INFRASOUND CALIBRATION EXPERIMENTS AT WHITE SANDS MISSILE RANGE: PLANNING AND PREPARATIONS

Eugene T. Herrin,[1] Paul W. Golden,[1] Petru Negraru,[1] Henry E. Bass,[2] Gary S. Hunter[3], William L. Andre[3], John V. Olson[4], Daniel L. Osborne[4], Milton A. Garces[5], Michael A. H. Hedlin[6] Kathie Hoffman,[7]

Southern Methodist University,[1] University of Mississippi,[2] U.S. Army Space and Missile Defense Command,[3] University of Alaska at Fairbanks,[4] University of Hawaii,[5] University of California San Diego,[6] Naval Surface Warfare Center White Sands,[7]

Sponsored by Army Space and Missile Defense Command

Contract No. DASG60-99-C-0018

ABSTRACT

There are now a number of permanent infrasound arrays in place in the United States, and several portable or temporary arrays can be deployed. The calibration of this combined network and a test of predictions of infrasound travel times in the atmosphere can be accomplished using explosive shots with active radar tracking and exact positioning. Currently there are plans for firing rocket launches with explosive charges at the White Sands Missile Range. This will serve as an accurate calibration experiment for infrasound arrays. A good first choice for test parameters is a 50 lb. charge on the downward leg of a rocket trajectory at a height of 50 km.

These tests will expand on information acquired from the Columbia disaster. Eight impulsive signals recorded at the Lajitas infrasound array in far west Texas on 1 February 2003 were found to originate from the Space Shuttle Columbia. These signals all had essentially the same back azimuth and so were considered to be multipath arrivals from a single explosion. Using a method employed at Los Alamos National Laboratory (LANL) in the study of bolides, it was determined that based on a peak period of about 1 second for the signals, the explosion had a yield of approximately 2 lbs. of TNT. The explosion occurred about 50 seconds before the Columbia broke up. The impulsive arrivals had signal-to-noise ratios of 3 to 10 at the Lajitas station, located about 600 km from the source. The altitude of the source was 63 km.

This observation reminded the authors of a set of rocket grenade explosions in 1961-1965 that produced similar signals. An explosion of 2 lbs. of TNT at an altitude of 67 km produced a signal at ground level with a peak period of about 0.8 seconds.

The calibration experiments will be discussed and plans provided for testing by the end of the 2004 calendar year.

OBJECTIVE

We are planning an experiment to explode at least one 50 lb. charge in the atmosphere at a height of 50 KM from a rocket launch with active radar tracking and exact positioning over the White Sands Missile Range (WSMR) in New Mexico. Signals from the explosion should be recorded at many permanent and temporary infrasound arrays in North America. Calibration of the network of arrays, including various noise reducing methods, and a test of predictions of infrasound travel times in the atmosphere can be accomplished. Validation of existing software for atmospheric and wave-form modeling should be possible as well.

RESEARCH ACCOMPLISHED

Low frequency acoustic signals are seen at the TXAR infrasound array in far west Texas for shuttle landing tracts across Northern Mexico and Texas. Figure 1 shows the tract for STS 107 (Columbia) on 01 Feb 2003 that is essentially the same as for STS 78. Figure 2 shows the signal from STS 78 that consists of “noise like” infrasound from the decaying shock wave. As seen in Figure 3, the signal from Columbia is clearly different in that impulsive arrivals are superimposed on the expected “noise like” background.

