ATTACHMENT 11

NOISE PREDICTION, MITIGATION AND MANAGEMENT PROGRAM

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NOISE PREDICTION, MITIGATION AND MANAGEMENT PROGRAM

1.0 Introduction

1.1 Performance Standards

There are no specific environmental performance standards for noise in 40 CFR 264.601. For Utah Department of Environmental Quality (UDEQ) and Occupational Safety and Health Administration (OSHA) requirements, see Section 1.2.

1.2 Required Programs

1.2.1 Noise

The Utah Joint Subcommittee on Open Burn/Open Detonation (OB/OD), comprised of members from the Utah Waste Management and Radiation Control Board and the Utah Air Quality Board, identified noise and ground vibration as areas of concern. The subcommittee requires evidence that OB/OD operations will not generate noise or ground vibration at levels that will have an adverse effect on nearby receptors.

When interpreting noise level standards, it is necessary to define the type of noise measurement reported. Single (discrete) noise events are generally expressed in decibels (dB), weighted to consider specific noise aspects. The most common weighting scheme used to measure impulsive noise is the peak sound level (dBP), which applies a linear weighting network. This weighs the sound energy contained in all frequencies equally. The C-weighting network (dBC) may also be used to express impulsive noise. This network emphasizes the lower frequency portion of the noise spectrum, thereby addressing the additional annoyance caused by low frequency vibration of structures.

The most common weighting scheme for measuring continuous noise is the A-weighting frequency network. It de-emphasizes the lower frequency portion of the noise spectrum to approximate the human ear's response to the noise. The sound pressure levels measured using the A-weighting network are expressed as dBA.

The Utah Joint Subcommittee on OB/OD stipulated in the April 1996 Draft "Permit Writers Guidance for OB/OD Treatment Facilities" that noise levels must be below 140 dB for impulsive (OD) noise and below 85 dB for continuous (OB) noise.

At the same time, OSHA guidance from 40 CFR 1910.95 stipulates protection against the occupational effects of noise exposure. It requires the implementation of administrative or engineering controls to reduce noise levels when the noise exposure to employees exceeds those levels listed in Table 1.

Table 1. Permissible Noise Exposures

Duration per Day (hours)	Sound Level (dBA Slow Response)
8	90
6	92
4	95
3	97
2	100
1 ½	102
1	105
½	110
¼ or less	115

1.2.2 Ground Vibration

Vibrations resulting from blast operations travel from the source to the receiver both through the ground (ground-borne) and air (airborne). Vibrations traveling at sufficient velocity may cause buildings and structures to shake and may even cause structural damage.

There are currently no guidelines or criteria for assessing annoyance related to single noise events. Only recently has equipment become available that allows subjects to register their annoyance if single events are experienced during their routine activities. Additionally, the amount of annoyance also depends on many factors, such as the characteristics of the noise, including the intensity and spectral characteristics, duration, repetitions, abruptness of onset or cessation, and the noise climate or background noise against which a particular noise event occurs. Social surveys show other factors influence annoyance, including:

- The degree of interference of the noise with activity;
- Previous experience of the community with the particular noise;
- The time of day during which the intruding noise occurs;
- Fear of personal danger associated with the activities of the noise sources;
- Socioeconomic status and educational level of the community; and
- The extent the people believe that the noise output could be controlled.

Guidelines developed by the Naval Surface Warfare Center (NSWC) (Pater, 1976) were used for evaluating the complaint potential from impulsive (OD) noise originating in the UTTR-North TTU. These guidelines are based on over 10 years of experience and represent the best compromise between cost, efficiency of range operations, and good community relations. The guidelines are shown in Table 2.

Table 2. Impulse Noise Guidelines

Predicted Sound Level (dBP)	Risk of Complaints
< 115	Low
115 - 130	Moderate
130 – 140	High; with possible complaints of damage
>140	High risk of physiological and structural damage claims; threshold of permanent physiological damage to unprotected human ears

Humans typically perceive ground-borne vibrations as low as 0.08 to 0.20 in./sec (Argonne National Laboratory 1993). A summary of typical vibration levels and corresponding responses is shown in Table 3.

