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Environmental Impact Analysis Process

ENVIRONMENTAL ASSESSMENT

TITAN IV
SOLID ROCKET MOTOR UPGRADE TESTING
AT EDWARDS AIR FORCE BASE, CALIFORNIA

MAY 10, 1988

DEPARTMENT OF THE AIR FORCE

ENVIRONMENTAL ASSESSMENT FOR TITAN IV SOLID ROCKET MOTOR UPGRADE TESTING AT EDWARDS AIR FORCE BASE, CALIFORNIA

May 10, 1988

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~~El Segundo~~, California 90009
Los Angeles,

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
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FINDING OF NO SIGNIFICANT IMPACT (FONSI)
ENVIRONMENTAL ASSESSMENT FOR TITAN IV
SOLID ROCKET MOTOR UPGRADE TESTING
AT EDWARDS AIR FORCE BASE, CALIFORNIA

DESCRIPTION OF THE PROPOSED ACTION

INTRODUCTION

To support the U.S. Department of Defense Space Program and to ensure access to space through the continued use of Titan solid propellant rocket motors, the U.S. Air Force (USAF) proposes to test-fire five Titan IV solid rocket motors at Test Stand 1-C, located at the Air Force Astronautics Laboratory (AFAL), Edwards Air Force Base (AFB), California, during the period from July 1989 to August 1990.

PROPOSED ACTION

The proposed action calls for the modification of an existing rocket motor test stand (Test Stand 1-C) and an associated receiving and inspection building located on Leuhman Ridge at AFAL to conduct the static test firings. Test Stand 1-C was used to test liquid rocket engines from 1965 until the early 1970s and was renovated in 1986 to test Titan solid propellant rocket engines (the 34D static rocket tests). Proposed test stand and receiving and inspection building modifications include refurbishment of and changes in structural, mechanical, and electrical systems; addition of a heat shield to protect the steel deflector plate; water collection basin improvements; and addition of instrumentation, control, and monitoring equipment. In addition to modifications to the test stand and associated buildings, an existing railroad spur will be upgraded to facilitate rocket motor transport. This upgrade will include improving roads, building a concrete-pad working area and asphalt parking areas, and modifying overhead high-voltage power lines.

Following renovation of the test stand and associated facilities, five three-segment Titan IV solid propellant rocket motors will be test-fired over a period of approximately 14 months. The tests will be conducted to

1. evaluate motor performance by measuring the thrust, motor case deflection, effects on fired cases and pressure of motors during firing;
2. measure insulator erosion;
3. evaluate nozzle performance by measuring force vectors, nozzle movement, and response time;
4. monitor ignitor performance through pressure monitoring; and
5. evaluate propellant performance by measuring burn time and rate.

SUMMARY OF ENVIRONMENTAL IMPACTS

NATURAL ENVIRONMENT

Air Quality

The proposed Titan IV rocket motor test firings will not significantly impact air quality at areas surrounding Edwards AFB. Primary constituents of the rocket exhaust will be aluminum oxide (Al_2O_3), hydrogen chloride (HCl), carbon monoxide (CO), and nitrogen (N_2). Afterburning in the atmosphere oxidizes some of the constituents, particularly CO to CO_2 and a small amount of N_2 to NO_x. A reasonable and conservative worst-case modeling analysis of the Titan IV motor exhaust indicates that the general population will not be exposed to HCl concentrations greater than the National Academy of Sciences (NAS) recommended limit for short-term public exposure (limit of 3 parts per million HCl, 10-minute average). Maximum downwind concentrations of CO and NO_2 are expected to be well below applicable federal and state standards.

The maximum downwind concentration of particulate matter less than 10 microns in diameter (PM_{10}) from the test firings will exacerbate existing exceedances of the state 24-hour standard of 50 micrograms per cubic meter. However, the worst-case predicted PM_{10} impact from a rocket test is only approximately 20% of the existing maximum 24-hr PM_{10} concentrations in the region. Given the relatively small number of tests (5) in a 14 month period. This is not considered a significant impact.

Soils

Implementation of the Titan IV testing program involves refurbishing the water containment berm at Test Stand 1-C because of its deterioration from earlier tests. Refurbishing the berm will not significantly affect the soils at Edwards AFB or the surrounding area. The deposition of HCl from the tests is expected to be heavy in the immediate area of the test stand based on the results of the 34D test firing. The impacts of this deposition to soils are expected to be small due to the use of the carbonate buffer system, the previously disturbed nature of the area, and the generally alkaline makeup of the soil.

In addition, soil erosion will occur in the immediate vicinity of the test stand, since approximately 344,000 gal of deluge water will not be trapped in the water collection system. The erosion will be limited in area, but perhaps extensive near the test stand. Pre- and post-test mitigation measures are proposed to minimize impacts to soils.

Hydrology

No significant impacts to groundwater or surface water hydrology will result from the Titan IV motor tests. All water used for the tests will come from a water storage tank fed from wells on Edwards AFB. Most of the deluge (cooling) water used in the tests will be conditioned with a carbonate buffer to mitigate potential effects of HCl absorption into the soil and low pH. Most deluge water will be deposited as acid mist (pH of 3 or lower) from the exhaust plume onto the ground surface near the test stand. The remainder of the deluge water not entrained into the exhaust gas stream will be collected and evaporated in concrete-lined channels and a basin located near Test Stand 1-C.

Water Quality

No significant impacts on water quality will result from the Titan IV tests. All deluge water contained in the channels and basin will be evaporated. The amount of deluge water that will be deposited from the exhaust onto the rocks and soil nearby will be large but will evaporate leaving a residue of HCl and inert nonhazardous compounds (mostly aluminum oxide and sodium chloride) on the ground surface. The amount of HCl deposition will have no significant impact on ground or surface waters.

Ecological Resources

No significant impacts to the ecological resources of Edwards AFB or surrounding areas are expected as a result of the Titan IV motor tests. Impacts to vegetation and habitat from acidic mist will be minor because much of the impact area has been previously disturbed. No critical habitat for threatened or endangered species will be lost as a result of the Titan IV test program. Adverse impacts to the desert cymopterus present in the area are unlikely because known populations occur outside the near-field deposition zone. Impacts to desert tortoises are presently uncertain because this species has only recently been observed in the area. Impacts to Mojave ground squirrels are presently uncertain because the presence of this species in the railroad spur construction area has not been determined. Planned additional surveys and monitoring of these species by the USAF, in consultation with DFG and USFWS, will provide additional information to avoid or minimize any impacts from future use of the test facility.

MANMADE ENVIRONMENT

Population

The renovation of Test Stand 1-C and the subsequent test program of the Titan IV rocket motors will have no significant impacts on population and housing at Edwards AFB or within surrounding communities. The Titan IV test program will utilize existing personnel at AFAL and Edwards AFB. Temporary staff from the USAF Space Division, Hercules, and their contractors will be on-site during renovation work and motor testing periods.

Socioeconomics

The proposed Titan IV test program is compatible with the surrounding land use, will require no land purchase and no construction work beyond the boundaries of the air base, and will not require additional permanent employment. No significant impacts on the socioeconomics of Edwards AFB, Los Angeles County, or Kern County, California, are anticipated.

Safety

All regulatory agency safety procedures and guidelines for rocket motor transportation and testing will be followed. Safety monitoring will be conducted during the tests. A protective clear zone of about 1 mile will be established around the test stand, and no one will be allowed into the immediate downwind area within the base boundaries. In addition, testing will only occur if the wind direction is such that the exhaust cloud will not proceed over housing areas. Thorough realtime dispersion monitoring, data analysis, and refinement of the rocket exhaust dispersion model will be conducted to determine if conditions would allow an easing of the wind restrictions for test firings. This process will ensure that if firings are conducted under alternate parameters, such testing would not in any way expose the general public to HCl concentrations above the recommended standards or reduce the level of protection provided by the current parameters. Essential test personnel will be located in a protected concrete bunker near the test stand. Realtime monitoring of bunker air supply, test area exhaust cloud and deposition will be performed in conjunction with downwind cloud monitoring. Tests will not proceed until appropriate meteorological conditions are verified.

