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CRITERIA FOR THE PNE SEISMIC NETWORK

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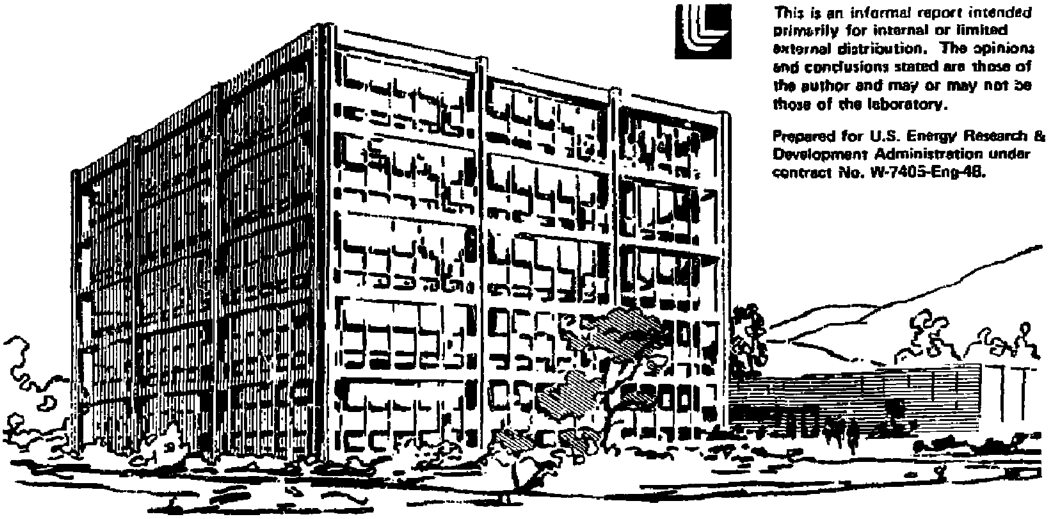
March 23, 1978



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CRITERIA FOR THE PNE LOCAL SEISMIC NETWORK*

ABSTRACT

A 1976 treaty between the United States and the Soviet Union permits a local seismic network to be deployed at the site of a peaceful nuclear explosion to monitor the event. This report provides criteria for the design and selection of the data-acquisition equipment for such a network. We discuss constraints imposed by the protocol of the treaty, the environment, and the expected properties of seismic signals (based on experiences at the Nevada Test Site). We also draw conclusions about the desired operating mode and describe criteria for a general seismic instrumentation system.

INTRODUCTION

In April 1976, the United States and the Soviet Union reached agreement on a treaty to monitor peaceful nuclear explosions (PNEs). The treaty, with its companion protocol, provides for on-site inspection teams to confirm that the purposes of such explosions are indeed peaceful. Both the treaty, titled "Treaty between the United States of America and the Union of Soviet Socialists Republics on Underground Nuclear Explosions for Peaceful Purposes" and the protocol were signed by Gerald R. Ford and Leonid I. Brezhnev on May 28, 1976. Ratification hearings by the U. S. Senate have not yet taken place. Under conditions spelled out in the protocol, the on-site team will be permitted to deploy a small local seismic network (LSN) at the PNE site to ensure that no clandestine collateral explosion occurred in conjunction with the PNE.

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*These criteria were developed by the Subcommittee of the Instrumentation Development Committee. The subcommittee was composed of:
B. C. Benjamin of Sandia Laboratories, Albuquerque (chairman)
J. R. Bannister of Sandia Laboratories, Albuquerque
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In this report, we provide criteria for the data-acquisition equipment in the LSN. Various constraints are imposed by the protocol, the environment, and properties of seismic signals determined from experiences at the Nevada Test Site (NTS). In conclusion, we describe a general seismic instrumentation system and operating mode. The proposed system would be suitable for a variety of monitoring applications under the Peaceful Nuclear Explosion Treaty and the Comprehensive Test Ban Treaty; both require versatility and quick deployment.

PROVISIONS OF THE PROTOCOL RELATED TO THE DEPLOYMENT OF LOCAL SEISMIC NETWORK

Constraints placed on the seismic system by the protocol or inferred from the negotiating record are summarized in this section.

CONDITIONS FOR LSN DEPLOYMENT

The protocol covers PNEs that take place in the United States, Soviet Union, or a third country where the PNE is sponsored by the United States or the Soviet Union. The United States and the Soviet Union must permit an LSN in PNEs with aggregate yields above 500 kt. No PNEs of more than 1500 kt are allowed.

Restrictions on the LSN

The protocol authorizes a system of seismic stations plus an optional central recording facility. The number of stations is variable and tied to the number of individual explosives in the PNE. Specifically, if the PNE consists of N explosives, the observing country may deploy a maximum of N plus 5 stations. The protocol restricts LSN deployment to N values from 4 to 34, permitting between 9 and 39 stations. An LSN will not be deployed for less than four individual explosives. The protocol covers contained and cratering PNEs.

Seismic stations may not be deployed more than 15 km from the nearest PNE explosive. The observer team can request specific station sites within this area after its arrival at the PNE site. The host country can reject requested sites on an individual basis.

The present working assumption, based on the negotiating record, is that each seismic station will consist of three transducers and the associated electronic hardware needed to either record the data locally or transmit them to a central recording site or both. These transducers will be orthogonally oriented, one vertical and the other two horizontal. The transducers presumably need not all be of the same type at any given station or from station to station.[1] The stations must contain their own power supply.

If data will be recorded at a central recording site, the protocol states that it may be transmitted between the seismic stations and the recording site by radio link. The protocol does not specify any frequency or range of frequencies for this link; nor does it exclude any. The protocol does, however, provide for such issues to be clarified before the observer team departs for the host country. Repeater stations may be used.

The observer team is required to enter the host country with two completely operational seismic systems. These are to be, in a practical sense, identical. The host country selects one set and forwards the other to the PNE site for use by the observer team. The team might be allowed as few as 20 days to deploy the system. After the PNE has been detonated and reentry into the working area authorized, the team has eight days to remove all equipment and prepare it for shipment. Because recording continues for three days after detonation, this could give only five days to collect the system hardware. No assurance is given in the protocol that all field hardware will be retrievable before the team is required to leave the site.

The Seismic Team

The protocol does not define a seismic team, but rather specifies the maximum number of personnel on the total observer team. For N explosives, the team can consist of N plus 10 persons (14 to 44 people). The team is expected to include some seismic specialists. However, to remain flexible, some personnel will probably be cross-trained to service several areas of the mission if necessary. Nevertheless, an effective seismic team size equivalent to 4 or 5 full-time personnel is anticipated.

Team Support

The protocol states that the transport of observer-team personnel and equipment within the host country will be provided by the host country. Neither the types of transport vehicles nor the level of service are specified. Whether the observer team will be permitted to work outside normal working hours is also unspecified. The host country will supply living and possibly working quarters for the team. We must assume that transportation will be by air, rail, or road. Humping in train and truck transportation over rough roads will be an important equipment design problem.

Seismic Data Handling

The LSN will be able to record data continuously from just before the PNE to 72 h after. The protocol requires all data to be recorded in parallel. That is, the signal from each seismic transducer must be split at some point and recorded independently on separate tapes in real time. After recording terminates, but before the observer team departs from the PNE site, each of these data sets is to be duplicated. This will result in four complete sets of data — two original and two duplicate. The observer team will be permitted to leave with two of these four sets; just which two are not specified. Also, the host country is to retain one of the two tape recorders.