Table 3. Response to Ground Vibration

Ground Vibration (in./sec)	Response
	Human
0.08	Perceptible
0.20	Noticeable
0.38	Unpleasant
0.80	Disturbing
1.30	Objectionable
	Structure
5.40	Minor damage (cracking plaster)
7.60	Major damage

Studies of vibration caused by coal mine detonations indicate that ground-borne vibration dominates structural shaking when the distance from the source to the receptor divided by the square root of the net explosive weight (NEW) is less than 50 (Northwestern University, 1981). At values greater than 50, airborne vibration dominates. In the case of the UTTR-North TTU, where the nearest off-site receptor (buildings at Oasis) is located approximately 5 miles (26,400 ft) away, it would take an OD event of over 278,000 lb NEW—nearly double the maximum OD limit of 149,900 lb NEW—in order for ground-borne vibrations to be dominant. Since the 149,900 lb NEW upper limit was put in place in order to protect people and structures at Oasis from the effects of airborne blast, its overpressure, and fragmentation, there should be no concern for ground-borne blast effects at Oasis.

2.0 Noise Prediction, Mitigation, and Management Program

The UTTR-North, in cooperation with the NSWC Dahlgren Division, has implemented an effective noise prediction, mitigation, and management program at the UTTR. This program combines computer modeling with public relations to reduce the impact of noise generated by TTU operations on potential off-site receptors while preserving mission readiness.
The program used to model and manage the noise impact from TTU detonation events was initially implemented in 1994 as part of the U.S. Navy program to treat Poseidon rocket motors at the UTTR-North TTU and has continued with the Trident (C-4) rocket motor treatment program. The program requires that the potential noise impact to nearby off-site receptors be evaluated prior to each OD event. These potential receptors include all off-site (outside the boundaries of the UTTR) population centers from Tremonton to Grantsville, Utah. A “go” or “no-go” determination is made based on the results of sound propagation modeling done before each treatment event.

Based on work conducted in partnership between UDEQ and DOD in 1993 and 1994, the State of Utah established a noise limit of 134 decibels (dB) as the limit of noise that may be focused in populated centers. The populated centers are those areas located within an arc inscribed between 43 degrees and 148 degrees from the UTTR, roughly corresponding to the eastern and southern side of the Great Salt Lake from Tremonton to Grantsville. UTTR management has established an operational sound limit of 124 dB in populated areas when no active sound monitoring is occurring and an operational limit of 127 dB in populated areas when active monitoring is occurring. If model predictions exceed these levels (124 dB / 127 dB), UTTR management may elect to cancel or delay the detonation.

2.1 Program Rationale

The current UTTR noise prediction, mitigation, and management program was developed based on the successes of the Poseidon program. The Poseidon treatment program involved the simultaneous detonation of two rocket motors with a combined NEW of 31,720 lb and a TNT-equivalent weight of 40,000 lb.[1] The maximum peak noise level measured at any off-site receptor location during a Poseidon detonation event was 125 dB. The noise prediction, mitigation, and management program has continued to successfully prevent excessive noise levels during the Trident I (C-4) treatment program with the treatment of over 11 million pounds of C-4 motors, ranging from 3,746 to 38,914 pounds NEW per motor, from 2001 to 2012.

Currently, the maximum demonstrated OD event corresponds to the NEW established by the successful detonation of two Trident I, C-4 stage I motors (39,000 lbs. NEW each) and one Trident I, C-4 Stage 3 motor (3,374 lbs. NEW) for a total of 81,374 1bs. NEW at the UTTR on August 31, 2004, and successful detonation of one Trident II D-5 motor (79,372 1bs. NEW) at the UTTR on September 18, 2006. The successful prevention of excessive noise (>134 dB) in population centers during these events resulted in the setting of the current maximum demonstrated (and verified) OD event for the site. Any subsequent increase in NEW by more than 10% of the revised maximum demonstrated OD event requires verification.

The noise prediction program is not applied to open detonation events of under 10,000 pounds NEW. Although these smaller events may at times be audible, they do not generate excessive noise levels at off-site receptor locations nor do they generate noise complaints.

Non-routine operations (emergency or mission essential) may include detonations of up to the range capacity of 149,900 lbs. NEW. Although no measured data are currently available for detonations of this size, a simple calculation can be used to predict the dB level for such an event. The sound pressure level of an acoustic signal is defined as:

[1] The NEW is calculated by summing the actual weight of each individual explosive compound contained within the item, and the TNT-equivalent weight is calculated by summing the TNT-equivalent weight of each individual explosive compound. The TNT-equivalent weight relates the sensitivity of any explosive compound to that of TNT.

$$SPL\ (dB) = 10 \log (P_1/P_0)^2$$

where:
P_1 = the sound pressure of the acoustic signal above atmospheric pressure
P_0 = a reference pressure, standardized at 20 micropascals.