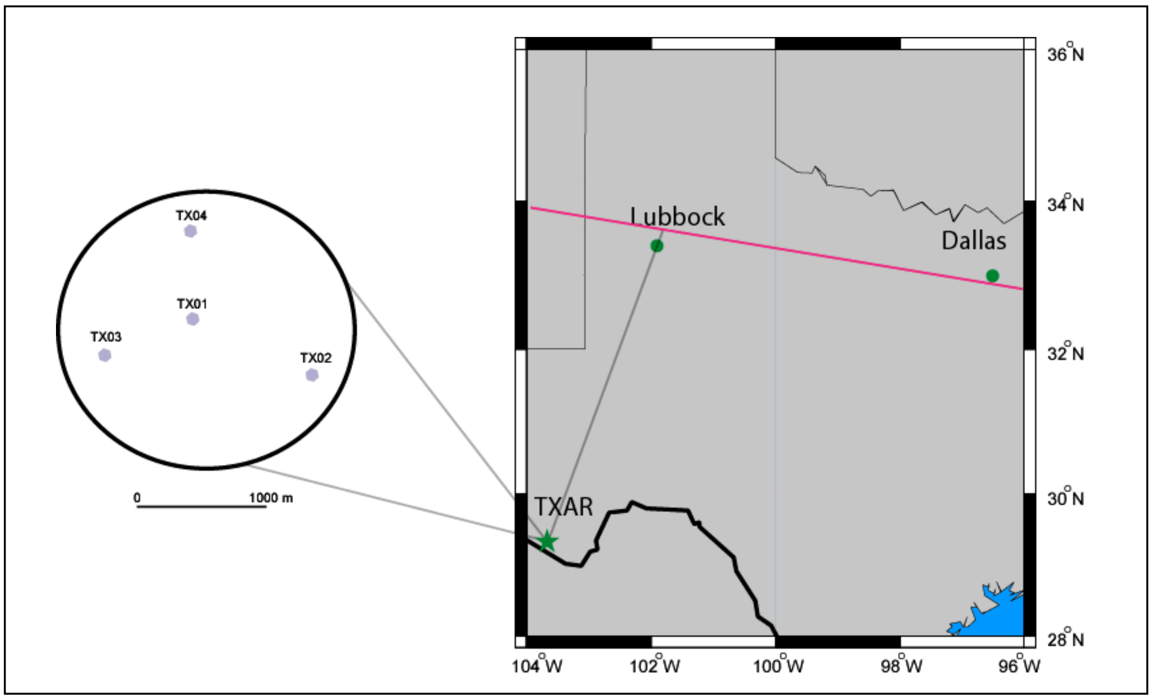

Figure 1. The re-entry path for STS 107 (Columbia) on 01 Feb 2003 from NASA. The path is similar to that of a previous mission, STS 78.

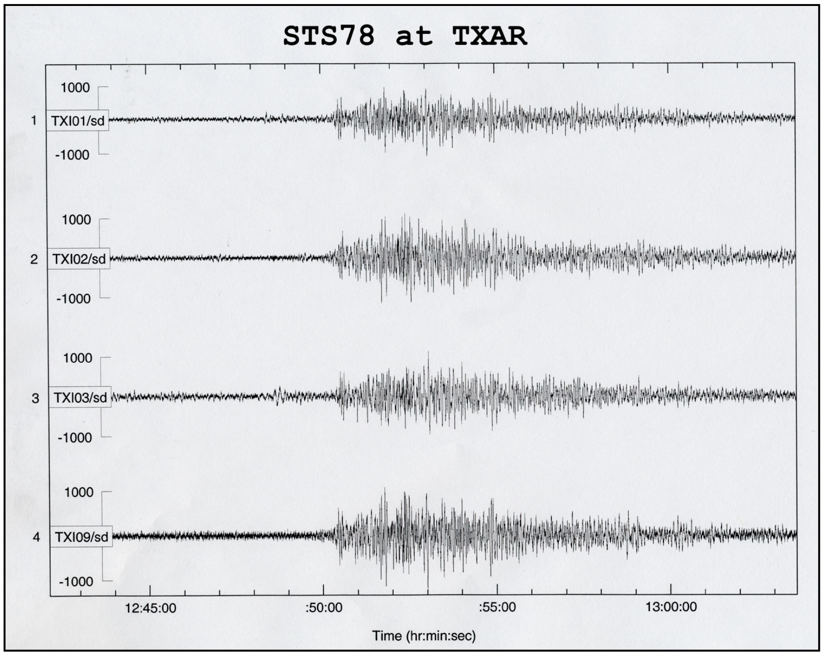

Figure 2. The signal from the normal re-entry of STS 78 consisting of "noise like" infrasound from the decaying shock wave.

