Background 2

The Air Force is responsible for verifying international compliance with nuclear weapons testing treaties. The principal test ban agreements in force are the Limited Test Ban Treaty of 1963, the Threshold Test Ban Treaty of 1974, and the Peaceful Nuclear Explosions Treaty of 1976. To accomplish this mission, the Air Force Technical Applications Center (AFTAC) operates and maintains the U.S. Atomic Energy Detection System, a worldwide system of sensors to detect nuclear explosions underground, underwater, and in the atmosphere and space. The system relies on seismic and hydroacoustic data, satellite information, and collected air and ground debris. AFTAC is headquartered at Patrick Air Force Base (AFB), Florida, and has 14 detachments, six operating locations, and approximately 70 equipment locations. Burnt Mountain is one of seven sites in Alaska, and 19 sites worldwide, that collect seismic data. The system uses multiple monitoring sites and sophisticated signal enhancement (beamforming) data analysis techniques to detect very small seismic sources and to distinguish between ground disturbances caused by nuclear weapons tests and those caused by natural geological phenomena such as earthquakes. AFTAC Detachmcnt 460 (Det-460), located at Eielson AFB (near Fairbanks, Alaska), is responsible for operating the Burnt Mountain observatory and several other seismic monitoring stations in Alaska.

Changes in world security following the Cold War call into question the necessity of the Burnt Mountain Seismic Observatory and other Air Force stations like it. The stations were installed to monitor the Soviet Union during a time when there was no access to Soviet territory. Today, a worldwide network of open seismic stations--including several on the territory of the former Soviet Union--am providing data that vastly supplements the Air Force's capabilities. The role of AFTAC's network of seismic stations is different in this new environment, but it remains important. AFTAC has recently been assigned to improve its capability to meet the more stringent monitoring requirements of the Comprehensive Test Ban Treaty currently being negotiated. This new assignment has increased the value of the data from Burnt Mountain. The Air Force views the observatory as one of an integral handful of recording sites that will comprise the core event detection network of the new treaty monitoring network. These closely monitored sites will be used to cue the open system to which events need [o be examined more closely. Furthermore, guaranteed future access to data from seismic stations in the former Soviet Union or near other regions where nuclear testing is likely to occur cannot be relied on. In this background paper, the Burnt Mountain Seismic Observatory is assumed to operate for 30 more years.

The option of closing the Burnt Mountain site is complicated by the possible loss of other Det-460 seismic stations (or at least the prospect of greatly increased logistical expenses at other stations). One seismic monitoring station, on the Aleutian Island of Attu, can only be reached by crossing two small bridges that need replacement or extensive repair. Two additional stations are located at Air Force radar stations, which provide power and some logistical support. If the radar facilities were closed for some reason, the seismic equipment would have to be powered independently or shut down. Closing these seismic stations would make the Burnt Mountain site that much more important, while keeping them open would be facilitated by using whatever replacement power system is selected for Burnt Mountain.

Gerald Epstein

Shed containing the RTGs powering one of the remote seismometers in the Burnt Mountain observatory.