Noise

Noise levels associated with the Titan test program will not significantly affect the general public due to the distance between the test site and the nearest unregulated area (3 miles). Noise produced during the test firings will be of short duration (approximately 2 minutes and 13 seconds for each event) and, at worst, will be a minor nuisance. Portions of the AFAL will be evacuated to minimize noise impacts to personnel on-site.

Archaeological and Cultural Resources

The areas surrounding Test Stand 1-C and the railroad spur do not contain unique archaeological or historic resources. As a result, the Titan IV test program will have no effect on archaeological or cultural resources.

FINDINGS

Based on the above, a finding of no significant impact is made. Copies of an Environmental Assessment of the proposed action, dated April 1988, can be obtained from

HQ Space Division
Post Office Box 92960
Worldway Postal Center
Los Angeles, California 90009-2960
ATTENTION: Mr. John R. Edwards, SD/DEV

John M. Hoffman, Col USAF
Chairman, Edwards AFB
Environmental Protection Committee

Roig

Raphael O. Roig, GM-14
Chairman, Space Division
Environmental Protection Committee

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ACRONYMS AND ABBREVIATIONS

AAQS	Ambient Air Quality Standards
Act	Federal Endangered Species Act of 1973
AFAL	Air Force Astronautics Laboratory
AFB	Air Force Base
AFTOX	Air Force Toxic Chemical Dispersion Model
AGL	Aboveground level
Al_2O_3	Aluminum oxide
APCD	Air Pollution Control District
C	Centigrade
Cl	Chlorine
CO	Carbon monoxide
CO_2	Carbon dioxide
CWMB	California Waste Management Board
dB	Decibels
dB(A)	Decibels measured on A weighting scale
DFG	California Department of Fish and Game
DOD	(U.S.) Department of Defense
DOT	(U.S.) Department of Transportation
EA	Environmental Assessment
EPA	United States Environmental Protection Agency
F	Fahrenheit
fps	Feet per second
gpm	Gallons per minute
H_2	Hydrogen
H_2CO_3	Carbonic acid
H_2O	Water
HCl	Hydrogen chloride
kts	knots
Lb	Pounds
Lb/ft^2	Pounds per square foot
m	meter
min	minute
Na	Sodium
NAS	National Academy of Sciences
NaCl	Sodium chloride (table salt)
Na_2CO_3	Sodium carbonate (soda ash)
N_2	Nitrogen
NASA	National Aeronautics and Space Administration
NGVD	National geodetic vertical datum
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
O_2	Oxygen
O_3	Ozone
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
ppm	Parts per million
PM_{10}	Particulate matter less than 10 microns in diameter
Regional Board	California Regional Water Quality Control Board, Lahontan Region
sec	second

SF_6	Sulfur hexafluoride
State Board	California State Water Resources Control Board
TSP	Total suspended particulates
$\mu g/m^3$	Micrograms per cubic meter
μm	microns
USAF	U.S. Air Force
USFWS	U.S. Fish and Wildlife Service

1. PROPOSED ACTION AND ALTERNATIVES

The U.S. Air Force (USAF), Headquarters Space Division, El Segundo, California, is proposing to perform five Titan IV solid rocket motor upgrade tests at the USAF Astronautics Laboratory (AFAL) Edwards Air Force Base (AFB), in eastern Kern County, California, between July 1989 and August 1990. The catastrophic loss of the space shuttle Challenger in January 1986, followed by the loss of the Titan 34D space launch vehicle at Vandenberg AFB in April 1986, and the mishap of the Delta launch from Cape Canaveral, also in 1986, severely impacted the U.S. space programs launch capability. In addition, the USAF desires launch vehicles with greater payload capacities equivalent to that of the Space Shuttle without depending on manned systems. Both of these factors generate the need for new and more powerful space booster systems. The proposed Titan IV solid rocket motor upgrade tests are necessary to improve the U.S. payload capabilities.

Each static test firing of the Titan IV motor is proposed for a duration of 2 min and 13 sec. The tests are expected to occur over a period of approximately 14 months. The probability of re-testing exists, however it is very low because extensive components tests are conducted prior to integrated testing. A static test employs a motor that is held within a test stand during firing, as opposed to an actual launch. Each rocket motor is manufactured in three segments for ease of transportation, and each segment is approximately 12 ft in diameter and 36 ft long. Subassembly of the units will occur at receiving and inspection building 1-D, while the segments will be stacked and mated on the test stand. Instrumentation will be attached to the rocket motors to monitor the tests.

This Environmental Assessment (EA) discusses the environmental impacts of the proposed static test firings of the Titan IV solid propellant rocket motors. The EA documents the compliance of the static test program with applicable federal, state, and local environmental regulations and identifies mitigation measures which shall be implemented to minimize the environmental impacts of the proposed test program.

This EA is being issued subsequent to, and will tier from, the EA produced in December 1986 for the static testing of Titan 34D solid propellant rocket motors (Brown and Caldwell 1986). The EA for the 34D tests is contained within this document for reference as Appendix A. This tiering effort is undertaken pursuant to the National Environmental Policy Act of 1970 as amended (42 U.S.C. 4371 et seq.), the Council on Environmental Quality Regulations (CEQ Regs) (40 CFR, Parts 1500-1508), and USAF Regulation 19-2 (AFR 19-2) (Air Force 1982).

Following the guidelines set out in the CEQ Regs. and AFR 19-2, this document will summarize the issues discussed in the EA for the 34D tests, incorporate important discussions by reference, and concentrate on issues specific to the proposed action.

1.1 PROPOSED ACTION

The USAF and Hercules, Inc., the Titan IV rocket motor manufacturer, intend to conduct static test firings at Edwards AFB to refine the final Titan IV design by

1. evaluating motor performance,
2. measuring insulator erosion,
3. evaluating nozzle performance,
4. monitoring ignition performance, and
5. monitoring propellant performance.

The motors will be tested with the nozzle pointing downward to provide better test results than the more conventional horizontal or nozzle-up test firings.

The proposed action consists of four major tasks: (1) modifications to an existing railroad spur, to a receiving and inspection building, and to the test stand, (2) transport and setup of rocket motor segments and necessary test equipment, (3) testing of the Titan IV rocket motors, and (4) operation of a deluge water recycling and treatment system. Each task is described in the following sections.

1.1.1 Project Location

Edwards AFB is located at the eastern edge of Kern County, California, in the Mojave Desert at an elevation of approximately 2,300 ft above NGVD. AFAL is located in the northeast corner of Edwards AFB (Fig. 1.1) about 11 miles east of the main base and is a research and development facility responsible for planning, formulating, and executing USAF technology programs for rocket propulsion and related space technology. Both solid and liquid rocket motors are tested at a number of test stands located at AFAL (Fig. 1.2). Test Stand 1-C (Fig. 1.3), which will be used for the proposed tests, is located on top of Leuhman Ridge at an elevation of approximately 3,200 ft above NGVD, or about 900 ft above the flat desert terrain west of Leuhman Ridge. The main buildings of the AFAL are located about 1 mile south of this test stand. The nearest town is Boron, located approximately 3.5 miles north-northeast of the test site. The Desert Lakes housing area is approximately 3 miles north of the test site (Fig. 1.3). Death Valley is approximately 80 miles to the northeast.