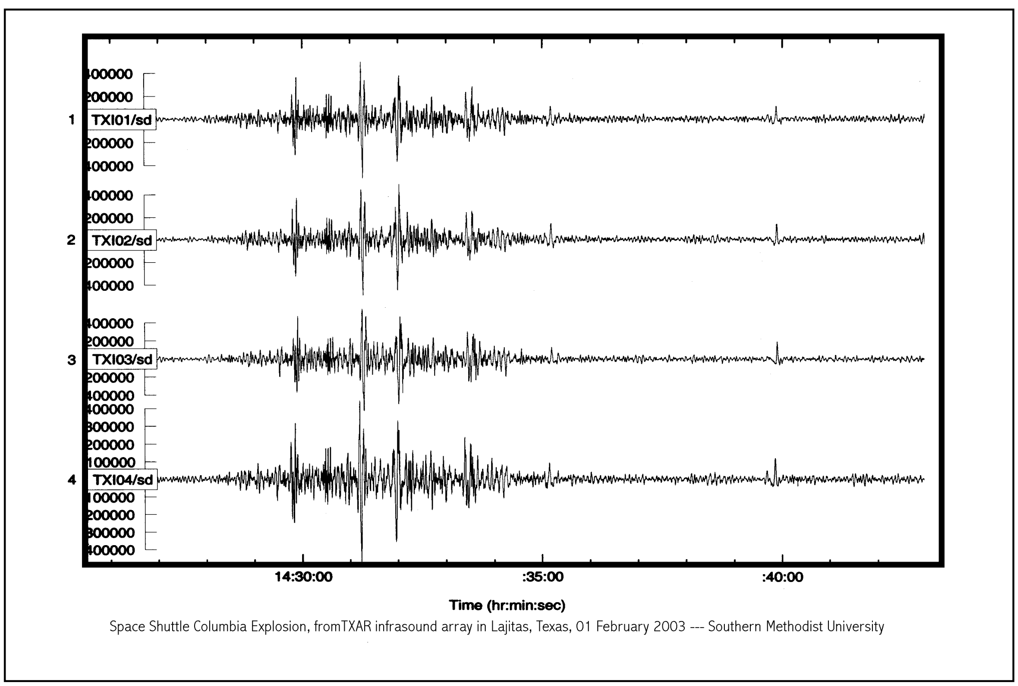

Figure 3. The signal from Columbia showing differences from STS 78 with impulsive arrivals superimposed on the "noise like" background.

Array analysis of the impulsive signals as summarized in Figure 4 show that the back azimuths of these arrivals are essentially the same within the expected analysis error. We conclude that the signals are multipath arrivals from a single event because the shuttle was traveling at a speed greater than Mach 19 at that time.

Arrival	Azimuth	Phase
14:28:13	18.11	0.312
14:29:44	19.01	0.311
14:30:26	19.01	0.311
14:31:08	20.31	0.312
14:31:51	19.01	0.311
14:33:22	19.41	0.313
14:35:05	18.65	0.307
14:39:40	17.34	0.307

Figure 4. Array analysis of the impulsive signals showing the back azimuths of all arrivals essentially the same.

Synthetic wave forms were computed using Inframap software based on the atmospheric model shown in Figure 5 using the time and location of an assumed explosion aboard the shuttle found by crossing the mean back azimuth from TXAR with the GPS shuttle tract data provided by NASA. The synthetic waveforms shown in Figure 6 show impulsive multipath arrivals, several of which agree in travel time with that of the observed arrivals at TXAR, within a few seconds. We consider this to be an excellent result for a travel path of over 600km. Parameters of the assumed explosion are shown in Figure 7. In order to estimate the size of the explosion we used an empirical formula based on atmospheric nuclear explosions. This formula was corrected for the known, factor of two difference between the effects of conventional vs. nuclear explosions, but was based entirely upon surface or low altitude events. We determined that the Columbia event occurred at a height of just over 63 Km. Correction of the predominant period – yield relation for altitude is made using the relation by Armstrong shown in Figure 8. Based upon this analysis the size of the shuttle explosion was between 2 and 3 lbs. of TNT equivalent.