Since dBs are logarithmic units, sound levels cannot be added by ordinary arithmetic procedures. The addition of sound levels must be performed on an "energy basis" as shown in the example below:

$$SPL\ total = 10 \log [(P_1/P_0)^2 + (P_2/P_0)^2],$$

where P_1=P_2
$SPL\ total = 10 \log 2\ (P_1/P_0)^2$
$= 10 \log 2 + 10 \log (P_1/P_0)^2$
$= 3 + 10 \log (P_1/P_0)^2$

This example shows that a doubling of sound energy results in a 3 dB increase in noise level.

In the case of the UTTR-North TTU, worst-case off-site peak noise levels resulting from the detonation of two Poseidon rocket motors (31,720 lbs. NEW) were measured at 125 dBP. The maximum OD treatment limit of 149,900 lbs. NEW is approximately 5 times that of the routine Poseidon detonations. Using the calculation presented above,

$$SPL\ total = 10 \log [(P_1/P_0)^2 + (P_2/P_0)^2 + (P_3/P_0)^2 + (P_4/P_0)^2 + (P_5/P_0)^2],$$

where P_1=P_2= P_3=P_4= P_5

SPL total	=	$10 \log 5\ (P_1/P_0)^2$
	=	$10 \log 5 + 10 \log (P_1/P_0)^2$
	=	$7 + 10 \log (P_1/P_0)^2$
	=	7 + 125 dB
	=	132 dB

Therefore, the estimated maximum peak noise level, excluding atmospheric refraction, generated at any off-site receptor location resulting from a detonation of 149,900 lbs. NEW is 132 dBP.

2.2 Program Components

The components that make up the UTTR noise prediction, mitigation, and management program are described below.

2.2.1 Meteorological Data Collection and Prediction

The UTTR weather office is located in Building 40075 of the Oasis compound. The mission of this office is to collect and process meteorological data to support UTTR mission requirements. Support functions specific to the operations at the TTU include a forecast (prediction) of the general weather conditions in the area of the UTTR-North and the Wasatch Front 24 hours prior to upcoming operations and a balloon sounding prior to all detonations greater than 10,000 lbs. NEW. Meteorological data collected include temperature, wind speed, wind direction, humidity, and barometric pressure. Weather balloon data are collected for approximately every 40 ft of vertical travel up to approximately 36,000 ft above mean sea level. The meteorological data are required to determine whether conditions are favorable for OB/OD and for date validation or direct input into the predictive sound propagation model.

Studies have found that variations of temperature and wind velocity with altitude can cause a noise event to be inaudible at one time and highly annoying at another time. This phenomenon is referred to as atmospheric refraction. Atmospheric refraction is the bending of sound rays caused by the variation with altitude of the speed of sound. This variation is a function of temperature and wind velocity. This bending of the sound rays can concentrate acoustic energy, causing significantly greater sound levels. Conversely, the sound waves can also be bent upward so that the acoustic energy of the event is dissipated by the atmosphere, resulting in a lower sound level on the ground.

2.2.2 Sound Propagation Modeling

Computer sound propagation modeling is a fast, efficient, and relatively inexpensive means to quantify and predict the noise environment over a large area. Noise modeling is conducted by the UTTR weather office prior to each detonation event greater than 10,000 lbs. NEW.
The Sound Intensity Propagation System (SIPS) is an ensemble of sound propagation models used at the UTTR to predict the noise level impact at off-site receptor locations. These models are used to evaluate the potential exposure of populated areas to impulse noise and determine whether a detonation should proceed.

The Air Force has historically used the original sound prediction model, with ray tracing methodology, at the UTTR for compliance with the Sound Focus Mitigation Plan while developing more advanced Sound Prediction models. The more advanced models use various computational methodologies (e.g. finite-difference) in conjunction with meteorological data, meteorological forecasts, and topography to predict the acoustic impact of detonations on populated areas.

The original Ray Tracing (RT) sound prediction model in SIPS is a semi-empirical ray tracing model developed by the NSWC in the 1990s for use in stand-alone personal computers with limited computational capability. The SIPS RT model divides the atmosphere into a number of horizontal layers. The sound velocity gradient in each layer is assumed to be linear and is obtained from weather data. This vertical meteorological profile, collected by atmospheric soundings, is assumed constant across the entire domain being modeled. Based on Fermat's Principle, sound rays are refracted through the air layers according to Snell's Law. Focal points are identified when the sound rays converge on the earth's surface. On the other hand, quiet zones are indicated when the sound rays are refracted aloft. At focal points, 15 dB is added to the semi-empirical mean peak sound pressure level, or a focus multiplication factor is calculated by the principle of energy conservation along a ray tube. SIPS RT model can include terrain effects, accounting for the blockage of blast waves by hills and the skipping of sound rays over flat water surfaces.