1.1.2 Renovation of Test Stand 1-C

Test Stand 1-C was previously used for the testing of liquid and solid propellant motors. The liquid propellant testing structures and equipment have been removed, and the test stand has been modified to accommodate Titan solid propellant rocket motors (description of modifications contained in Sect. 1.2.2, Appendix A). Proposed modifications for the Titan IV tests include addition of a new environmental closure, expansion of the heating and cooling system, addition of work platforms in the test cell, augmentation of the Data Acquisition System capacity including a back-up generator, creation of a new upper stand structure to accommodate the greater engine height and width, addition of a new thrust measurement system to gather flight load data, modification of the lower stand to accommodate this motor and upper

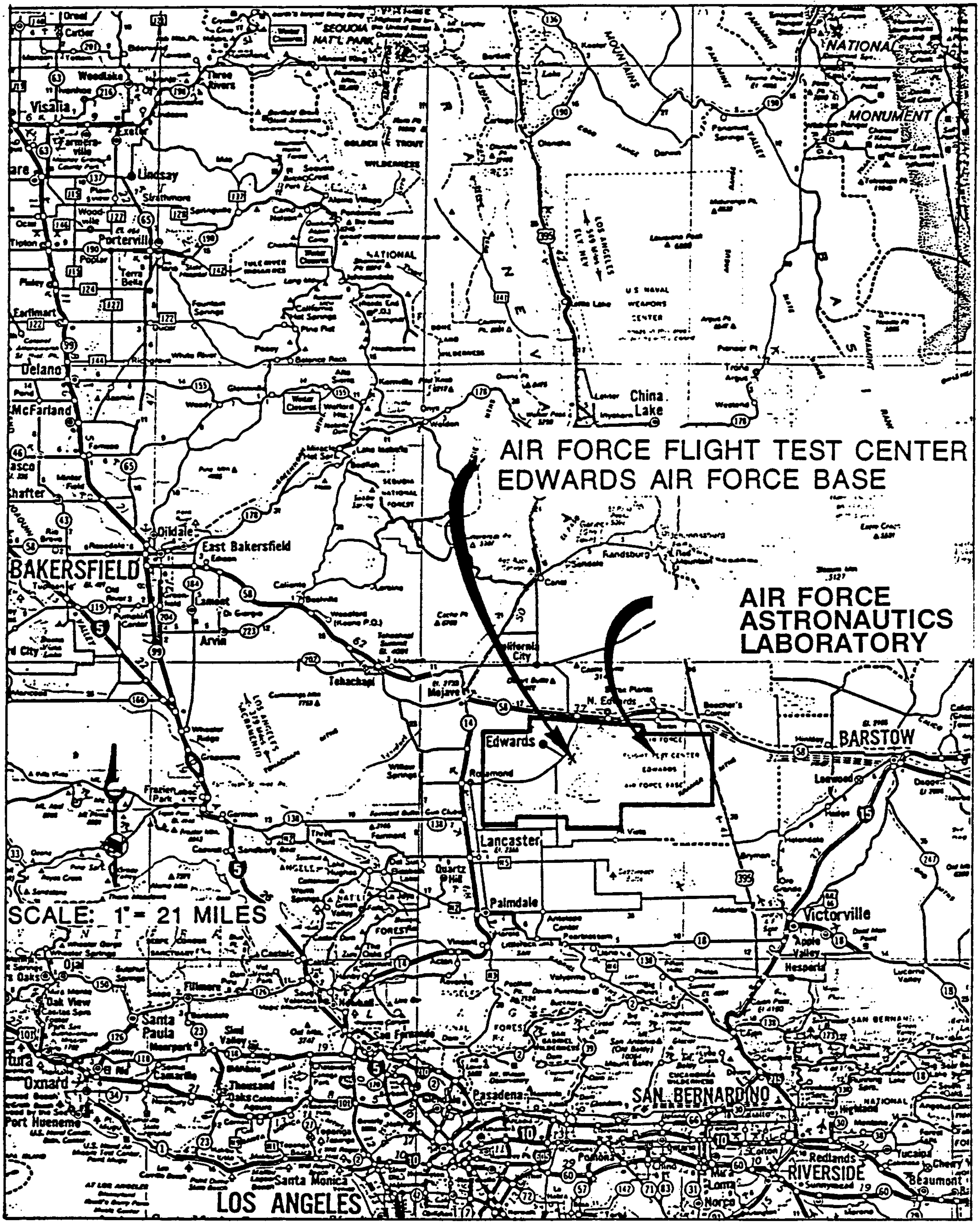

Fig. 1.1. Location of Edwards Air Force Base.

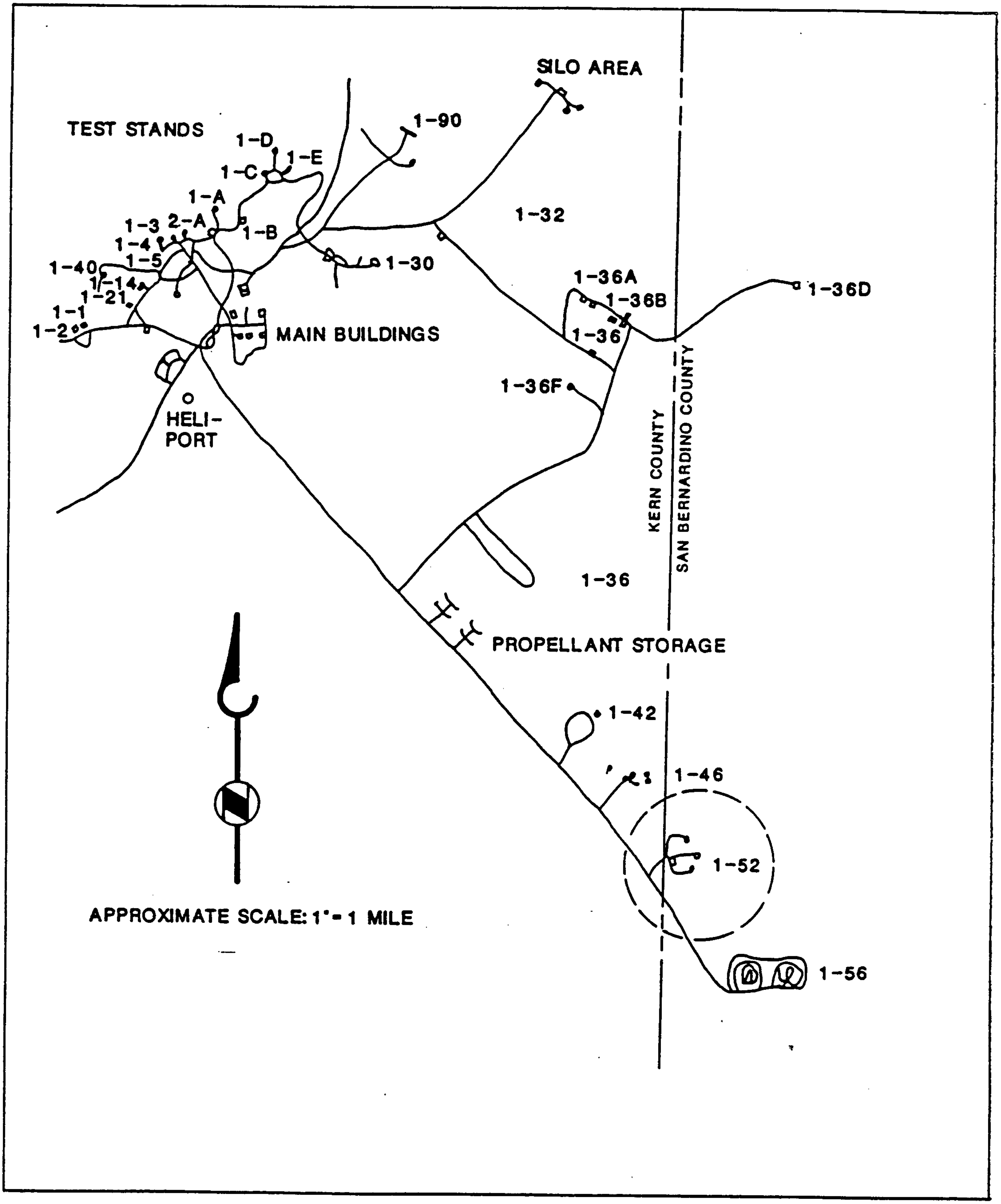

Fig. 1.2. Air Force Astronautics Laboratory.