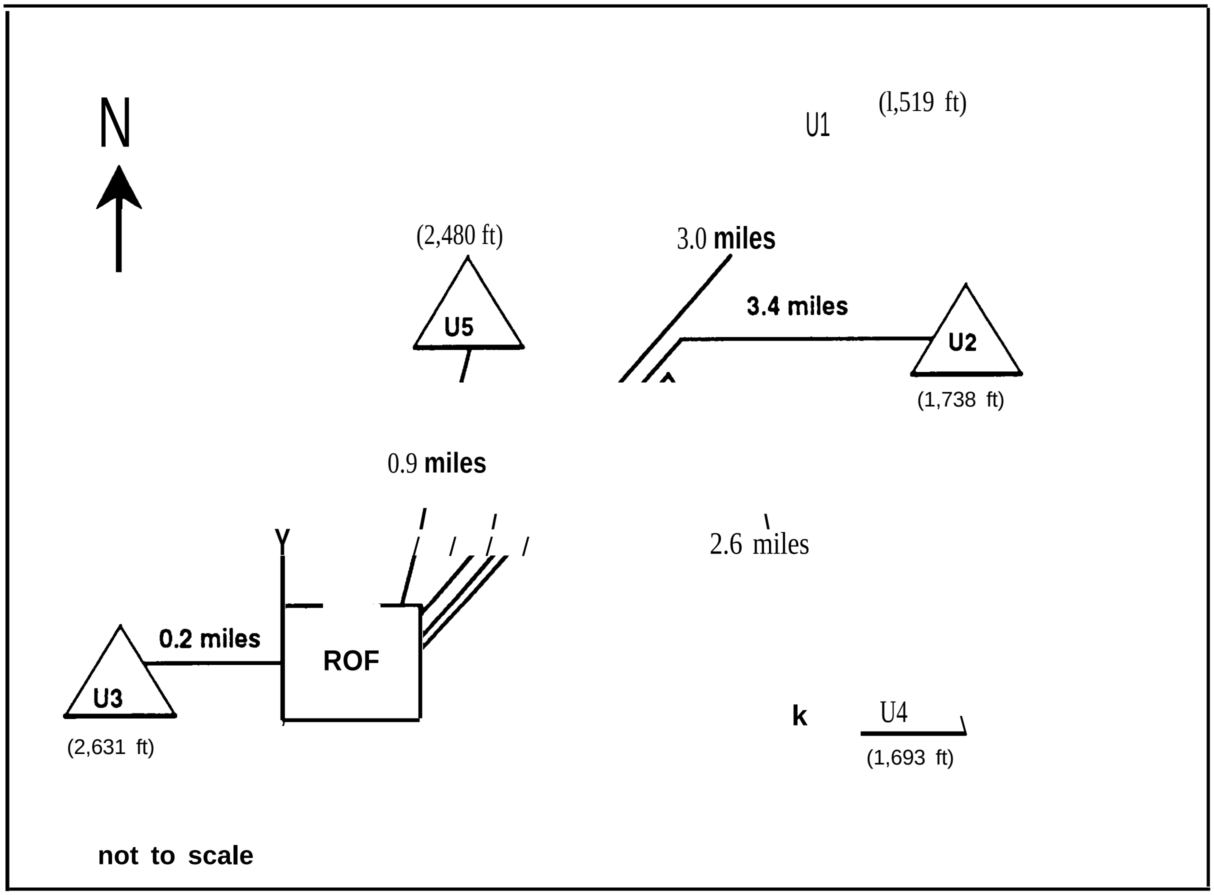
EQUIPMENT AND OPERATIONS

The principal equipment at Burnt Mountain consists of the borehole seismometers to collect the seismic data and a signal multiplexer and a radio to communicate the data offsite for analysis. There are five seismometers clustered within a 1.5 mile radius and linked to a central communications station via surface-laid data cable (figure 2-l). The remote terminals (RTs)--identified as sites U1, U2, U3, U4, and U5--each consist of a borehole, a seismic sensor, and a metal frame shelter for housing the power generators and associated power conditioning equipment (figure 2-2). The remote operating facility (ROF), near site U3, houses the signal multiplexer and the communications equipment. Data from the five sensors are fed to the ROF via data cables, multiplexed into a single data stream, transferred to Fort Yukon, Alaska, via line-of-sight UHF radio, transmitted to Det-460 at Eielson AFB via satellite link, and then sent on to AFTAC headquarters and also to McClellan AFB near Sacramento, California. Multiple seismometers are used to increase the sensitivity of the readings. The five data signals are computer processed to diminish noise, allowing clearer characterization of the seismic activity.

Each equipment shed is fenced in and the surrounding area is cleared of trees and other vegetation to a distance of 50 feet. There are two additional shelters located near the ROF. One serves as lodging for maintenance crews and the other houses the station's all-terrian service vehicle.