OPERATING ENVIRONMENT AT PNE SITES

In general, equipment at a PNE site must be designed for extreme weather conditions, although the terrain is not expected to be too difficult. For instance, the Soviets may elect to construct the Kama-Pechora Canal, planned for an area where snow covers the ground much of the year, and the seismic stations could be buried in permafrost. The terrain at this site, however, is generally wooded, rolling hills. (Conditions at this site are detailed in Appendix A.) At the other extreme is the Egyptian proposal to excavate a canal from the Mediterranean Sea to the Qattara Depression, a desert area with intense heat.

Specific environmental criteria are given in Appendix B. These criteria are only guidelines and may be modified for particular pieces of equipment; the central-station equipment, for example, will not have to meet immersion criteria. The criteria do not directly address questions related to physical security.

EXPECTED SIGNAL CHARACTER

Because this discussion is based almost entirely on NTS experience, the conclusions drawn may be biased by peculiarities of NTS. In addition, the data are concerned with contained underground detonations and do not address cratering detonations, which may be encountered in PNEs.

Amplitudes

An extremely wide range of amplitudes must be monitored to do a thorough job. At one extreme is the necessity to record the complete, explosion-induced initial-ground-motion signal, including spall-closure spikes of 40 G with a good signal-to-noise ratio (S/N). At the other extreme is the requirement to detect smaller events in the postshot environment down to a background noise level of 10^{-6} G. The largest of these postshot events are 1.2- to 1.3-magnitude units[2,3] less than the initial ground motion from the explosion (i.e., the peak amplitude of the strongest aftershocks are about 1/16 to 1/20 of the peak values of the initial motion). The majority of them are more than 2 magnitude units less than the critical motion (i.e., the amplitudes are less than 1/100 of those of the initial motion).

Enough data exist to estimate the expected ground motion as a function of yield and distance from an explosion.[4,5] This information has been used to plot vector acceleration, velocity, and displacement in Figs. 1, 2, and 3, respectively, for the largest and smallest yields relevant to LSN deployment under the treaty. The maximum expected-aftershock level and the upper limit for the majority of the aftershocks (assuming that the relationships noted above hold), are also shown in Fig. 1.

Figure 4 shows typical quiet-site values[6] of background noise in terms of peak acceleration and velocity, and Fig. 5 shows corresponding typical values of displacement. All of the above, including the observations of Jackson[7] on a low-yield Yucca Flat event, are summarized in Fig. 6 where it is seen that covering the entire range at a quiet site requires a system with a dynamic range of more then 160 dB. However, the seismic background at the actual sites is likely to be much higher than the quiet-site level because of several factors. For instance, the monitoring will be at the surface, as opposed to an underground vault where vegetation and wind can combine to double or triple the noise level. A thaw or freeze could also strongly affect the background. The PNE event can produce many small postshot stress-release events that may provide a continuous noise background for larger aftershocks. It is not unreasonable, then, to expect a seismic background on the order of 1 μG or more. Therefore, for postshot monitoring, only the estimated largest aftershock and the possible site background will be considered; the range to be covered then becomes 1 G to 1 μG (120 dB) in the postshot environment and 40 G to 400 μG (100 dB) at shot time.

Frequency Content

Outside the spall region and its immediate vicinity, the difference in frequencies between ground motion from the explosion and that from the aftershocks is small. The evidence available indicates that the signals are limited to about 30 Hz on the high side. On the low side, the available data are less definitive.

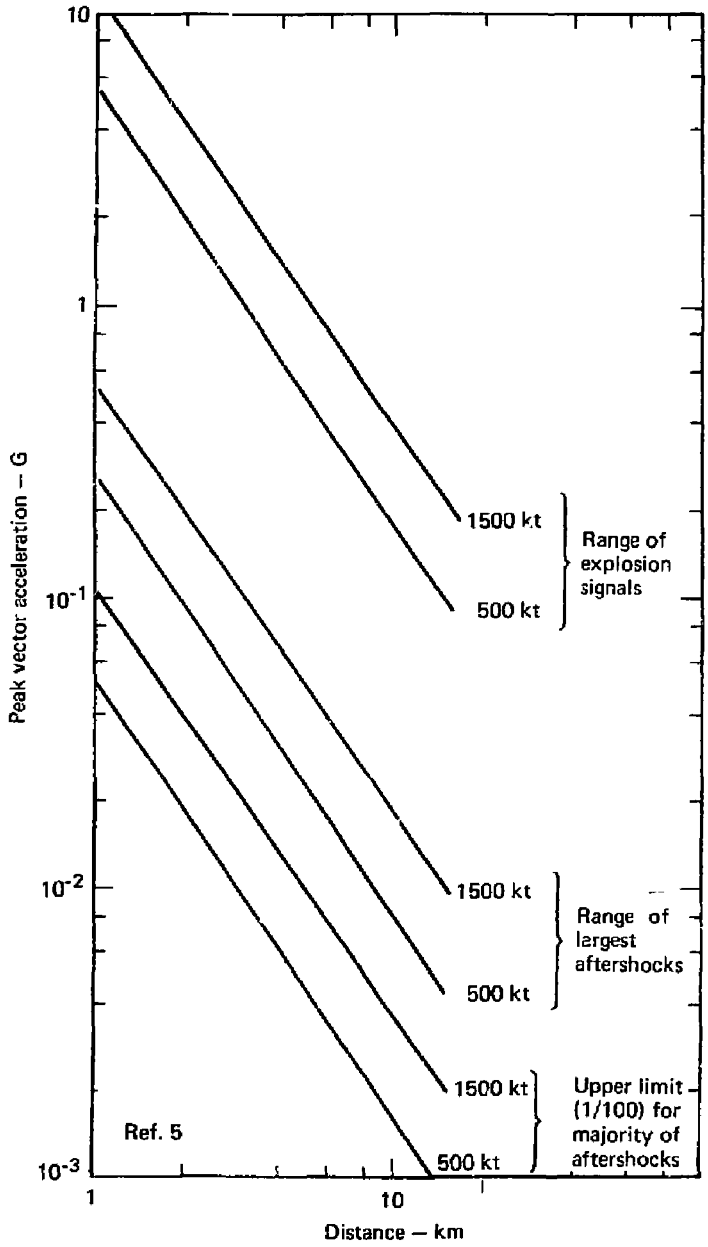

Fig. 1. Peak vector acceleration as a function of distance.