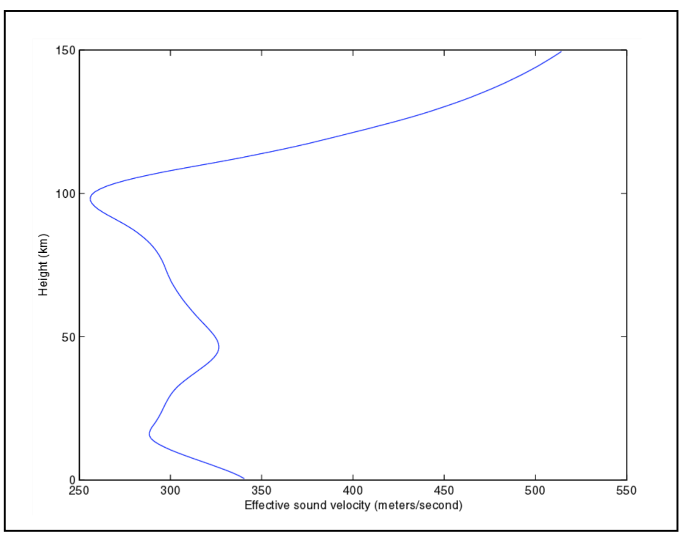

Figure 5. The atmospheric model used for computing synthetic wave forms using Inframap software.

