \$170.6K = -\$511.8 + \$1023.6K = \$512K reduction

3) Alternate (3)--Replace modified node (4) at POW-M with a modified logistic node (1) (Alaskan Sector). Minimal impact due to adding maintenance test equipment initial and replenishment spares = \$12K net addition for alternate (3).

4) Alternate (4)--Having all radar/PMFL data be processed at the ROCC will eliminate the computer and display equipment at the nodes, two displays should be added at the ROCC and replenishment spares and repair material will be thus affected.

Initial Spares	Computer \$108.8K reduction Displays \$152.3K reduction ROCC Displays \$50.8K addition
Replenishment Spares	Computer \$62K reduction Displays \$86.8K reduction ROCC Displays \$28.9K addition
Repair Material	Computer \$31.5K reduction Displays \$31.5K reduction ROCC Displays \$10.5K addition

Total Impact = \$382.7K reduction Alternate (4)

5) Alternate (5)--Intermediate level maintenance to be performed CAM-M, POW-M, BAR-3, and Chimo. Initial and replenishment spares and repair material will be thus affected.

a) Add back reductions from alternate (4) of \$382.7K

b) Add maintenance test equipment spares at BAR-3 and Fort Chimo ≈ \$24K (see Alternate (3)).

∴ Total additions for alternate (5) = \$382.7K + \$44K or \$427K.

6) Alternate (6)--Intermediate level maintenance to be performed at POW-M and GAM-M only. All data processed at the ROCC. Initial and replenishment spares and repair material will be thus affected.

a) Include reductions from alternate (4) of \$383K.

b) Delete additions from alternate (5) of \$44K.

c) Delete \$341K spares stored at only four sites.

∴ Total reductions for alternate (6) = \$383K + \$44K + \$341K = \$768K.

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-78