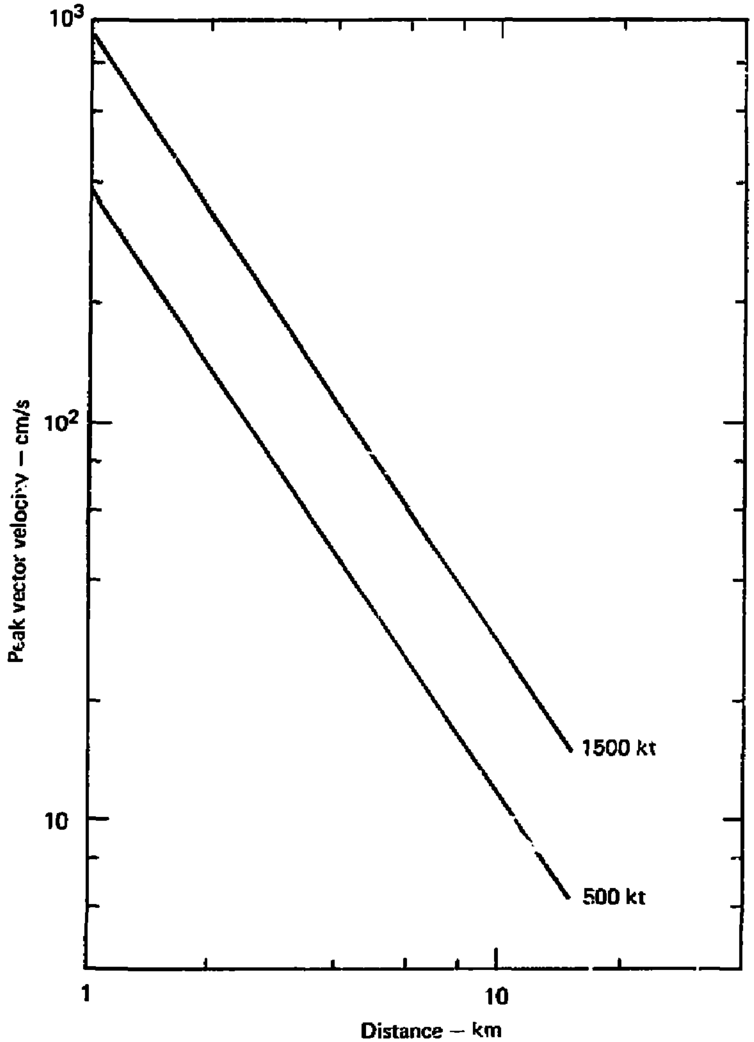

Fig. 2. Peak vector velocity as a function of distance.

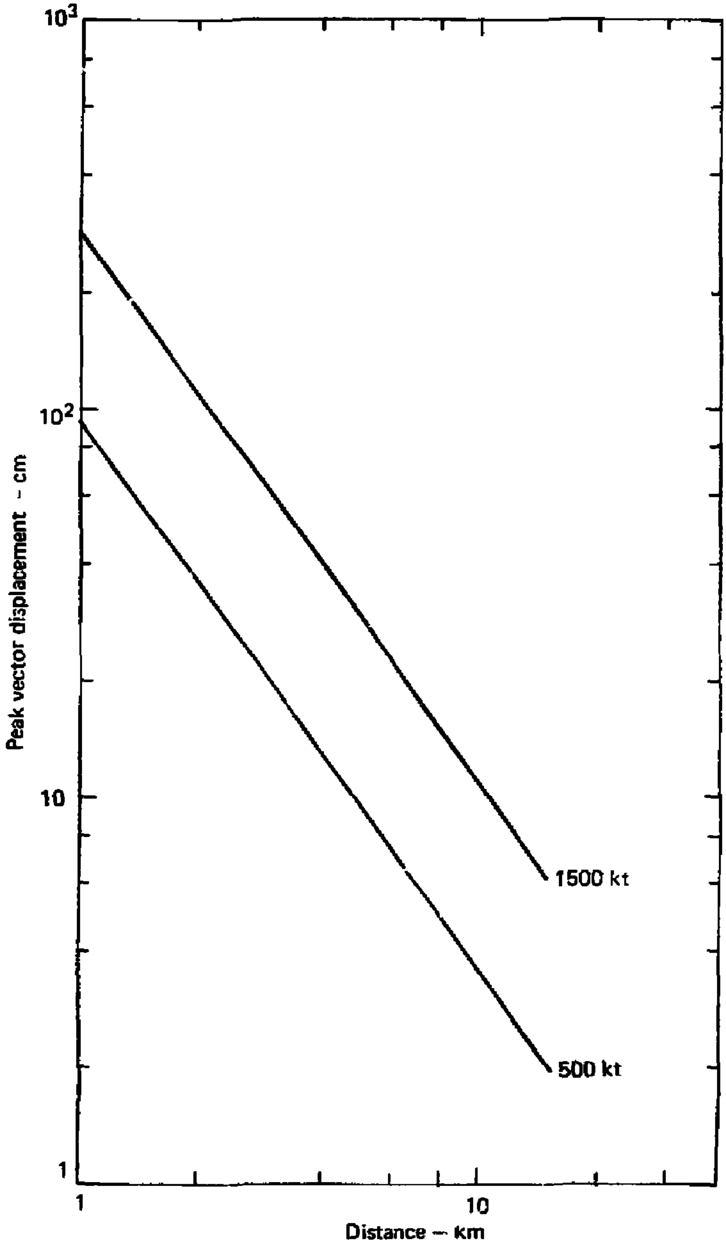

Fig. 3. Peak vector displacement as a function of distance.

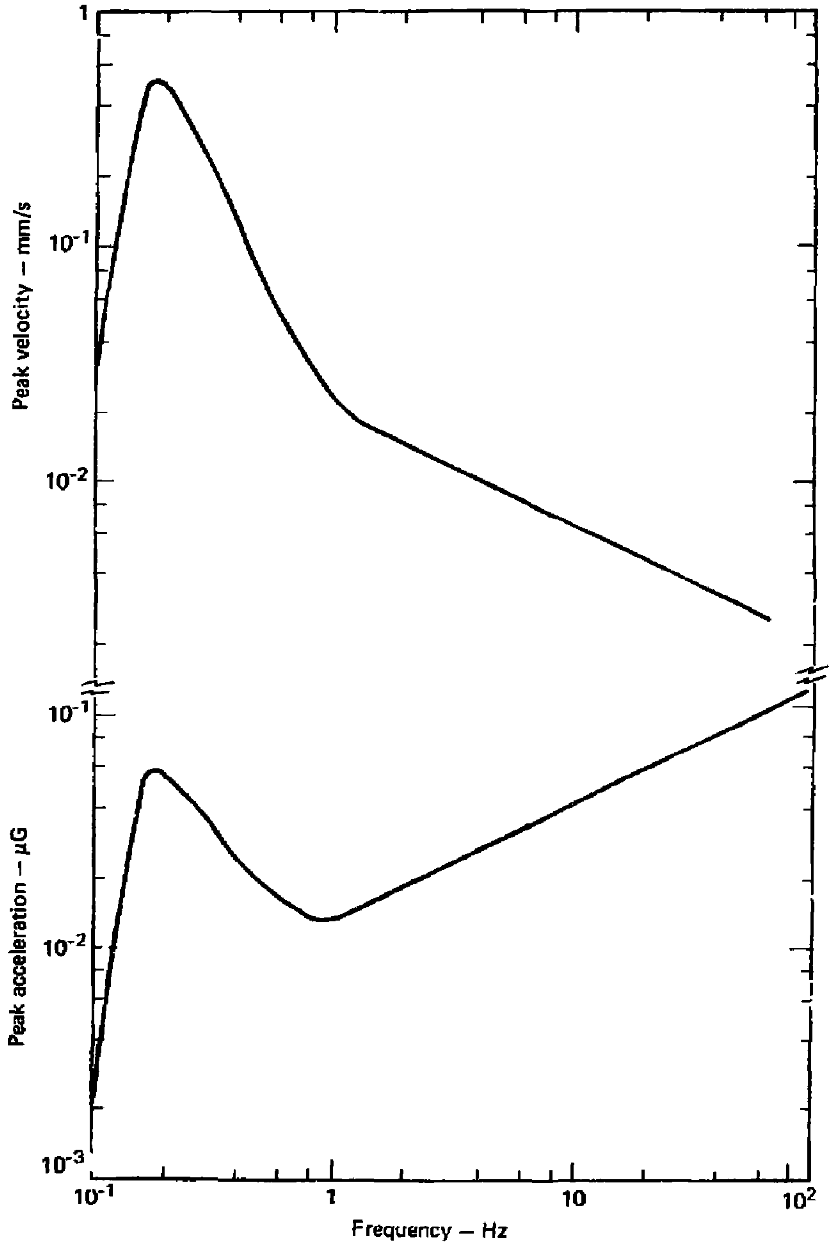

Fig. 4. Quiet-site peak accelerations and velocities.