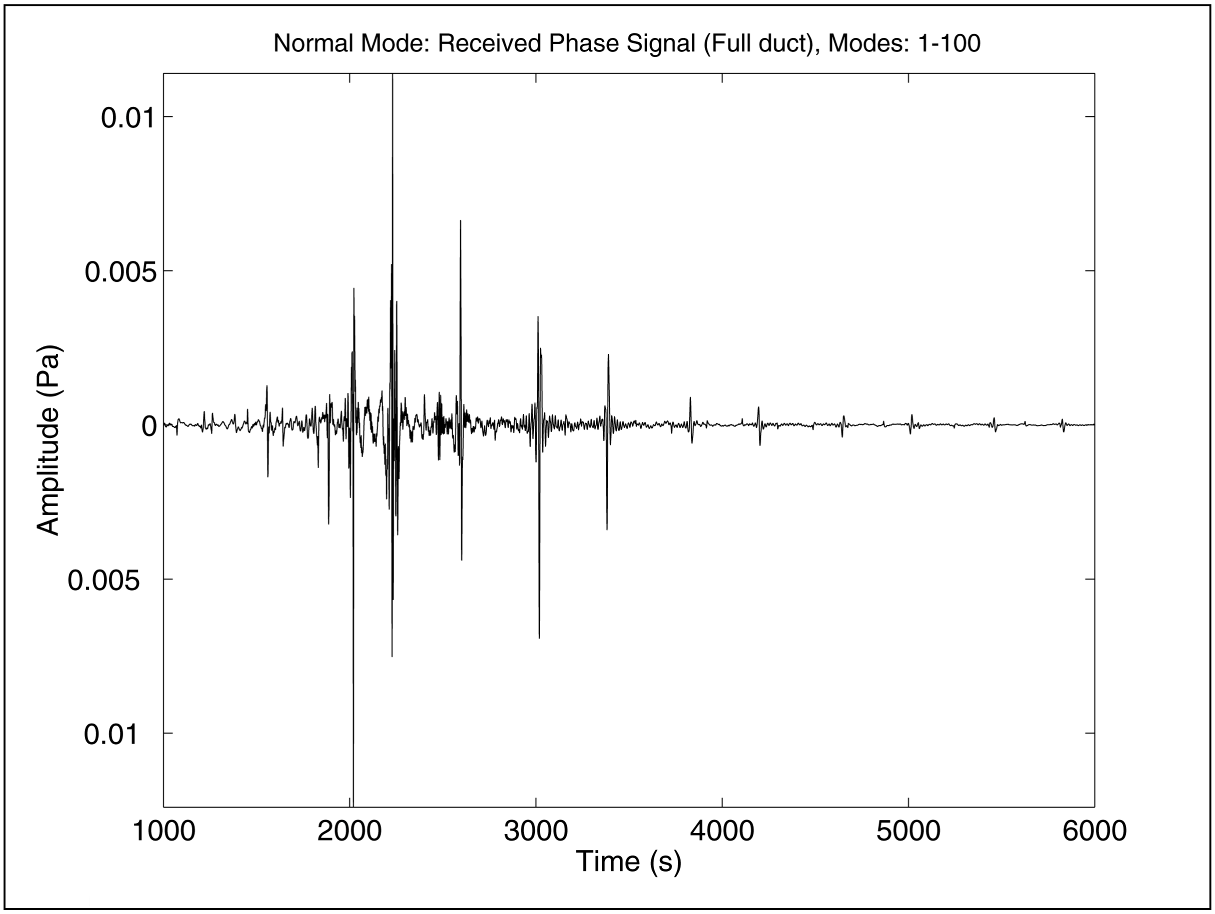

Figure 6. Synthetic waveforms from Inframap showing impulsive multipath arrivals, several of which agree in travel time with the observed arrivals at TXAR.

Our best estimate of the parameter of the explosion

On 1 February 2003

Location:	33.85 N	101.92 ± 20 km
Time:	13 56.65 Z ± 0.1 min	
Height:	63.3 km	
Speed:	Mach 16.2	

Figure 7. Parameters of the assumed explosion.

Empirical formula for estimating yield of atmospheric Explosions modified for HE instead of nuclear source

Point source at low altitude

$$Y \approx (2) \times 2.63 \times T^{3.34}$$

Where Y is the yield in tons

T is dominant period of infrasound signal

Correction for altitude Z (from W. T. Armstrong (1998)
20th Seismic Research Symposium, p. 554
For constant period yield estimate is proportional to ambient pressure where

$$P(z) = P_o\, e^{-Z/H}$$

Where H is pressure scale height of atmosphere (about 7 km)

Figure 8. The period-yield relation of Armstrong.

HISTORICAL PESRPECTIVE

The results above reminded the authors of "grenade" experiments concluded four decades ago. From 1960 to the early 1970's, NASA conducted a series of rocket grenade experiments to produce infrasound as a means to study the mesosphere. The experiments were comprised of rocket launches at four latitudes, four times per year, for 12 years. In the initial experiment 28 sounding rockets were launched from 1960 to 1963. Temperature, pressure, density and wind measurements were derived from the received infrasound signals. During this early period the grenades were the equivalent of 1 or 2 pounds of high explosives. The charges were ejected and exploded at 4 to 6 km intervals to profile the atmosphere from ~30 to ~90 km. Radar and other ranging systems were used to measure the location of the explosions. The time of the explosions was recorded by photocells on the payload. Later, charges from 1/4 pound to 1/2 pound were used up to 50 km, and 2 to 3 pound grenades from 50 to 90 km.

The frequency of infrasound signals received varied with altitude of the explosion; signals less than 1 Hz were received from the higher explosions. These experiments were all reported in a series of NASA Technical Reports from 1963 onward. We propose to explode high altitude small charges to produce infrasonic waves for confirmation of the performance and calibration of infrasound arrays. The signals from a known charge, when exploded, can be used to characterize the performance of an infrasound array. Charges exploded near the earth's surface can be complicated due to reflections, damping, and multi-path problems. Low altitude explosions require very large charges to generate infrasound waves. However, small charges exploded at high altitudes can produce infrasound very well. Furthermore detonation of explosives in the mesosphere and lower ionosphere can produce acoustic waves that can be used for diagnostic measurements of the atmosphere.