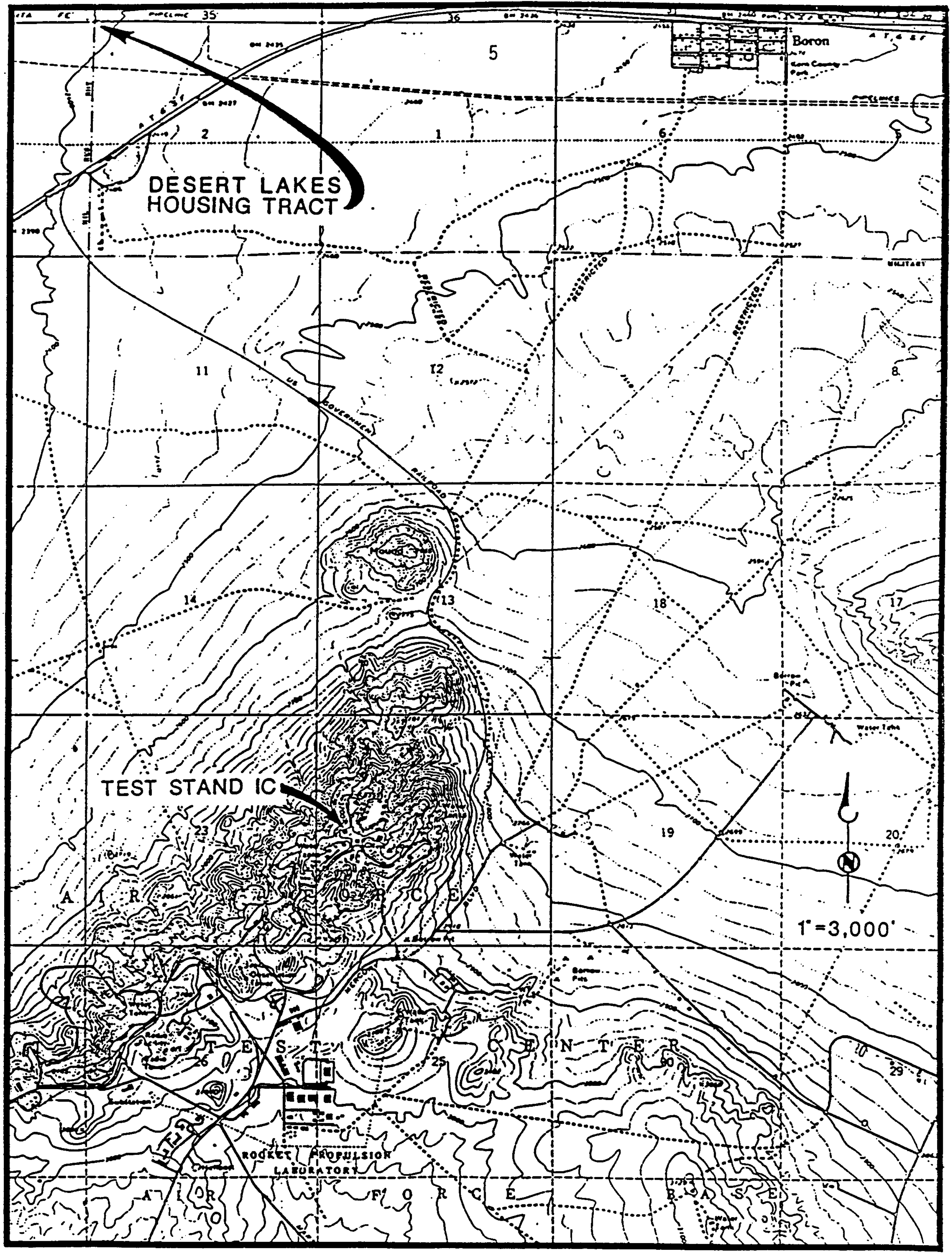

Fig. 1.3. Location of Test Stand 1-C at Air Force Astronautics Laboratory.

structure configurations, modification of the exhaust plume deflector and its ablative material to withstand increased exhaust thrust and temperature, reconstruction of the berm around the test stand used to collect quench water to the configuration used previously in the 34D test (Appendix A, Sect. 1.2.2), and modification of the water deluge system to accommodate the more highly erosive nature of the exhaust plume.

1.1.3 Modification of Receiving and Inspection Building

The receiving and inspection building (1-D) will be used for inspection and preparation of the rocket motor segments before they are moved to the test stand for stacking and testing. Modifications to this building would include providing new electrical, water, and compressed air services; adding a drain to the current drain system; creating a new spray booth; modifying work platforms; adding a new large roll-up door to one of the bays, and adding a new computer room.

1.1.4 Modification of Railroad Spur

The existing railroad spur will be used for the movement of motor segments to and from the Hercules Bacchus Works near Salt Lake City, Utah. The existing spur will be modified by creating a flat working area upon which cranes and vehicles can operate on both sides of the spur. Construction will consist of earth excavation, and other operations to create asphalt parking lots and road upgrading, concrete pads and footings, and rail spur refurbishment. The concrete pad will be approximately 100 ft by 50 ft; the road to be upgraded is approximately 300 yds in length. Overhead power lines will also be modified by the addition of more poles. The USAF will ensure that the test stand, cranes, and power lines are sufficiently grounded from lightning effects.

1.1.5 Transportation and Test-Firing Setup

The Titan IV rocket motor segments to be used for the test-firings will be transported to AFAL by common-carrier rail service from the manufacturer's Hercules Bacchus Works Plant 1 facilities approximately 25 miles east of Salt Lake City, Utah. The motor segments will be transported in Titan IV railroad cars. Motor segments will be hoisted onto an open car and locked into a restraint system. An environmental cover, which will be grounded from lightning effects, will then be placed over the segment and an attached environmental-control unit will provide temperature and humidity control within the cover. The process will be reversed to unload the segment. The storage facilities and transportation routes are not identified in this EA for security reasons. Regulations of the U.S. Department of Defense (DOD) (DOD Directive 6055.9-S), Air Force (AFR 127-100), and the U.S. Department of Transportation (DOT) (49CFR, pts. 172, 173, and 174) will be observed to ensure compliance in transport, movement, and handling of all Titan IV rocket motor segments. Segments will be stacked and mated according to Hercules, Inc.'s standard procedures and safety regulations. Following each test, the spent rocket motors will be disassembled and transported off-site for detailed examination.

1.1.6 Testing of Titan IV Rocket Motors

Each three-segment Titan IV rocket motor will contain 680,694 lb of propellant. Each test firing will last approximately 2 min, 13 sec, and will yield extensive data regarding rocket performance, structural and thermal loads on the test stand structures and rocket motor, and other critical performance parameters.