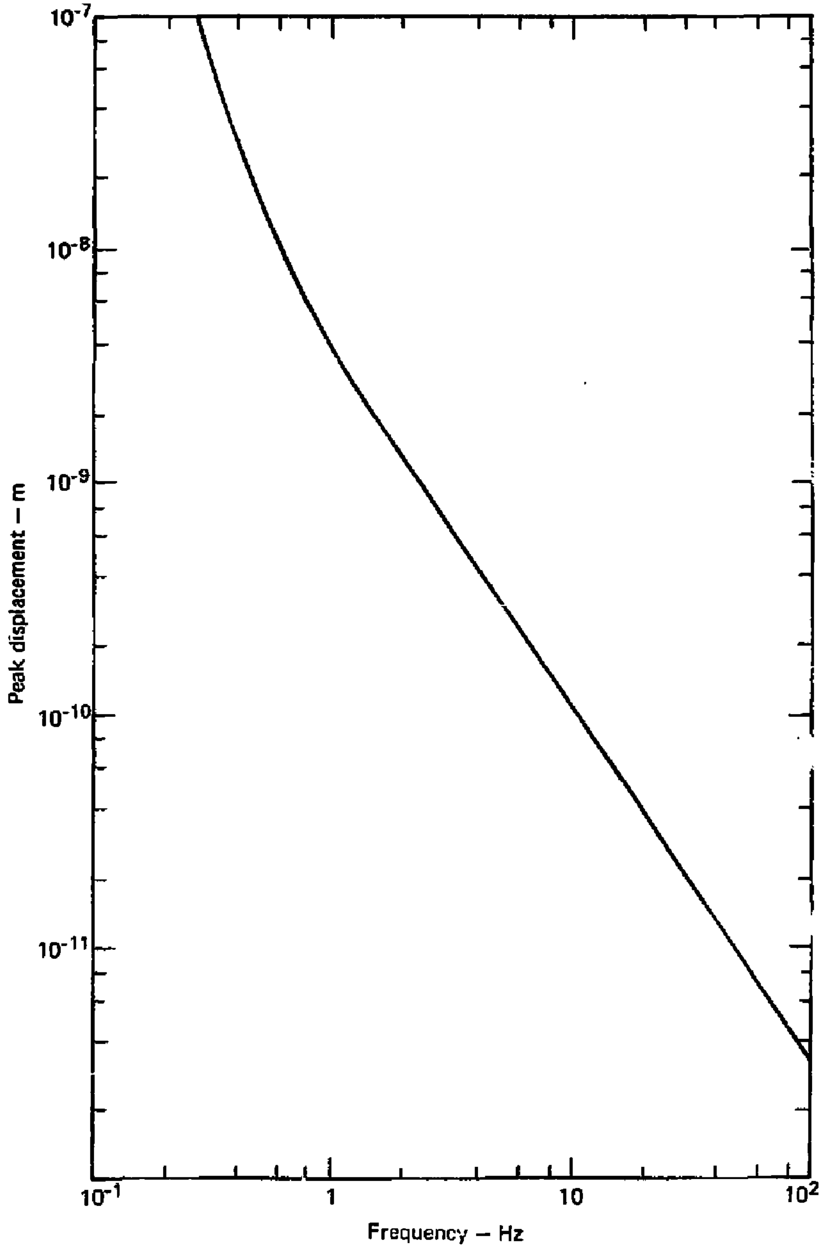

Fig. 5. Quiet-site peak displacements.

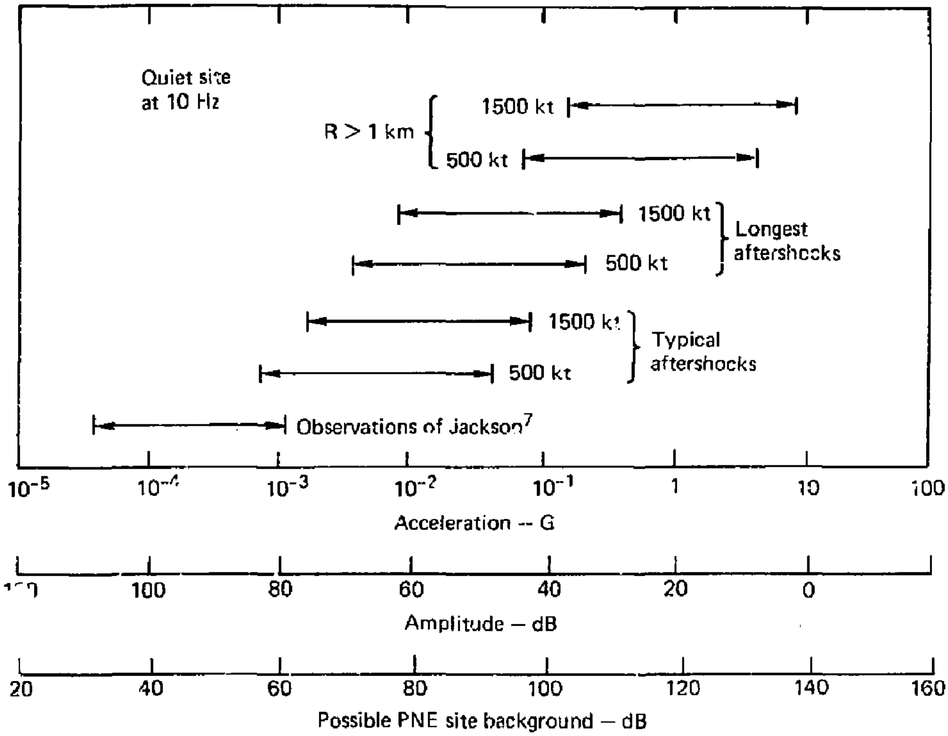

Fig. 6. Summary of expected amplitudes in terms of acceleration.

Figure 7 shows a family of PSRV spectra computed from Environmental Research Corporation (ERC) regression formulas derived from recordings of 11 Pahute Mesa events. The PSRV spectra are comparable to smoothed-amplitude spectra of velocity records. All of these clearly peak at less than 10 Hz and decay rapidly at greater frequencies. On the other hand, significant energy is present at 1.0 Hz and below.

Figure 8 is the Fourier amplitude spectrum of an acceleration record for a postshot event[7] following a low-yield Yucca Valley explosion. It is typical of many that have been recorded and shows little energy outside of the 1-to-30-Hz range. On the other hand, Fig. 9 (Ref. 8) shows two aftershocks in the Jorum event. These spectra are presented in terms of displacement and show the background noise level before the event (primarily caused by the system). It is difficult to use this as the basis for a strong statement on bandwidth, but a system that has a flat response to accelerations up to at least 30 Hz is necessary for the postshot events that are not associated with spall; values as high as 35 to 50 Hz are desirable. For the main event, spall closure makes a 100-Hz response desirable.

Number of Events

Brink[9] and Westphal[10] did extensive seismic monitoring at NTS during the early 1960's. Later others studied the high-yield Boxcar, Benham, Jorum, and Handley events.[3,11,12] Results are summarized in Fig. 10 where the cumulative number of events is plotted against time for each event. This discrepancy between the number of postshot events following Jorum reported by the USGS[12] and that reported by Perret[3] is due to differences in the length of monitoring time and the detection threshold.

Although many different experiences are illustrated in Fig. 10, they can be summarized. The shallow, low-yield explosions in Yucca Flat are characterized by a great deal of postshot activity (all associated with the subsidence zone) until the surface collapses. Then the activity practically ceases. On the other hand, the seismic activity following high-yield explosions on Pahute Mesa appears to have occurred at a slower rate. In addition, the high-yield explosions have initiated seismic activity on nearby faults (14 km from the shot point in the case of Benham) lasting for days in some cases. Specifically, Hamilton *et al.*[12] list 836 aftershocks in the first 72 h following Benham, 187 following Jorum, and 344 following Handley.