There are three site visits programmed each year: one scheduled maintenance, one scheduled inspection, and one unscheduled maintenance. However, since 1985--when most of the radioisotope thermoelectric generators (RTGs) were installed--there has been an average of six visits a year for the purposes of maintenance, inspection, and orientation. There has never been a station outage caused by the RTGs since the first one was installed in 1973. There have been sig-

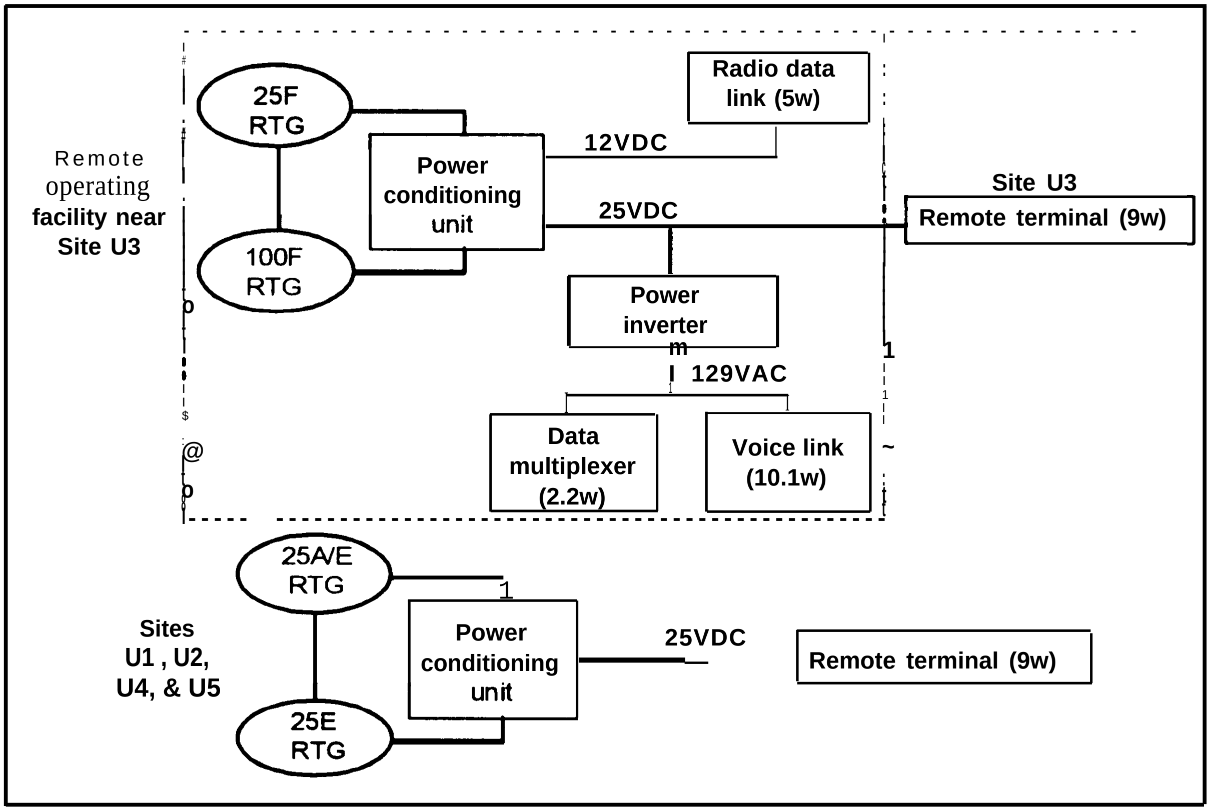
FIGURE 2-1: Layout of Burnt Mountain Seismic Observatory Showing Distances Between Equipment



KEY: ROF = remote operating facility.
Numbers in parentheses are elevations given in feet above sea level.

SOURCE: Wright Laboratory, Aeropropulsion and Power Directorate, Aerospace Power Division, "Power System Assessment for the Burnt Mountain Seismic Observatory," report prepared for the Air Force Technical Applications Center, March 1994.

FIGURE 2-2: Configuration and Measured Power Requirements of Equipment at Burnt Mountain Seismic Observatory



NOTES:

- 25A/E, 25E, 25F and 10OF refer to the RTGs model numbers.
- Remote terminals - Designed in the early 1980's with Transistor-Transistor Logic (TTL) technology.
- Power conditioning units - Designed in 1985 using discrete transistor technology for operation with RTGs.
- Data multiplexer - Line Sharing Unit that multiplexes data from the five sites at Burnt Mountain. Designed using Small Scale Integration-complementary metal-oxide silicon (CMOS), analog, TTL technology.
- Inverter - Converts direct current (DC) to alternating current (AC) to provide power for the data multiplexer. Technology is discrete and TTL,
- Voice link - Voice frequency responder for testing the communications circuit. Since an inverter is used to power the data multiplexer, AC power is available to accommodate and AC powered responder.
- Radio data link - Commutronics radio with Small-Scale Integration technology, analog and discrete.