A more computationally sophisticated Finite Difference – Time Domain (FD-TD) sound prediction model has also been developed and included in SIPS. The FD-TD model is based on computationally solving the Navier-Stokes equation for sound energy propagating through air. The FD-TD model uses high resolution, time-variant, three-dimensional weather prediction data to explicitly calculate the transmission of impulse sound through the variable local meteorological conditions from the UTTR to populated areas of the Wasatch Front. Due to relatively high computational requirements, the FD-TD model is server based. The FD-TD model has been evaluated since 2018 and in use since 2021.

The Air Force expects to refine existing noise models and evaluate new models for use at the UTTR in efforts to continuously improve noise impact management. Air Force professional staff and contractors will continue to exercise their best judgment and use available models at their disposal to prevent excessive noise from impacting populated centers.

2.2.3 Model Inputs

The SIPS sound propagation models require both pre-defined as well as user-defined data to accurately predict the blast impact. Pre-defined data include a grid map to define the areal extent of the model (a grid has been established for the "Great Salt Lake and Vicinity" map), location of the source (TTU), and elevation of the blast (0 meters for surface blasts). The calculated impulse energy for the specific weapon system as well as topographical considerations are predefined in SIPS. The impulse energy release can be calculated by summing the TNT blast equivalent for each individual explosive compound contained within the weapon system. User-defined data required to be input prior to the model run include impulse energy released and meteorological conditions across the domain.

2.2.4 Model Output

The output generated by SIPS is in the form of a grid noise map covering the domain including the TTU and populated areas along and around the Wasatch Front. Peak surface noise level values are calculated to the nearest 1 dB. The grid printout produced by SIPS shows surface level dB values calculated for each location.

2.2.5 Verification Monitoring

On-site noise monitoring provides documentation of measured noise levels that can be used to validate the results of computer modeling. A comprehensive monitoring study utilizing hand-held noise monitors (Bruel and Kaehr Model 2236) was conducted at the UTTR from July to August 1996. The results of verification monitoring have shown that the SIPS RT sound propagation model in use at the UTTR provides accurate prediction of sound focusing at off-site population centers. (A report detailing the study, "Sound Studies of OB/OD Activities at the UTTR," is available through NSWC and 75 CEG/CEIE.) Continued verification monitoring is employed as the SIPS models continue to be refined.

2.3 Program Implementation

The above described program components are implemented as follows:

- A forecast of the general weather conditions is predicted 24 hours prior to expected operations at the TTU.

- A balloon sounding is conducted prior to all TTU OD operations of 10,000 lb NEW or greater to determine whether meteorological conditions are appropriate to conduct operations (e.g., wind speed). This determination may be for confirmation of meteorological predictions for the time of the balloon sounding, thereby validating hourly meteorological predictions for use in the SIPS FD-TD (or similar) model or for direct measurement and use in the SIPS RT model.

- Predictive computer sound propagation modeling is conducted prior to any detonation event greater than 10,000 lb NEW. Wind direction, wind speed, and other critical weather data are input into the SIPS predictive noise model. The computer model predicts peak noise levels at off-site receptor locations from Tremonton to Grantsville, Utah. Results are interpreted from Table 4.

- All disposal operations must be completed within three (3) hours after the radiosonde data confirming accurate meteorological forecasts or showing favorable meteorological conditions that do not indicate focusing of sound in populated areas. For the purposes of this requirement, focusing is defined as predictions of noise in excess of the 134 dB limit agreed to with UDEQ.

Table 4. Go/No-Go Decision Matrix

Peak Noise Level (dB)	Action[a]
≤ 127	Proceed with detonation as scheduled. (≤ 124 dB when NO active receptor monitoring is occurring)
125/128 - 134	Proceed with critical operations. Postpone non-critical operations if feasible.
135 - 140	Only mission essential and emergency operations may proceed, and then only after 75 CEG/ CEIE and the 75 ABW/PA have been notified. 75 ABW/PA[b] and 75 CEG/ CEIE implement procedures to communicate to the public and manage potential noise complaints.
> 140	Postpone all operations. Emergency operations may proceed only by order of the 75 CES or 75 CEG / .

3.0 Complaint Management

Specific procedures are in place to effectively manage public complaints. The four key functions that comprise the complaint management procedures and how they pertain to TTU operations are described below. Results of computer noise modeling are maintained on file at the UTTR by the 75 CEG/CEIE.

Pre-planned detonation events that will likely result in excessive noise levels will be coordinated through 75 ABW/PA at least two weeks in advance to ensure proper public notification and complaint management.