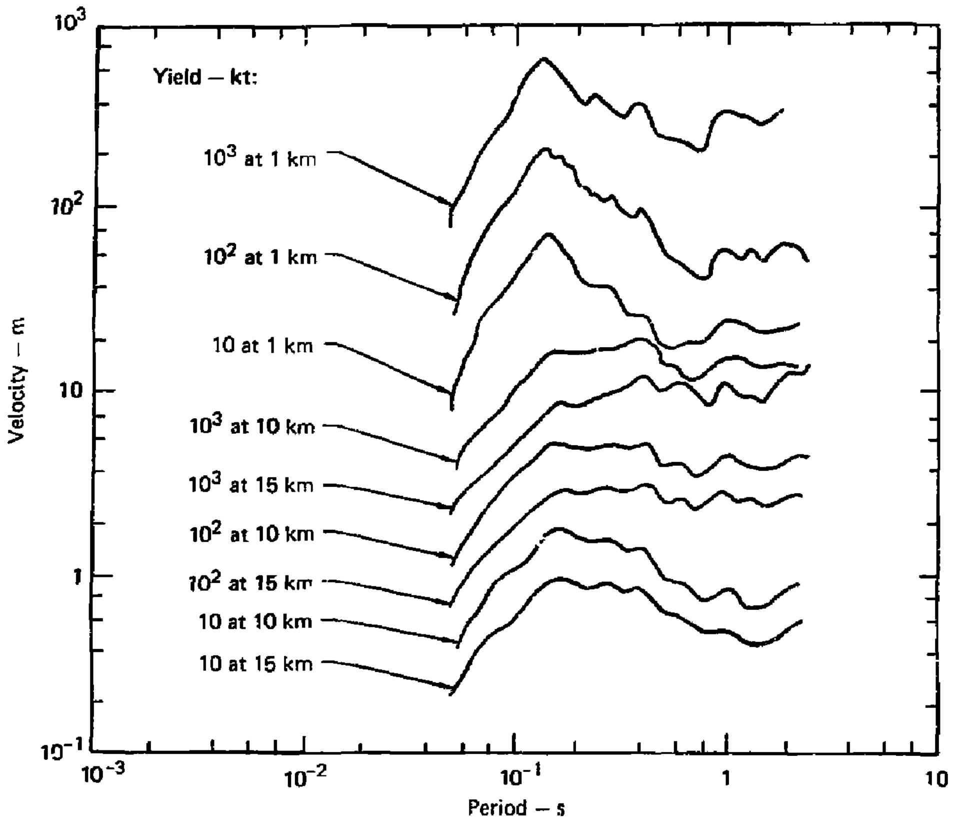

Fig. 7. The PSRV spectra for Pahute Mesa events.

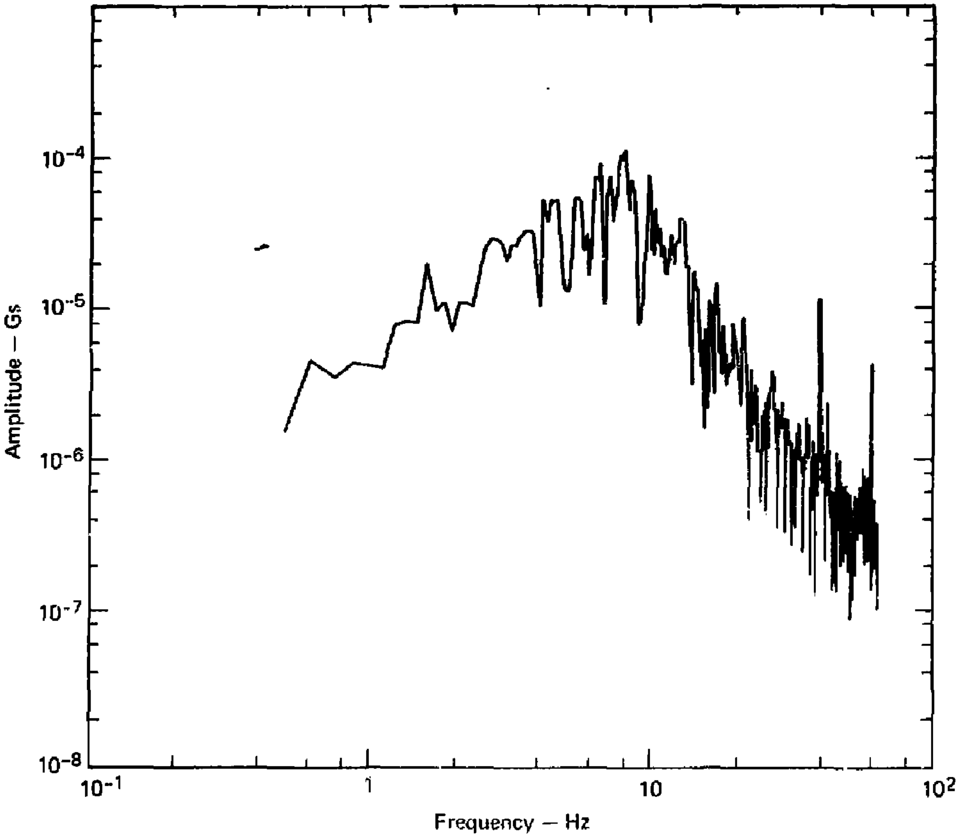

Fig. 8. Amplitude spectrum ror an acceleration record of a typical aftershock resulting from subsidence of a low-yield Yucca Flat experiment.

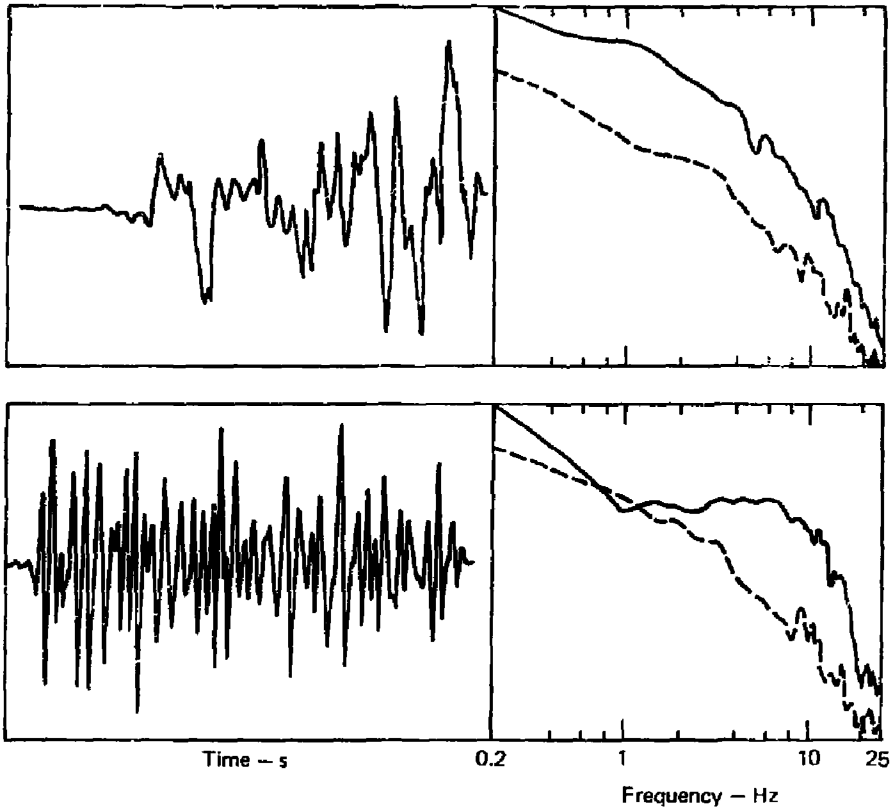

Fig. 9. Seismograms and amplitude spectra of two Jorum aftershocks given in terms of displacement.