SOURCE: Wright Laboratory, Aeropropulsion and Power Directorate, Aerospace Power Division, "Power System Assessment for the Burnt Mountain Seismic Observatory," draft report prepared for the Air Force Technical Applications Center, Patrick Air Force Base, FL, Oct. 29, 1993, nal outages associated with problems with the power conditioning electronics, radios, seismic instruments, and data cable. [1]

RADIOISOTOPE THERMOELECTRIC GENERATORS

The seismometers, multiplexer, and radio equipment discussed in the previous section require low, but very reliable power. These devices are currently powered by 10 RTGs. There are two Sentinel 25 RTGs each at sites Ul, U2, U4, and U5, and one Sentinel 25 and one Sentinel 100 RTG at the ROF near site U3. Currently, the Sentinel model 25s generate about 9 to 20 watts and the model 100 generates about 54 watts. The larger RTG is used at site U3 to power the communications equipment as well as the site's monitoring device. The RTGs produce low voltage direct current (DC) output; power conditioning and conversion equipment is used to convert the power to the necessary voltages and forms (DC or alternating current--AC). Each of the five RTs uses electricity in the form of 25V DC, The ROF uses electricity in two forms, 129V AC and 12V DC. There currently is no power distribution capability between the five RT sites at Burnt Mountain.

RTG technology was developed under the Atomic Energy Commission's "Beneficial Uses of Radioactive Material" program begun in 1959, RTGs are used in remote applications such as Arctic stations and space vehicles, where small amounts of highly reliable, low-maintenance power are required. The first RTG was installed at Burnt Mountain in 1973 and nine additional ones were installed in 1985. The unit installed in 1973 was purchased directly from Teledyne. Some of the units installed in 1985 came from the Federal Aviation Administration; others were Navy surplus. They have never failed to produce power.

The RTGs at, Burnt Mountain differ slightly from one another in terms of their date of fueling and power capacity. Thus their useful life at the station also varies. Table 2-1 shows when the RTGs will cease to provide enough power for their associated equipment. The RTGs, as currently configured, could fully power the observatory until March 2009. Several of the units could be used longer, but all would need to be replaced or modified by June 2019 at the latest. These are the earliest dates that the generators would have to be replaced. Advances in the system electronics that reduce power requirements should outpace RTG power degradation, The Air Force has considered several options for extending the life of the RTGs. [2]

- Discontinuing the use of the voice link used to test the communications circuit. This would extend the life of the RTGs at site U3 by 10 years, making the RTGs at site US the first to need replacement (in 201 2).
- Allowing the power to cut off at site US. When coupled with the previous option, this would extend the life of the RTGs at the station until 2018.
- Installing improved thermoelectric modules (TEMs), the internal RTG components that convert the heat into power.[3] The current TEMs have an efficiency of about 5 percent: improved ones would be about 15 percent efficient, effectively tripling the power outtput of the RTGs,[4] With improved TEMs, the RTGs could power the observatory equipment until

[1] Lt. Col. Terry Fout, letter to Alaska Porcupine Caribou Commission, Nov. 3, 1992.

[2] C01. Terry A. Schmidt. Technical Operations Division, McClellan AFB. letter to the Air Force Technical Applications Center on the status of Burnt Mountain radioisotope thermoelectric generators.

[3] Refitting the RTGs with new TEMS would require an additional Certificate of Compliance from the Nuclear Regulatory Commission, See section on Licenses and Emergency Plans in chapter 5 of this report.

[4] Improvements in thermoelectric conversion efficiency depend on the timing of the installation. Were new modules fabricated today, their efficiency would be on the order of 1() percent. If they were fabricated in 20 years or so, 15 percent efficiency may be possible given the potential advances in thermoelectric material technology.