The Titan IV solid propellant, which burns at a given rate from the core toward the casing in each segment, consists of ammonium perchlorate oxidizer, aluminized synthetic-rubber binder fuel, and various other additives to stabilize mass and control the burning rate (the propellant composition is identical to that used on the 34D test). The combustion products at the nozzle will be particulates, consisting mainly of aluminum oxide (Al_2O_3), gaseous hydrogen chloride (HCl), hydrogen (H_2), nitrogen (N_2), and carbon monoxide (CO). Several water nozzles will be used to quench and cool the rocket and exhaust during these tests.

A comparison of rocket motor parameters is as follows:

Parameter	34D test	Titan IV test
Sea Level Thrust (Mlb)	1.2-1.34	1.5
Exit Velocity (ft/sec)	8,144	8,750
Burn Time (sec)	120	133
Weight of propellant (1,000 lb)	466	681

1.1.7 Deluge Water Handling System

The Titan IV rocket motor tests will use an extensive deluge water system since the exhaust will be a very hot high-velocity gas stream, and the tests will be undertaken with the nozzle of the motor pointing down. A large deflector shield, called the flame bucket, will divert the exhaust to a horizontal plane. The deluge water system, which is primarily used to cool the flame bucket, is described in the following sections.

1.1.7.1 Water Quantity

The Titan IV tests will require more water than was used for the 34D tests (Appendix A, Sect. 1.2.5.1) due to the larger motor size and longer firing time. Each test firing will require approximately 674,000 gal of cooling (deluge) water compared to the approximately 570,000 gal required for the 34D tests. Table 1.1 shows water uses for the 34D tests and the proposed Titan IV tests.

1.1.7.2 Water containment and treatment system

The deluge water will be supplied from two existing storage tanks. A combination of 3-million-gal and 400,000-gal tanks supply the total system.

Table 1.1. Water use for the Titan IV and Titan 34D rocket motor test firings

	Start-up	Ignition	Shut-down	Quench	Total
Average Flow Rate (gpm)					
Titan IV	80,000	155,000	80,000	1,000	--
Titan 34D	70,000	140,000	70,000	1,000	--
Change for Titan IV tests	+10,000	+15,000	+10,000	Same	--
Water Flow Duration (min)					
Titan IV	2.0	2.2	2.0	10.0	16.2
Titan 34D	2.0	2.0	2.0	10.0	16.0
Change for Titan IV tests	Same	+0.2	Same	Same	+0.2
Water Supply Volume (gal)					
Titan IV	160,000	344,000	160,000	10,000	674,000
Titan 34D	140,000	280,000	140,000	10,000	570,000
Change for Titan IV Tests	+20,000	+64,000	+20,000	Same	+104,000
Water Volume Collected (gal)					
Titan IV	160,000	-0-	160,000	10,000	330,000
Titan 34D	140,000	-0-	140,000	10,000	290,000
Change for Titan IV Tests	+20,000	Same	+20,000	Same	+40,000

As shown in Table 1.1, approximately 330,000 gals of deluge water will be collected in the basin at Test Stand 1-C and will flow into the 6-ft high concrete channels that connect Test Stands 1-C and 1-D and into the mixing basin. The system will be refurbished due to wear that occurred during the 34D test. The estimated storage volume available in these channels is 816,000 gal.--an amount sufficient to contain the deluge water produced by each test.

Much hydrogen chloride in the rocket exhaust will dissolve in the deluge water forming hydrochloric acid and lowering the pH of the water. However, the deluge water will be pretreated with sodium carbonate, raising the pH to about 11 to mitigate the low pH which occurs in the mist fallout beneath the exhaust plume. Conditioning of the water will be performed by addition of sodium carbonate in the mixing basin.

1.2 ALTERNATIVE ACTIONS

Alternative actions to the proposed testing of Titan IV rocket motors at Edwards AFB include alternative types of tests and alternative sites for the tests.

1.2.1 Alternative Tests

Horizontal and nozzle-up static test firings were considered for this program but were rejected by the USAF and Hercules because the forces acting on the rocket motors in these configurations are different from the forces in the nozzle-down launch position. The purpose of the proposed tests is to simulate as closely as possible the forces acting on the rocket motors during launch conditions. The nozzle-down tests were chosen for this reason.

1.2.2 Alternative Sites

The USAF had previously conducted a nationwide search for the best site to conduct Titan motor tests, as described in Appendix A (Sect. 1.3.2). These sites were reviewed for appropriateness for the Titan IV tests. Edwards AFB was chosen. Other sites were rejected for the reasons stated in the Appendix. In addition, the modifications undertaken at AFAL to Test Stand 1-C for previous tests make it an even more desirable and logical site.

1.2.3 No-action Alternative

If the proposed solid rocket motor tests are not conducted, development of Titan IV rocket motors will be unacceptably delayed. If there is no action and, hence, no tests, there will be no subsequent flights of the Solid Rocket Motor Upgrade from Vandenberg AFB and Cape Canaveral AFS. This would preclude DOD's capacity to launch new, heavier, critical payloads.

2. ENVIRONMENTAL SETTING

2.1 NATURAL ENVIRONMENT

2.1.1 Geology and Soils

Edwards AFB is located in the western portion of the Mojave Desert at an elevation of approximately 2,300 ft above NGVD. Rocket Test Stand 1-C is located at AFAL on Leuhman Ridge at an elevation of approximately 3,200 ft above NGVD, approximately 900 ft above the desert floor to the west of Leuhman Ridge. Soils in the test area are slightly alkaline (pH ranges from 7.4 to 8.4) and consist of a surface layer of blown sand covering an impermeable layer of sandy soil mixed with clay. A more complete description of geology and soils is contained in Appendix A, Sect. 2.1.1.

2.1.2 Meteorology and Air Quality

Existing meteorological/climatological and air quality conditions at Edwards AFB are described in the EA for the Titan 34D rocket motor tests (see Appendix A, Sect. 2.1.2 for a description of the climatological conditions). However, one change with regard to air quality should be mentioned. The federal 24-hr and annual Ambient Air Quality Standards (AAQS) for total suspended particulates (TSP) have been eliminated and replaced with 24-hr and annual AAQS for particles less than 10 microns in diameter (PM_{10}). The new PM_{10} standards are shown in Table 2.1, along with other existing state and federal standards.

Regional air quality data in 1986 (California Air Resources Board, 1987) in the vicinity of Edwards AFB was not significantly different from the 1980-85 data summarized in Appendix A. However, although very limited PM_{10} data were available for the earlier assessment, more PM_{10} data are now available. The 1986 PM_{10} data for three monitor sites in the vicinity of Edwards AFB are summarized in Table 2.2. The data indicate that the area is in compliance with federal PM_{10} AAQS (the annual average at Mojave is not considered valid because of the small number of observations) but is in violation of the 24-hr and annual California PM_{10} standards.

As with the earlier period, the 1986 data indicate that the area is well within the California and federal AAQS for carbon monoxide (CO) and nitrogen dioxide (NO_2) and is well over the federal AAQS for ozone (O_3). No monitoring data for sulfur dioxide and lead were available for the Edwards AFB vicinity.

2.1.3 Surface Water and Groundwater Resources

Consistent with the desert environment, there are no major surface water resources in the area. Runoff from Leuhman Ridge flows predominantly eastward into Rogers Dry Lake, which generally contains water only from November to May. The principal groundwater resources to be used for the proposed tests are the Lancaster and North Muroc subunits of the Antelope

Table 2.1. Ambient air quality standards

		Federal		
Pollutant	Averaging time	Primary standard ($\mu g/m^3$)	Secondary standard ($\mu g/m^3$)	California ($\mu g/m^3$)
Sulfur dioxide	1 hr			655
	3 hr		1300[a]	
	24 hr	365[a]		131
	Annual	80		
[b]Particulate matter (PM_{10})	24 hr	150[a]	150[a]	50
	Annual	50	50	30[d]
Nitorgen dioxide	1 hr			470
	Annual	100	100	
Carbon monoxide	1 hr	40,000[a]		23,000
	8 hr	10,000[a]		10,000
Ozone	1 hr	235[c]	235	
Lead	30 day			1.5
	Calendar quarter	1.5	1.5	

[a] Not to be exceeded more than once per year.