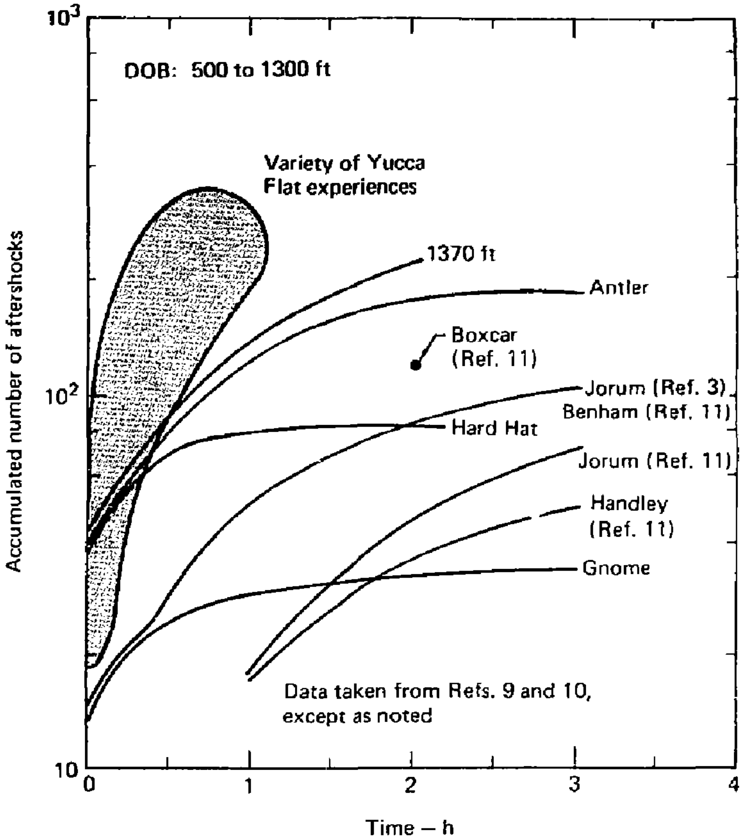

Fig. 10. Accumulative number of aftershocks vs time for a variety of explosions.

CONCLUSIONS

On the basis of the information presented in the preceding sections, past experience with seismic recording of nuclear explosions, and some judgments about the probable state of the art in seismic instrumentation, we propose that the seismic system meet the criteria discussed in this section.

General Description

The system should consist of remote seismic stations and a central recording and playback facility. The signals from these transducers should be filtered and converted from analog to digital format. The digital signal should be available for both local recording and radio transmission. Radio transmission capability is desired at present, while local recording is a possible future development. The central station must be capable of recording the incoming signals in digital format on two separate tape recorders so that two copies of the data are provided in real time. Provisions for checkout, duplication of the tapes, as well as real-time monitoring, must be included.

The events to be recorded range from a large initial explosion to very small postshot seismic events occurring up to 72 h after the initial explosion.

The Remote Seismic Stations

A package containing transducers to monitor three orthogonal components of ground motion (one vertical and two horizontal) appears to be specified by the negotiating record.[1] However, provision for up to six transducers is desired. Not all transducers have to be of the same type. The package will be buried 0.3 to 1.0 m and should be waterproof and able to withstand the stresses imposed by local freezing and thawing of the ground.

The orientation of the horizontal components should be marked on the outside so that the package may be aligned with radial and transverse directions, if desired.

A provision for leveling the canister should be provided. In addition, because some of the canisters may be repositioned by the initial ground motion, the transducers should be insensitive to tilt, or there should be a provision for remotely releveling the canister without requiring personnel to revisit the site. A provision for calibration of the transducer both at and away from the instrument is necessary. Individual stations should be calibrated separately.

The stations may be located in rugged terrain where access to the station sites is difficult and emplacement time limited. Once in place, the stations will be expected to operate for a minimum of 30 days on standby and 4 days at full power. The operational status must be controllable remotely. A local power source sufficient to operate the station must be included. Status monitoring of the power supply and operational level is to be supplied. Radio equipment must be sufficient to transmit and receive signals sent over 45 km of hilly wooded terrain. The use of repeater stations is permitted but undesirable. Radio frequencies are not specified but frequencies in the range 150 to 260 MHz are expected.

The seismic signals of interest are expected to hit their maximum of 40 G in the first minute after the shot and their minimum of 1 μG between the first minute and the end of the recording period 72 h later. As a minimum, we would like to be able to record signals during the first period with a maximum amplitude from 0.1 G to 40 G with a frequency content of 0.1 Hz to 100 Hz ± 3 dB and a minimum resolution of 1 part in 1000. In the postshot regime, we would like to record signals with maximum amplitude from 1 mG to 1 G with a frequency content of 0.1 Hz to 50 Hz ± 3 dB and a minimum resolution of 1 part in 1000. In all cases, the resolution should not be limited by the internal system noise. There is some interest in recording signals at a level of 10^{-8} G. Presumably, this could be met by using suitable transducers to recover low-level signals, but it is not a primary consideration.

The number of stations in the system will be either 12 or 20. The first number is compatible with standard 14-track tape recorders. The second is one-half the maximum number of stations allowed. Radio and power-supply equipment may be placed on the surface. Provisions for tie down and for operation in the extremes of environment decribed earlier in this report should be made. These pieces of equipment should be waterproof. Although transmission of the signals to a central recording area is the desired mode of data handling, provision should be made for providing a parallel signal for local recording. The instrumentation for actually recording the signal locally is not part of the present projected system. The radio link should contain a provision for reception and transmission for distance measuring purposes. Suitable field-test equipment is to be part of the system.

The Central Station

Provision should be made for simultaneous recording of two sets of data. The data will consist of the digital signals from the seismic stations as well as the station-monitoring information, including full-scale sensitivities and voice information. The seismic data are to be recorded digitally. A record of the complete 72 h is required, suggesting the necessity of high-density tape recording. In the event that data compression is required, a measure of the maximum amplitude of the omitted data is necessary. Relative timing information for all recorded seismic signals shall be provided within 1 ms. Provision for determining absolute time to the nearest 0.1 s is required for all signals. A shot-time fiducial signal will be supplied and should be recorded with a relative timing error of less than 1 ms.

Unlike the remote stations, the central station will be supplied with 105-to-125-V, 55-to-65-Hz ac power. Provision must be made for both playback and real-time analog monitoring of selected channels. Simultaneously, CRT displays of at least six channels must be possible. In addition, a hardcopy device (recording oscillograph or pen recorder) is also desirable. Duplication of the digital data must be possible to provide the required copies of the data.

Provision to remotely calibrate both the transducer (previously mentioned) and the electronics must be provided. Provisions for executing both operational and gain-status changes for the remote stations must be present. Each station and each component is to be individually addressable. Because repair time will be at a premium, modular construction is desirable. Replacement parts and test equipment are to be provided.

The environmental conditions affecting the equipment at the central station are described earlier. Antennas and other external equipment are subject to the same environmental conditions as the remote stations. The radio link should be able to receive and transmit for distance measuring. Because th. treaty provides that the United States is to retain one of the tape recorders, they should be easily removable.