TABLE 2-1: RTG Models, Power Demand, and Estimated Replacement Dates

Site number	RTG serial number	RTG model number	Present power output (watts)'	Site power demand _(watts)[b]	Estimated replacement dates
U1	8	Sentinel 25E	10.4	9.0	June 2018
	17	Sentinel 25E	14.8		
U2	9	Sentinel 25E	9.8	9.2	January 2018
	20	Sentinel 25E	14.4		
U3	1	Sentinel lOOF	42.3	26.2	March 2009
	14	Sentinel 25F	10.4		
U4	10	Sentinel 25E	9.5	9.0	June 2019
	18	Sentinel 25E	15.1		
U5	4	Sentinel 25A	6.7	9.0	August 2012
	19	Sentinel 25E	14.6		

a power losses of 20 to percent due to heat losses have been factored in.
b Measured loads of the equipment as recorded by the Air Force Technical Applications Center/Technical Operations Division engineers during a June 1992 site visit.

SOURCE: Office of Technology Assessment based on data from Wright Laboratory, Aeropropulsion and Power Directorate, Aerospace Power Division, 'Power System Assessment for the Burnt Mountain Seismic Observatory,' report prepared for the Air Force Technical Applications Center, March, 1994.

2032 to 2047 depending on the particular site. The TEMs do not have to be installed immediately to realize these gains. Putting them in anytime before the RTGs otherwise become too weak to power their equipment is sufficient.

There are other power management techniques that could extend the operating life of the RTGs. For example, swapping generators number 14 and number 17 would extend the lifetime of the Burnt Mountain RTGs by 21/2A years (to September 2011). Also, installing future generations of seismic and power conditioning electronics, which are likely to require less power, would extend the useful life of the RTGs. With these kinds of power management methods and likely improvements in system electronics, it is entirely possible that RTGs could power the Burnt Mountain station well into the second if not third decade of the next century.[5]

STRONTIUM-90 FUEL

Each of the RTGs at Burnt Mountain contains between 1.2 and 3.9 pounds of Strontium-90 (Sr-90) fuel. Sr-90 produces the heat needed in the RTGs via radioactive decay, not through fission or fusion. It is manufactured as a byproduct of spent nuclear fuel reprocessing. [G] Sr-90 has

[5] John F. Vogt, Sentinel Program Manager, Teledyne Brown Engineering-Energy Systems, personal communication, Mar. 18, 1994.

a half-life of 28 years. This makes it suitable for long-term power uses. RTGs do not require constant refueling.

In the RTGs, the Sr-90 fuel is in the form of hockey puck-sized disks of strontium titanate ($SrTiO_3$ or $SrTiO_4$), a solid ceramic material. This material was selected in large part for its strength, fire-resistance, and low water-volubility.

Sr-90 is the main source of environmental risk associated with the RTGs at Burnt Mountain. It is not an explosive material, but is hazardous if dispersed by other means. Sr-90 and its only radioactive decay product, Yttrium-90 (Y-90), are both beta emitters. Beta particles from Sr-90 travel about 10 inches in air and those of Y-90 travel about 100 inches in air. The particles travel shorter distances in liquids and solids. Close contact with the radioisotope through ingestion or inhalation is necessary to deliver a long-term beta dose of radiation to the body. Beta particles, such as those from decay of Sr-90, also create x-rays (Bremsstrahlung radiation) as they are slowed down in the surrounding fuel and shielding material. X-rays are penetrating radiation that can deliver a radiation dose from outside the body.

Sr-90 follows calcium metabolically, and if ingested or inhaled in a biologically available form (i.e., as a substance that is soluble in the bloodstream or other fluids of a living organism) accumulates in the bones. From there it continues to deliver radiation to associated tissues over its entire radioactive life. This has been found to induce bone cancer and in some cases leukemia.' If Sr-90 is ingested or inhaled in a relatively nonbiologically available form--such as strontium titanate--the material passes from the body naturally, delivering primarily a short-term dose of radiation.

LOCATION AND CLIMATE

Burnt Mountain is located at 67°25' north latitude, 144°36' west longitude, approximately 62 miles north of the Arctic Circle (figure 2-3). It is a remote area about 50 miles from the closest villages (Venetie, Arctic Village, and Chalkyitsik) and 56 miles from the nearest Air Force facility (Fort Yukon Air Force Station),

The site was chosen for a seismic observatory because of its geologic structure and long distance from human sources of noise. Its hard-rock surface surrounded with soft soil yields very clear seismic signals with minimum noise.