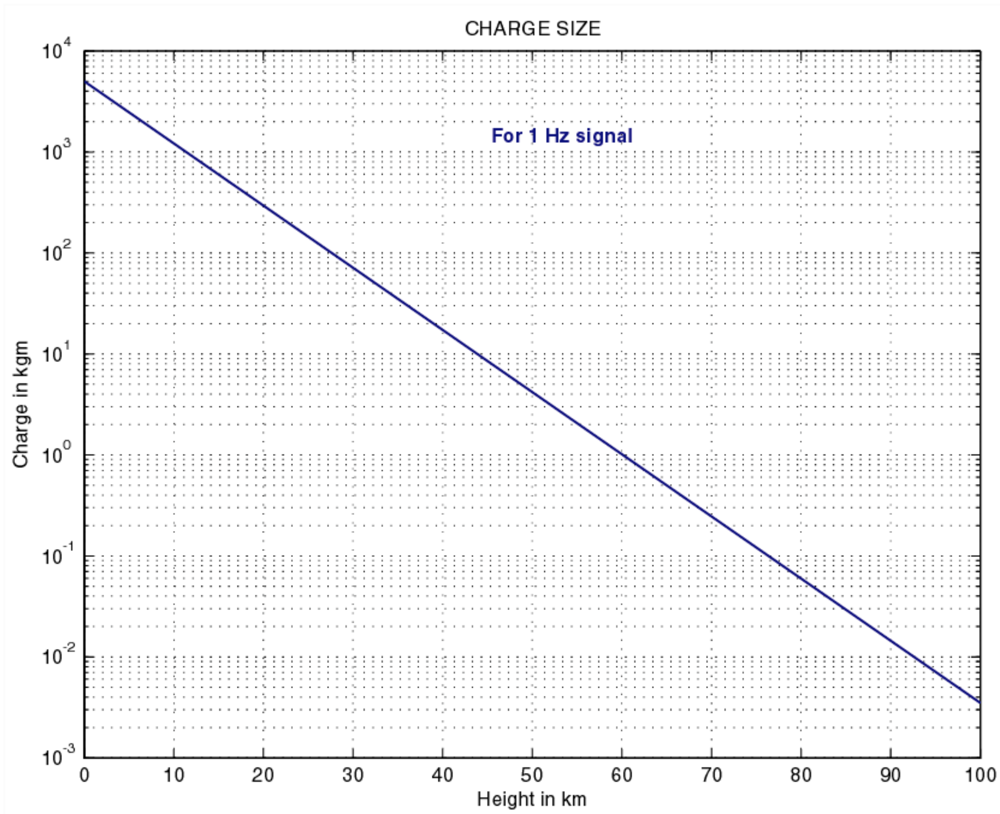

Figure 9. The scaling relation between yield and height of burst that is expected to produce infrasound waves with a predominant period of about 1 second.

CONCLUSIONS AND RECOMMENDATIONS

Explosion experiments can be conducted at White Sands Missile Range using rockets capable of reaching heights of many tens of kilometers. Figure 9 shows the scaling relation between yield and height of burst that is expected to produce infrasound waves with a predominant period of about 1 second. Signals of this period are expected to be observed at many permanent and temporary infrasound arrays in North America provided the timing of the experiment is designed to minimize the effect of atmospheric global winds. We believe that the signals produced will be useful for calibrating the existing infrasound arrays and for validating synthetic data based upon Inframap calculations. Our preliminary design, on the first of the experiments, was to fire a charge of 50 lbs. of TNT equivalent, on the downward leg of a rocket trajectory at a height of 50 km. This was carried out near the autumnal or vernal equinoxes, when the zonal winds are at a minimum. Figure 10 shows typical performance characteristics for a single stage Orion depending on the maximum payload. We include our proposed performance for the 50 lb. explosion at 50 km. Current plans to use the Orion rocket are driven partially by cost, since it is less expensive than the smaller Lance missile due to required up front costs for certifying Lance rounds. Figure 11 shows the planned configuration of the single stage Orion vehicle proposed for the experiment. Figure 11 illustrates one possible flight path for the first of the experiments indicating the launch, apogee and impact site of the rocket.

Plans are in process to order 10 explosive charges in FY 2004 for future missions. In addition to the first experiment described previously, future funding may allow additional missions firing up to 3 explosions a day, at two hour intervals, and possibly two or three missions scheduled over a year. Multiple missions could provide experiments at an equinox and at times when the zonal winds are at maximum from the east and/or west. We have requested a meeting at WSMR in October for planning purposes to set dates and schedules for the missions.