[b] Particles with an aerodynamic diameter less than or equal to 10 micrometers.

[c] Standard is attained when the number of days per calendar year with maximum hourly average concentration greater than 235 $\mu g/m^3$ is less than or equal to 1.

[d] Geometric mean.

Table 2.2. Monitored PM_{10} concentrations for area near Edwards AFB for 1986

Location	No. of obs.	24-hr conc.		No. of obs. >		Annual means		Annual standards	
		Max.	2nd Max.	50[a]	150[b]	Arithmetic	Geometric	CA.	NAAQS
Barstow	60	161	92	11	1	40.1	35.9	30	50
Victorville	39	114	81	16	0	47.2[c]	43.9	30	50
Mojave	12	130	79	10	0	64.1[c]	59.3	30	50

[a] California 24-hr AAQS, not to be exceeded.

[b] Federal 24-hr AAQS, allowed to be exceeded once per year.

[c] Not considered a valid comparison against AAQS due to insufficient number of observations.

Valley. Groundwater recharge to these aquifers is primarily from subsurface inflow. Groundwater is low in total dissolved solids and generally good in the Lancaster subunit. The North Muroc subunit has high sodium and arsenic contents. A more complete description of surface water and groundwater resources is contained in Appendix A, Sects. 2.1.4 and 2.1.5.

2.1.4 Ecological Resources

A description of ecological resources in the vicinity of Edwards AFB and Test Stand 1-C is contained in Appendix A, Sect. 2.1.6. An update of these data were made in a biological resource evaluation for the proposed action prepared in March, 1988 (Appendix C). A summary of this information is presented below.

2.1.4.1 Vegetation

Three plant communities characterize the vicinity of the test site. The Joshua tree woodland consists of relatively open stands that become more dense on alluvial fans. The creosote bush scrub community is generally found on slopes, hills, and well-drained sandy flats throughout the area. The alkali sink vegetation is found in poorly-drained depressions and margins of dry lake beds. The immediate vicinity of the test facility has been severely eroded and supports only scattered vegetation due to past rocket motor tests.

2.1.4.2 Wildlife

Wildlife species common in the vicinity of the project area are described in Sect. 2.1.6.2 of Appendix A.

2.1.4.3 Endangered and threatened species

There are no federally listed or proposed threatened or endangered species within the project area [letter dated February 10, 1987, to Elaine M. Archibald, Brown and Caldwell Consulting Engineers, from Gail C. Kobetich, U.S. Fish and Wildlife Service (USFWS), Sacramento, California]. However, the following five candidate species for listing may be present in the area:

Mojave ground squirrel (Spermophilus mohavensis)
Desert tortoise (Scaptochelys agassizii)
Mojave desert blister beetle (Lytta inseperata)
Alkali mariposa (Calochortus striatus)
Desert cymopterus (Cymopterus deserticola)

These species are all classified by the USFWS as Category 2 species (i.e., taxa for which existing information indicates they may warrant listing but for which substantial biological information to support a proposed rule is lacking). The Mojave ground squirrel is also listed as a threatened species by the State of California. In addition, the Mojave spineflower (Chorizanthe spinosa) is considered a USFWS Category 3 species (i.e., a species that has previously been considered as a candidate for federal listing as an endangered species, but is no longer being considered for such listing) (Appendix A). Descriptions of each of these species can be found in Sect. 2.1.6.3 of Appendix A.

2.2 MAN-MADE ENVIRONMENT

2.2.1 Population

As noted in Appendix A, Sect. 2.2.1, the area around the test site is sparsely populated. The nearest off-base population centers are the town of Boron (approximately 3.5 miles north-northeast of the test area) with a population of approximately 2,000, and the Desert Lakes community (approximately 3 miles north of the test area). The bulk of the on-base population at Edwards AFB is approximately 11 miles west-southwest of the test site area.

2.2.2 Socioeconomics

The primary socioeconomic interactions between Edwards AFB and its region are with southeastern Kern and northern Los Angeles counties (Appendix A, Sect. 2.2.2). The Palmdale-Lancaster area in north Los Angeles County serves as the local focus of military-related expenditures and housing.

2.2.3 Noise

Noise levels in the vicinity of the test site have not been measured to determine long-term or average noise levels. However, noise levels can reach 100 dB or more during aircraft testing on the nearby Precision Impact Range Area. The entire Edwards AFB area is subject to frequent overflights of high-powered military aircraft that often fly faster than the speed of sound, creating sonic booms.

2.2.4 Archaeology and Cultural Resources

As addressed in Appendix A, Sect. 2.2.4, no archaeological or cultural sites are known to exist sufficiently close to the test site area to be of concern. A survey of that area was conducted in December 1986, and no cultural or paleontological resources were found. A subsequent survey was undertaken on March 28-29, 1988 (Appendix D), by base personnel to amend the earlier report to include the potential for impacting cultural resources at the site of the new construction proposed for the rail spur area (Sect. 1.1.4). The pad area and adjoining 5 acres (Fig. 2.1) were examined without finding any archaeological or cultural resources.