Packaging and Shipment

All equipment must be packaged for air freight to the host country and for rough handling by host-country personnel enroute from the port of entry to the PNE site. The remote stations must be portable and easily installed in a few hours.

Summary

In general, we envision a system with the following characteristics:

- A set of 12 or 20 self-powered remote field stations with at least one, and possibly two, sets of three-component transducers that are collectively capable of recording signals ranging from 40 G to 1 μG over a frequency range 0.1 to 100 Hz. Digital electronics capable of giving a resolution of 1 part in 1000 in the range from 40 G to 1 mG is desired.

- A radio telemetry network capable of transmitting the digital data generated at the remote stations to a central recording station over 45 km of hilly wooded terrain. Future developments may include parallel local recording.
- A central station capable of receiving the signals from the remote stations and recording them on two separate tape recorders. Provision for real-time monitoring and duplication of the tapes is required. The central station can be assumed to have a power source capable of delivering several kW of 105-to-125-V, 55-to-65-Hz ac power.

The system should include provisions for changing operational status, releveling, and changing gain. Finally, the system will be expected to operate in remote environments and withstand rough handling.

APPENDIX A

CLIMATE AT THE PECHORA-KAMA CANAL SITE

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The site of the Soviet Union's proposed Pechora-Kama Canal has a Boreal Forest type of climate characterized by:[13]

- Below-freezing temperatures for about six months of the year.
- Temperatures less than 10°F in the coldest month.
- Temperatures more than 50°F for three months, with the average temperature less than 65°F in the warmest month.
- A rapid transition from winter to summer and from summer to winter.
- Annual precipitation of 10 to 20 in.; the maximum falls in summer.

Temperatures

Average temperatures for the Pechora-Kama Canal area (interpolated from isotherm maps in Refs. 13-18) are 0°F in January and 60°F in July. In such a strongly continental climate, the daily temperature range is about 40°F[14,18]; this indicates average minimum and maximum temperatures of -20°F and +20°F, respectively, in January. In July, the approximate average daily range would be 40°F to 80°F.[14] Estimates of the absolute lowest and highest temperatures expected during a given year are -40°F and 95°F, respectively.

Precipitation

References 13 through 18 agree that the P-K Canal area receives an average annual precipitation of 15 to 20 in.; two-thirds of this amount occurs in the summer. Winter snowfall makes up the other third with an average depth of two feet and greater depths in drifts. Snow covers the ground for about 200 days in a typical year.[13]

Winds

Prevailing wind directions and their frequency with respect to eight compass points (from Refs. 14, 16, and 18) are shown in Table A-1.

Data on windspeeds are practically nonexistent. Considering storm tracks at the P-K location, I would estimate winds to average 5 to 10 mph throughout the year. Winds should be calm on winter evenings. Speeds up to 50 mph might occur in some winter snowstorms and briefly in summer thunderstorms. Tornadoes or other severe wind phenomena have never been reported in Central Russia.

Other Phenomena

Skies are cloudy 60 to 7 % of the time.[17,18] Between 10 to 15 thunderstorms[13,18] occur each year, most of them in the summer. About 10 days per year, primarily in winter, are foggy.

Table A-1. Prevailing wind directions for the P-K canal area.

	Jan.	Apr.	Jul.	Oct.
Direction	West	West	West	Southwest
Frequency, %	>40	>40	~40	>40

APPENDIX B

ENVIRONMENTAL ANALYSIS OF THE LSN FOR THE PNE MONITORING SYSTEMS

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In this appendix, we present results of analyzing the manufacturer-to-deployment logistics diagram for the PNE (Fig. B-1), the translation of these into environmental severities expected throughout the sequence (Table B-1), and suggested tests (Table B-2).

The approach taken to derive the expected environmental severities was to, wherever possible, select the severities on a probabilistic basis using a criterion of 1% "risk" that a particular environmental severity would be exceeded at the deployment locations of interest, in the transportation vehicles to be used, or in the storage, handling, and utilization methods to be applied. The method is conservative in that it estimates the risk by using data from the most severe applicable location.

Two data sources were used in the analysis:

- MIL STD 210 B.
- Data from the ERDA/DOE Environmental Data Bank (EDB).

The source for each derived environmental severity is indicated in Table B-1. Suggested tests from MIL STD 810 C are listed in Table B-2.

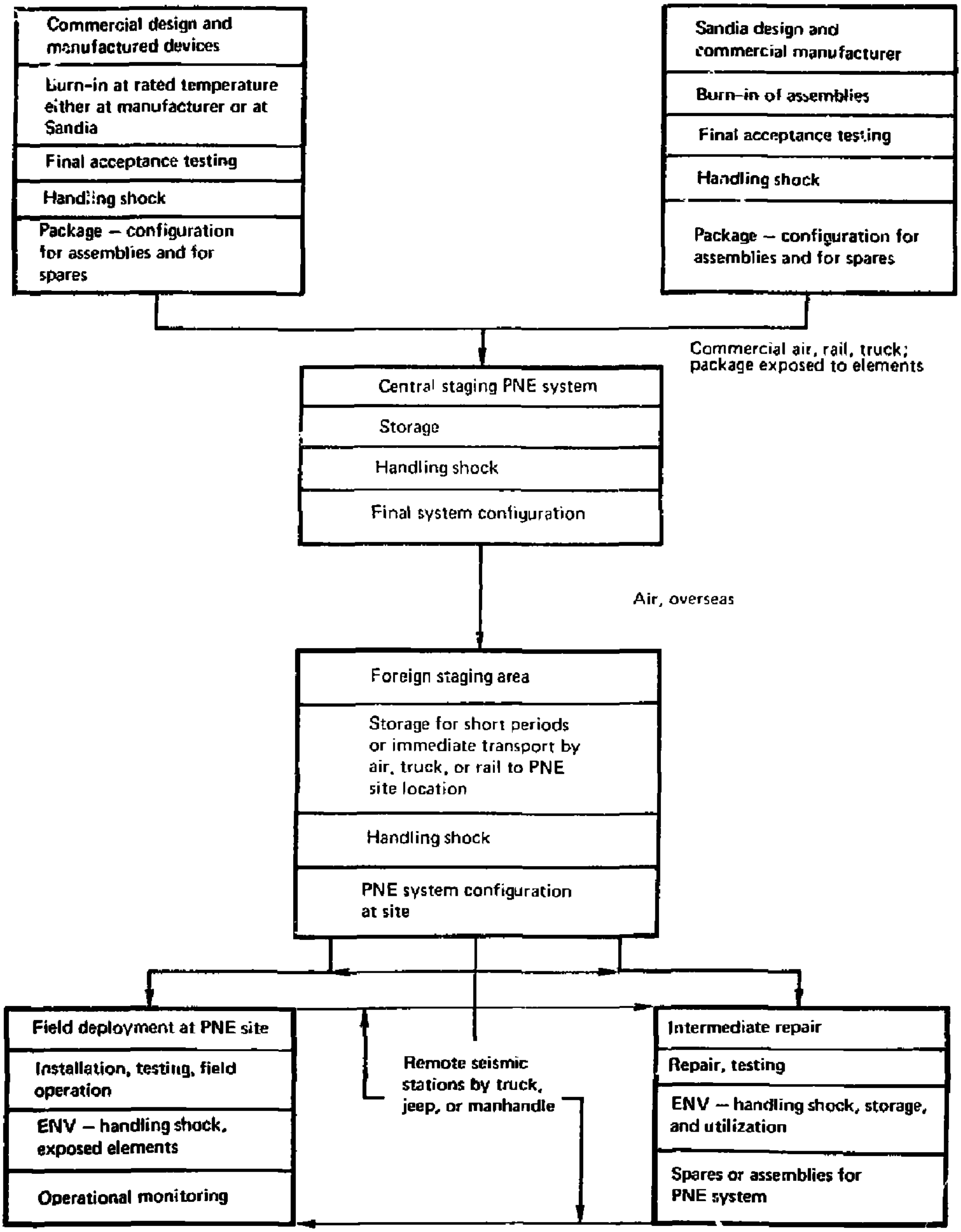

Fig. B-1 The PNE manufacture-to-use sequence.