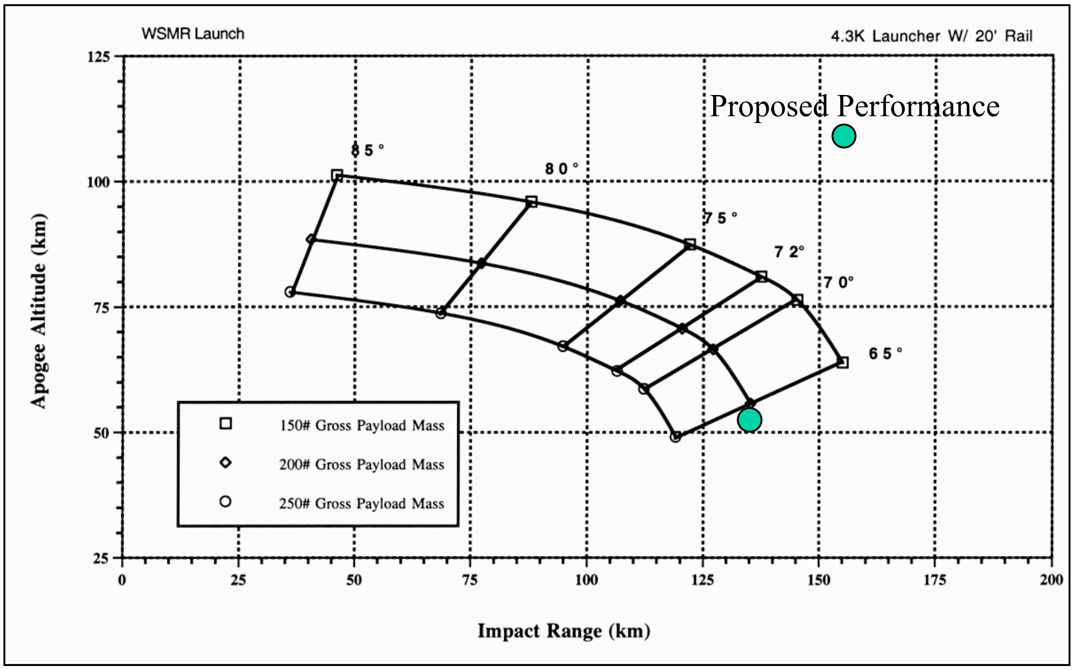

Figure 10. Typical performance characteristics for a single stage Orion rocket depending on payload.