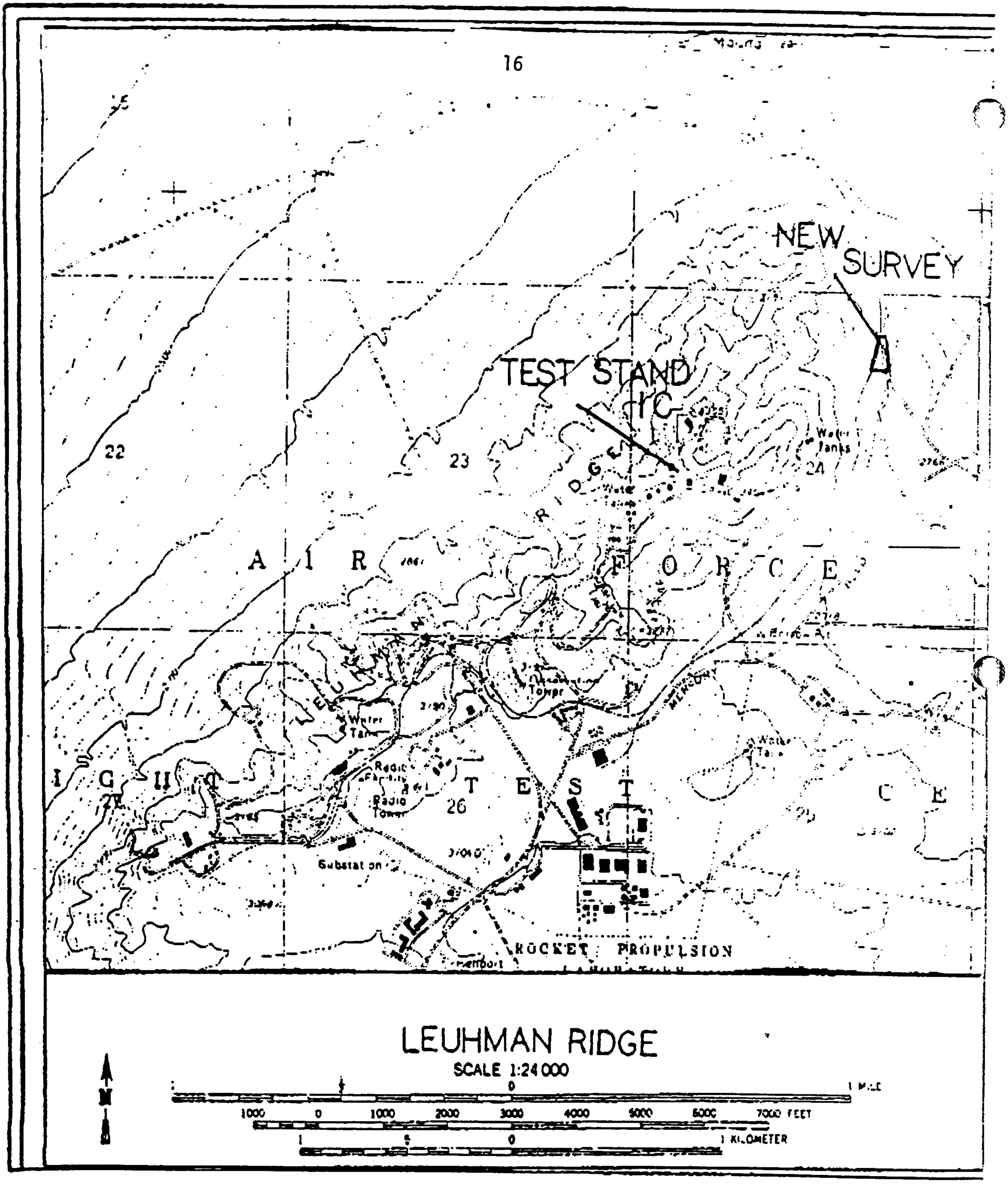

Fig. 2.1. Site of the March 28–29, 1988, cultural resources survey at the Air Force Astronautics Laboratory.

3. ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

3.1 IMPACTS TO GEOLOGY AND SOILS

The proposed construction for the Titan IV rocket motor tests will not adversely affect the geologic and soil resources of the area. Erosion will be minimized during construction of the rail spur improvements by the use of best management practices. The deposition of HCl from the tests are expected to be heavy in the immediate area of the test stand based on the results of the 34D test firing. The impacts of this deposition are expected to be small due to the use of the carbonate buffer system, the previously disturbed nature of the area, and the alkaline nature of the soil.

In addition, soil erosion will occur in the immediate vicinity of Test Stand 1-C, since approximately 344,000 gal of deluge water will not be trapped in the water collection system. The erosion will be limited in area, but perhaps extensive near the test stand. Soil erosion will be mitigated by pre-firing erosion control measures such as recontouring, the addition of riprap, or the construction of check dams in the area where erosion is likely to be the heaviest. In addition, post-firing mitigation efforts may include recontouring, mulching, and revegetation of affected areas. These mitigation efforts will minimize impacts to soils.

3.2 IMPACTS TO AIR QUALITY

This section deals with the analysis of impacts to ambient air quality. The nearfield effects of HCl deposition are addressed in the sections on soils, surface water and groundwater resources, ecological resources, and safety.

3.2.1 Estimated Rocket Motor Emissions

Each of the five Titan IV solid rocket motors will contain 680,694 lb of propellant. This is approximately 50% more propellant than was burned in the June 1987 test-firing of a Titan 34D booster. Since the propellant to be used in the Titan IV tests is very similar to that used in the earlier test (Appendix A, Sect. 3.2.1), the composition of exhaust constituents is expected to be the same, except that a relatively small amount of chlorine is expected with the Titan IV tests. The amounts of these constituents will increase over the earlier test due to the larger amount of propellant.

The estimated emissions at the nozzle of the rocket motor are shown in Table 3.1. These values were provided by Hercules Aerospace Company and are based on thermochemical data calculated by a computer program known as the KENVIL code. These data are shown in Appendix G. The nozzle emissions shown in Table 3.1 account for 99.7% of the propellant mass burned. The remaining 0.3% of the exhaust mass is made up of a variety of minor constituents not expected to be of significant concern.

Chemical reactions within the exhaust plume are expected to slightly alter the nozzle exhaust products within a short time after the emissions.

Table 3.1. Titan IV static firing emissions at nozzle (per motor)

Constituent	Pounds per test
Al_2O_3	244,247
HCl	143,912
H_2	15,058
N_2	56,777
CO	149,258
CO_2	16,978
H_2O	52,328
Cl	1,681

Table 3.2. Titan IV effective atmospheric pollutant emissions[a]

Constituent	Pounds per test
Al_2O_3	244,451
HCl	145,641
NO_x[b]	11,704
CO	37,789

[a] Compounds such as N_2, CO_2, H_2O, etc. are not considered air pollutants.

[b] Expressed as NO_2.

Specifically, the chlorine (Cl) is assumed to react with hydrogen to produce a small amount of additional hydrogen chloride (HCl), any remaining H_2 will oxidize to form water, some CO will oxidize to form CO_2, and some of the nitrogen (N_2) within the exhaust plume is expected to produce a small amount of nitrogen oxides (NO_x). The calculation of CO and NO_x amounts after the initial reactions are detailed in Appendix F. After these initial chemical reactions, the effective atmospheric emissions following the "afterburning" process are estimated to be as shown in Table 3.2. After the afterburning process, the exhaust plume contacts the deluge water and forms a tenacious sludge. The constituents of this sludge are primarily Al_2O_3, $AlCl_3$, HCl, and some ablative material from the flame bucket. This material is not a significant contributor to impacts on Air Quality. Rather, this issue is addressed in Sect. 3.3 on Impacts to Surface Water and Groundwater and Sect. 3.8 on Safety.

The constituents listed in Table 3.2 are of potential concern with regard to local or regional air quality. Al_2O_3 is not known to be toxic, but is expected to form small particles during the combustion process. Current air quality standards (Table 2.1) regulate the concentrations of PM_{10}. To be conservative, all emissions of Al_2O_3 were assumed to form particles less than 10 μm in diameter.

Based on the estimated emissions and on the previous dispersion modeling analysis for the Titan 34D rocket motor tests (see Appendix A), it was concluded that the only air pollutants of potential concern for the Titan IV tests are Al_2O_3 (assumed to be PM_{10}) and HCl. The quantities of NO_2 and CO are expected to be too small to have a significant impact relative to existing standards. Therefore, only PM_{10} and HCl were considered in the dispersion modeling analysis.

3.2.2 Dispersion Modeling Analysis

3.2.2.1 Model description

The Air Force Toxic Chemical Dispersion Model (AFTOX) was chosen to estimate concentrations of the rocket emissions at several distances downwind. AFTOX (Kunkel 1986) is a simple Gaussian puff model which was modified by the Air Force Geophysics Laboratory from a model called SPILLS (Fleischer 1980). AFTOX does not account for spatially or temporally varying winds, chemical reactions within the plume, or deposition effects. The AFTOX model is capable of simulating continuous or instantaneous releases of liquid or gas. For a release of finite duration, AFTOX simulates a plume segment with a series of overlapping puffs.

Rather than directly using the six discrete Pasquill stability categories (A-F) which are traditionally a part of atmospheric dispersion models, AFTOX uses a continuous stability parameter ranging from 0.5 to 6 to interpolate between the discrete Pasquill-Gifford dispersion curves in order to calculate the distribution of material within each puff. This alleviates the often sharp changes in predicted concentration when moving from one Pasquill stability category to the next. AFTOX computes the stability parameter based on either wind speed and solar insolation or on the standard deviation of horizontal wind direction. For the simulation of Titan IV rocket emissions, the former option was used. AFTOX uses Pasquill-Gifford dispersion parameters which are assumed in the model to be appropriate for 10-min average concentrations.