Detonations that may potentially result in noise levels exceeding 139 dB at any off-site receptor location must be approved by the Division Director, 75 CEG/CEIE. The Division Director determines a “go” or “no go” based on critical factors ranging from public safety to national security.

3.1 Complaint Receipt

Complaint receipt includes screening, logging, and classifying information from the complainant. Complaints are screened from general communications flow and directed to the appropriate office, logged to monitor the status of individual complaints, and classified according to the source category of the complaint.

75 ABW/PA acts as a funnel for the receipt of complaints and claims from the public. All complaints regarding noise (and ground vibration, if any) are directed to 75 CEG/CEIE. 75 CEG/CEIE personnel record information received from the complainant on Air Force Materiel Command (AFMC) Form 3514, Environmental/Sonic Boom/Noise Complaint (see Figure 1). Complaints are then logged and complaint forms are filed according to the source category of the complaint (aircraft noise, blast noise, etc.).

3.2 Complaint Response

Complaint response includes identifying the issues that define the complainant's problem, identifying the specific source of the complaint, formulating a response, sending out the final response to all interested parties, logging out the complaint, as well as storing and maintaining the complaint file.

75 ABW/PA personnel contact the complainant to obtain needed detail, investigate the complaint to determine the likely source, and formulate the response. The response states the results of the complaint investigation and details the measures to be implemented to mitigate further occurrences. 75 ABW/PA is responsible for logging out the complaint and maintaining the complaint file.

3.3 Management

The management function includes internal follow-up, statistical evaluations of aggregate data, and interpretation of the statistical outputs to identify policy changes or mitigative measures. 75 CEG/CEIE has overall responsibility for managing complaints related to TTU operations.

3.4 Public Awareness

75 ABW /PA is responsible for the public awareness function of the complaint management program. Public awareness involves providing information to the public regarding complaint procedures, ongoing efforts to reduce noise, as well as informing the public of the date, time, and expected duration of upcoming unusual or exceptional noise events. The 75 ABW /PA phone number is published in community relations articles and pamphlets and announced during local television and radio programming when necessary.

Figure 1. AFMC Form 3514, Environmental/Sonic Boom/Noise Complaint

ENVIRONMENTAL/SONIC BOOM/NOISE COMPLAINT	
DATE RECEIVED	TIME RECEIVED
BY WHOM	
CALLER/LETTER WRITER	TELEPHONE NUMBER
ADDRESS	
COMPLAINT (*include details*, *location*, *damage*, *exact time(s)*, *aircraft signed*, *etc.)*	
RESPONSE (*By whom*, *time*, *method*)	
SUBSEQUENT ACTIONS/ADDITIONAL REMARKS	

4.0 Ground Vibration

Due to the isolated location of the UTTR-North TTU in relation to off-site receptors, the potential impact of ground vibration is considered to be insignificant (see Section 1.2.2). Additionally, no public complaints or damage claims have been found to be attributable to ground vibration resulting from TTU operations (Freeman, 1997). Therefore, no program to measure or mitigate ground vibration is warranted.

5.0 Assessment of Potential Health Risks

5.1 Noise

Studies have shown that extensive noise exposure to humans has adverse physical impacts, with hearing impairment the most prominent effect. Damage to hearing is common to those who experience extended noise levels of 100 dB and greater. The threshold for pain occurs at 140 dB. Other direct physiological effects that may occur due to extensive noise exposure include increased cholesterol and blood sugar, dilation of blood vessels and pupils, stomach acid, and kidney effects (Samuels, 1981). Noise is also found to heighten fear, anxiety, and irritation, especially in the elderly, sick, and hypersensitive populations (Jansen, 1985). Non-physiological effects of noise exposure include annoyance, speech and sleep interference, and interruption of daily activities. Low frequency sound can be directly absorbed through the surface of the body and can excite sense organs other than the ears. The effect is similar to the effect of mechanical vibration on the body, causing the internal organs to vibrate and disturbing the nervous system, digestion, and sight. Very intense low frequency noise (0–20 Hz) can cause a sensation of vibration, disequilibrium, and motion sickness.

The UTTR noise prediction, mitigation, and management program described in Section 2.0 was developed to ensure that off-site human receptors are not exposed to noise levels that result in unacceptable risk to human health. Additionally, the USAF Hearing Conservation program ensures that hearing protection is worn by TTU operators and others working in the vicinity of the TTU and that their hearing is tested regularly. When these programs are implemented properly, no impact to human health is expected.

5.2 Ground Vibration

No potential health impacts are expected from ground vibrations resulting from TTU operations.

6.0 References

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