Table B-1. Manufacture-to-deployment sequence PNE system.

Environment	Intensity	Duration	Producing event	Estimated excedance risk[a]	Reference
Acceleration	3 G	0.5 to 1 s/ occurrence	Cargo aircraft-landing	Unknown	EDB ' .354
	9 G	0.5 to 1 s/ occurrence	Cargo aircraft-landing and turbulence	<0.01	FAA light recorder max cal
	0.7 G	1 to 2 s/ occurrence	Truck-emergency braking	<0.01	ED. 734
Acoustic noise	148 dB to 160 dB overall (max amplitude at about 0.15 kHz) Ref 0.0002 dyn/cm^2	Indeterminate, awaiting loading on aircraft	External noise near jet engines, run-up and take off (16 to 32 ft from intake)	Unknown	EDB-618
Atmospheric contents					
Dust/sand	Dust particle concentrations of 0.177 g/m^3 with wind speeds of 18 m/s at height of 3 m. Bulk of the particle sizes was less than 15 μm except for some sand particles (up to 1000 μm) that may be in motion within a few metres of ground level.	Several hours	Dust storm, desert locations	0.01	MIL STD 210 B
Salt	Size -0.002 mm to 0.04 mm. Deposition on fixed objects can be appreciable	Indeterminate	Coastal locations	Unknown	EDB 1008
Biotic	Mold, fungi	Continuous	Storage and/or implant especially in tropic and temperate zones	Undetermined	EDB 281
Botanical	Not applicable	Indeterminate	Growth and entanglement by vines and roots	Unknown	No data reference
Humidity	95 to 100%	Continuous	Location in wet, warm areas	0.01	MIL STD 210 B
	5 to 20%	Continuous	Location in dry, hot areas	0.01	MIL STD 210 B
Precipitation					
Rain	0.80 mm/min	Indefinite	Rainstorms	0.005	MIL STD 210 B

Drop Size, mm	No./m^3
0.5 - 1.4	2626
1.5 - 2.4	342
2.5 - 3.4	45
3.5 - 4.4	6
4.5 - 5.4	1
5.5 - 6.4	<1

Above rainfall may be accompanied by intermittent winds up to 18 m/s

Table B-1 (continued)

Environment	Intensity	Duration	Producing event	Estimated excedance risk[a]	Reference
Snow					
Blowing	Above-ground	Indefinite	Snowstorms	0.01	MIL STD 210 B
	Height (m) / Flux ($g/m^2/s$)				
	0.05 / 530				
	0.10 / 200				
	0.25 / 66				
	0.50 / 32				
	0.75 / 22				
	1.0 / 16				
	2.5 / 6.9				
	5.0 / 4.0				
	7.5 / 3.3				
	10.0 / 2.2				
	Accompanied by a wind speed of 13 m/s at a height of 3 m				
Size	0.02 to 0.4 mm			0.01	MIL STD 210 B
Load	48.9 kg/m^2 specific gravity 0.1	24 h		0.01	MIL STD 210 B
Hail	0.125 to 2 in. diameter	Infrequent	Hailstorms	Unknown	MIL STD 210 B
Icing	0.5 in. thick, specific gravity 0.9	1 to 7 storms/ year	Freezing rain, hoarfrost, rime	Unknown	MIL STD 210 B
Hoarfrost	Several inches thick, specific gravity less than 0.2	Indeterminate	Freezing fog accretion	Unknown	MIL STD 210 B
Pressure					
Surface	1080 mbar to 508 mbar (15,000 ft)	Indefinite	Altitude of specific location above sea level	Unknown	MIL STD 210 B
Air	817 mbar	4 to 8 h/ flight	Pressur: 1 cargo aircraft	>0.01	MIL STD 210 B
	1080 mbar to 384 mbar	20 min	Climb to 8 km, unpressurized aircraft	Unknown	MIL STD 210 B
	255 mbar	0 to 5 min	Loss of cargo-hold pressure	Rare	MIL STD 210 B
Radiation, solar	0 to 1120 W/m^2	Daily, dawn to dusk	Cloudless day, desert	0.01	MIL STD 210 B
Shock	1-m freefall on a hard surface	Infrequent	Rough handling	>0.01	EDB 341
	4.7 G, 14 ms, 1/2 sin	Frequent	Run-in-out, rail transport	Unknown	EDB A1354
	43 G, 20 ms 1/2 sin	Infrequent	Humping and switching rail	0.01	EDB A1354
	7 G, 77 ms 1/2 sin	Frequent	Truck bumps and potholes	Unknown	EDB A1354

Table B-1 (continued)

Environment	Intensity	Duration	Producing event	Estimated excedance risk[a]	Reference
Temperature					
Climate	Climate temperatures for deployment are $-54^{\circ}C$ and $+58^{\circ}C$		World-wide 0.01 risk extremes		MIL STD 210 B
Induced	33 to $66^{\circ}C$	24-h cycle	Storage/transport near ceiling	0.01	EDB 80
	-25 to $-34^{\circ}C$	24-h cycle	Storage/transport	0.01	EDB 80
Vibration	Acceleration 0-pkg / Frequency Hz				
	1.8(constant) / 10-2000	continuous, per trip	Truck transport governs values given, encompasses rail, military turbo-prop, civilian turbojet, and military turbojet cargo aircraft	0.01	EDB A1354

NOTE: (1) Above description is an envelope of all anticipated transport modes; it is very comprehensive for a given mode. Transport by foreign vehicle is assumed to be somewhat comparable to American counterpart.

(2) True environment is broad-band random in nature and can be described in this manner if test facilities are available to permit random-vibration testing.

Environment	Intensity	Duration	Producing event	Estimated excedance risk[a]	Reference
Wind					
Steady	22 m/s	At least 20 min	Wind storms (excludes tornadoes and hurricanes) at 3 m above ground	0.01	MIL STD 210 B
gust	29 m/s with a directional charge of 15 deg to 30 deg from the steady				

NOTE: Multiplication factors for wind speeds at various equipment heights are as follows:

Height (m)	Factor-steady	Factor-gusts
1.5	0.917	0.946
3.0	1.0	1.000
6.0	1.09	1.057
9.0	1.147	1.092
12.0	1.189	1.117

[a] Estimated probability that intensity will be exceeded.

Table B-2. Suggested test, PNE, MIL STD 810 C.

Environment	Method	Test level	Page
Acceleration time	513.2	5B-2I	513.2-3
Acoustics	515.2	A	515.2
Rain	506.1	3.1	506.1-2
Salt fog	509.1	3.1	509.1-6
Dust	510.1	3.1	510.1-2
Humidity	507.1	3.3	507.1-3
Fungus	508.1	3.1	508.1-1
Low pressure	500.1	3.1	500.1-1
High temperature	501.1	3.2	501.1-2
Low temperature	302.1	3.1	502.1-3
Shock	516.2	3.4	516.2-3
Vibration	Procedure X	Table 514.2-VI Fig. 514.2-7 pp. 514.2.40	
Leakage (immersion)	512.1	1.1	512.1-1

Wind — use values in environmental study
Icing — use values in environmental study
Frost — use values in environmental study

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