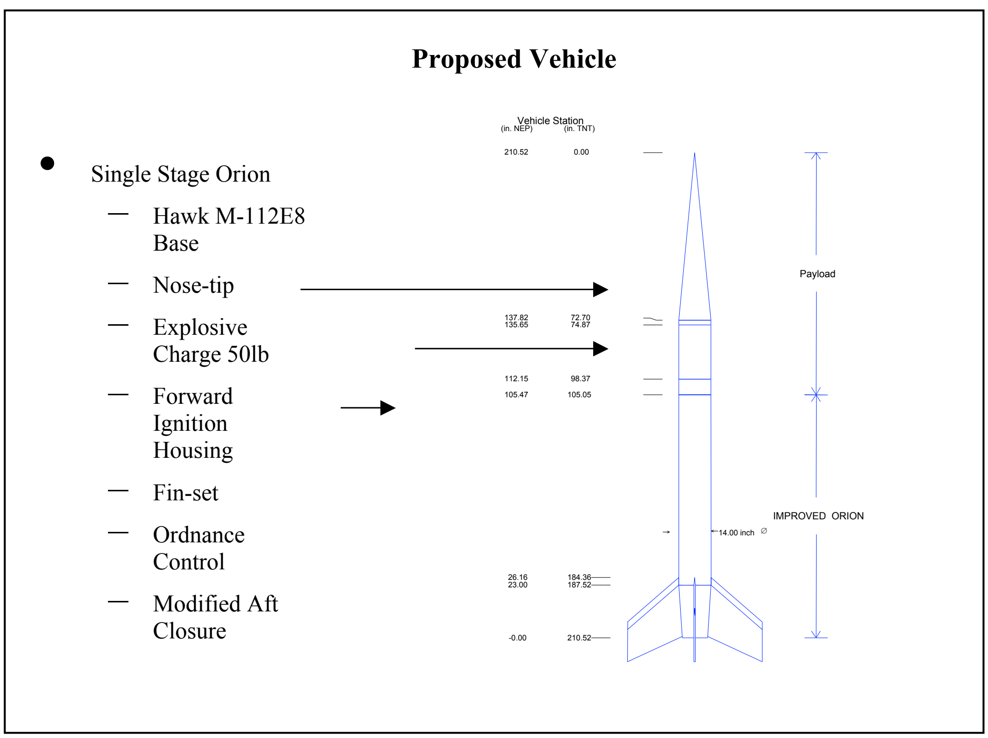

Figure 11. Planned configuration of the single stage Orion vehicle proposed for the experiment.

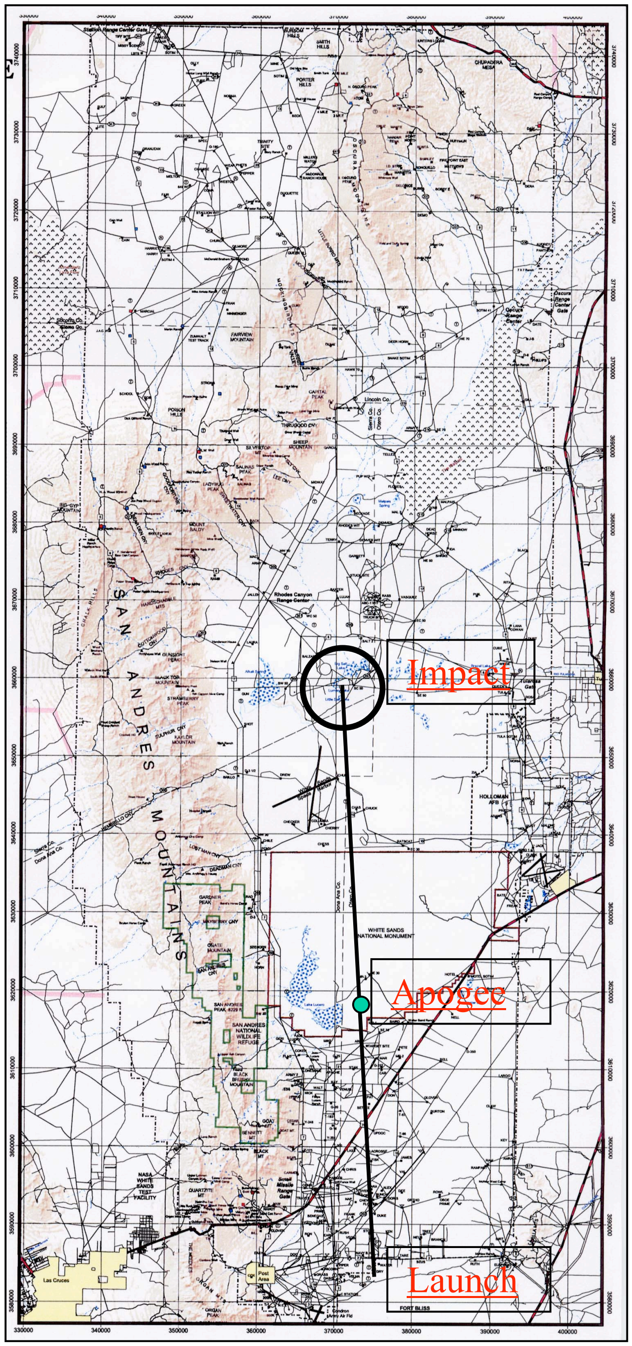

Figure 12. A proposed flight path for the first of the experiments.

REFERENCES

Armstrong W.T., (1998), Comparison of infrasound correlation over differing array baselines in Proceedings of the *20th Annual Seismic Research Symposium on Monitoring a Comprehensive Test Ban Treaty (CTBT*), p. 554.

Osborne D.L, H. Nielsen, M. Conde, J.V. Olson and C. R. Wilson, (2003), Infrasound Generating Rocket Grenade Experiment for Investigations of Infrasound Array Capability and Diagnostic Tool to Study the Mesosphere and Lower Ionosphere, White Paper, University of Alaska.