The Burnt Mountain observatory lies in the foothills of the Brooks Range, so the terrain in the immediate vicinity is mountainous. There is a 1,100-foot difference in elevation between the highest and lowest of the sensor sites. The land is tundra that varies from barren rocky ground to areas of considerable cover, mostly white and black spruce and some aspen, birch, and wil-

Gerald Epstein

View of the ROF site at Burnt Mountain. The RTGs powering this site are located inside the structure within the fence. Several kilometers in the distance is a small clearing containing one of the remote seismographs.

[6] Sr-90 is ~l~o formed in nuclear weapons explosions and is a component of radioactive fallout.

[7] John H. Harley, "Radioactive Fallout, " *McGraw-Hill Encyclopedia on Science and Technology,* 7th ed. (New York, NY: McGraw-Hill, 1992).

FIGURE 2-3: Map of Alaska Showing the Location of the Burnt Mountain Seismic Observatory and Nearby Communities

SOURCE: Office of Technology Assessment, 1994.

lows. Vegetation has been cleared to a distance of 50 feet from each of the sensor sites. Discontinuous permafrost exists in the area, There is also wildlife in the area, including barren-ground caribou, grizzly and black bears, moose, and a variety of fur bearers and ptarmigan.[8]

The climatic conditions at Burnt Mountain are not known precisely; the nearest weather observatory is at Fort Yukon. Climatic conditions for Fort Yukon are summarized in table 2-2. Average daily temperatures range from -22°F in the winter to 63°F in the summer, and extremes of -71° to 100°F have been recorded. Humidity is nil to low year round. Precipitation is moderate. Wind speeds are low year round. Monthly average wind speeds range from 3 to 7 knots. Gusts as high as 35 knots were recorded during the 1980s.

The extreme northern location of the site limits daylight that might be useful for solar power. Average daily daylight ranges from 21 to 24 hours during the summer and 2 to 3 hours

[8] Corps of Engineers, Alaska District, *Environmental Impact Assessment,* AFTAC Project F/1081 (Anchorage, AK: May 1972).

TABLE 2-2: Climate Conditions at Fort Yukon

	Temperature Low (°F)	High (°F)	Other	
Winter (average)	-22	-2	Wind (average)	less than 5 knots (5.8 mph)
Spring (average)	29	54	Wind (gusts)	35 knots (40 mph)
Summer (average)	42	63	Precipitation	17 inches annually
Fall (average)	-9	6	Humidity	low
Extremes	-71	100		

SOURCES: Wright Laboratory, Aeropropulsion and Power Directorate, Aerospace Power Division, "Power System Assessment for the Burnt Mountain Seismic Observatory," draft report prepared for the Air Force Technical Applications Center, Oct. 29, 1993; and Letter from Senators Stevens and Murkowski to the Office of Technology Assessment, Oct. 27, 1993.

during the winter. Certain days in the winter, though, receive no sunlight at all. The average daily insolation, a measure of the intensity of sunlight, varies between a low of 0.1 MJ/m^2 in December to a high of 18.5 MJ/m^2 in May.[9]

There are no roads in the area. All personnel and materials are flown in from Fort Yukon via helicopter. Fort Yukon is the principal staging area for Burnt Mountain, but is only marginally more accessible. Personnel and incidental materials are flown in and bulk supplies are delivered via barge. Bulk transport from Fairbanks is by road to Nenana (50 miles southwest of Fairbanks) and then by barge on the Yukon River to Fort Yukon. There are three barge trips per year--June, July, and September.

The Alaska District Corps of Engineers conducted an Environmental Impact Assessment for siting the observatory at Burnt Mountain and two other locations in 1972. The assessment focused almost exclusively on the environmental impact of the construction of the facilities, not on their operation. Impacts discussed clearing vegetation and soil erosion as a result of vegetation removal and road access.[10]

[9] Solar Energy Research Institute (now the National Renewable Energy Laboratory), *Solar Raciialion Energy Resource Atlas of the United States*, SERUSP-642-1037 (Golden, CO: October 1981). Data is for Big Delta, AK, with panels tilted at 64° (latitude) from horizontal.

[10] Corps of Engineers, op. cit., footnote 8.