3.2.2.2 Meteorological input

The meteorological conditions for the Titan IV rocket tests will be bounded by mitigating measures similar to those described in the EA for the Titan 34D testing (Appendix A, Sect. 3.2.7). The only modifications to the previous meteorological constraints will be as follows:

1. As a requirement for testing, there will be no thunderstorms within 25 mi.

2. Comprehensive realtime meteorological and dispersion monitoring, data analysis, and refinement of the rocket exhaust dispersion model will be conducted to determine if the conservative meteorological conditions could be relaxed to an expanded wind corridor and lowered wind direction height requirements. These measures will ensure that if the firings are conducted under alternate meteorological conditions, the testing would not expose the general public to HCl concentrations above the recommended standards or reduce the level of protection provided by the current conditions.

If the expanded southeast portion of the wind corridor is used, some on-base personnel would be evacuated for safety purposes.

The five Titan IV rocket tests will be conducted from July 1989 through August 1990. Therefore, the yearly range of meteorological conditions, except as limited by the mitigating measures, must be considered for model input. However, due to the rather stringent limits placed on meteorological conditions under which a test firing could be conducted, a limited range of dispersion conditions is expected.

The dispersion rates simulated by AFTOX are affected primarily by wind speed and solar insolation. As with the earlier Titan 34D test, windspeeds must be over 5 knots (2.6 m/sec). Solar insolation will be governed by a requirement for daylight testing and a requirement that the surface-based nocturnal temperature inversion has dissipated. This will generally limit the tests to daylight hours after 10 a.m. Also, a required temperature decrease of at least 1°F from 6 ft to 54 ft above ground-level ensures relatively strong surface heating. Thus, unstable conditions (strong turbulent mixing) are ensured for the tests.

AFTOX model runs were conducted for four sets of meteorological conditions. These conditions and the corresponding stability parameters and plume heights are shown in Table 3.3. Note that a stability parameter of 4 corresponds to moderate turbulent mixing, while a parameter of 1 corresponds to intense turbulent mixing.

Case 4 was formulated to approximate the conditions under which the Titan 34D rocket motor was tested. The height at which the plume/puff stabilized for that test was visually estimated at between 2000 and 2500 ft above the desert floor surrounding Leuhman Ridge (personal communication, Lt. G. Rinehart, USAF AFRPL/SEH, and E. J. Liebsch, ORNL, March 29, 1988). To be

Table 3.3. AFTOX meteorological cases

Meteorological and dispersion parameters	Case 1	Case 2	Case 3	Case 4
Windspeed	5 kts (2.6 m/s)	8 kts (4.2 m/s)	13 kts (6.7 m/s)	25 kts (13 m/s)
Solar elev. angle	48°	63°	43°	56°
Stability parameter	0.9	2.1	3.0	3.4
Plume/puff height	1524 m (5000 ft)	1484 m (4869 ft)	990 m (3246 ft)	610 m (2000 ft)

conservative, in the current analysis a plume height of 2000 ft was assumed. Another conservative factor is that the additional heat release from the larger Titan IV rocket is not taken into account in using this value. Although the total water deluge flow rate is expected to be slightly larger (approximately 11%), the 50% larger propellant mass is expected to more than offset this factor. Plume rises and total plume heights for the other wind speeds were estimated by extrapolation from the Titan 34D value according to the commonly used Briggs plume rise formulae (Briggs 1971). These calculations are shown in Appendix E. It should be noted that for the 5-knot windspeed (Case 1), the extrapolated plume height was over 7000 ft. To account for the possibility of an elevated subsidence inversion, a plume height of 5000 ft. was used for this case. As explained in the EA for the Titan 34D rocket test (Appendix A, Sect. 2.1.2), such inversions occur in the area occasionally. The presence of a strong subsidence inversion would tend to act as a cap, allowing little additional plume rise beyond the level of the inversion.

3.2.2.3 Modeling assumptions

The entire amounts of pollutants listed in Table 3.2 were assumed to be released into the atmosphere. It is known that the water deluge will remove some, perhaps significant amounts, of the emissions, but the quantities are uncertain. To be conservative, it was assumed that there is no removal. As a plume disperses and contacts the ground, pollutants are also deposited. The deposition was also ignored in this analysis. In addition, removal of constituents by chemical reactions was ignored.

The AFTOX option for a continuous gaseous release was used to simulate rocket motor emissions. The length of the release was assumed to be 2 min, 13 sec, based on data provided by Hercules Aerospace Company (see Appendix G). This is slightly longer than the 2-min Titan 34D test, due to the larger volume of propellant to be burned and the rocket motor geometry.

For the AFTOX model runs, the plume was assumed to be released at its calculated final plume height. Although this assumption tends to underpredict concentrations very near the source, it will not significantly affect concentrations at points beyond the distance at which final plume rise is reached. The distance to final plume rise is expected to be well within the boundaries of Edwards AFB under all meteorological conditions meeting the constraints described above.

3.2.3 Model Results

3.2.3.1 Averaging time considerations

The concentration contour plots from the AFTOX model runs revealed that the plume segment (simulated by a series of puffs) had the appearance of a puff after a relatively short travel time (>10 min). This is because the extent of horizontal (x and y direction) dispersion quickly became large relative to the initial length of plume segment. Since the AFTOX model presents the concentration predictions at a "snapshot" in time, it is necessary to make some adjustments of the predicted concentrations for this instantaneous "puff" or plume segment in order to determine concentrations over the averaging times of interest. The plume segment will pass a given receptor in a relatively short time (well under 1 hr for the transport distances of interest here). Thus, the maximum 1-hr concentration, for example, will be well below the peak instantaneous concentration, or even the average concentration, during passage of the plume segment.

With regard to HCl concentrations, the peak instantaneous concentrations estimated by AFTOX were used as a conservative estimate of the 10-min average concentrations. Due to the finite length of the release and resulting plume segment, the concentration tends to "flatten-out" briefly (on the order of a minute or so) as the maximum concentration is reached during passage of the plume segment. The concentration on either side (upwind and downwind directions) of this peak will drop off according to the Gaussian distribution. Thus, a true 10-min concentration may be, for example, only 75% of the peak concentration. As the plume segment disperses with distance, the 10-min concentration will approach the peak concentration, making the above assumption less conservative.

For obtaining 24-hr PM_{10} concentrations, it was necessary to estimate the average concentration over the time of plume segment passage at a given distance. This was done by a rough averaging of the nearly Gaussian distribution of concentration in the X-direction. Although somewhat crude, such estimates are probably within 25% and are of sufficient accuracy given the other uncertainties involved. The average 24-hr concentration at each distance of interest was determined by multiplying the average concentration over the length of the plume segment by the ratio of (plume segment passage time in hours)/24.

3.2.3.2 Maximum predicted HCl concentrations

Maximum predicted ground-level HCl concentrations are shown in Table 3.4. The maximum predicted HCl concentrations are well below the NAS guideline of 3 ppm at all distances for cases 2 through 4 (NAS 1980). The only predicted exceedance of the NAS guideline was for case 1 at 2 km downwind. However, because of the vigorous mixing associated with the light

Table 3.4. Maximum predicted 10-min HCl concentrations

Distance[a]	Case 1 (5 kts) (ppm)	Case 2 (8 kts) (ppm)	Case 3 (13 kts) (ppm)	Case 4 (25kts) (ppm)
1 km	<1	neg.[b]	neg.	neg.
2 km	8.9	neg.	neg.	neg.
4 km	0.8	neg.	neg.	neg.
6 km	0.16	0.4	neg.	neg.
10 km	0.02	0.93	0.2	0.2
15 km	neg.	0.6	0.4	0.6
20 km	neg.	0.3	0.5	0.75
25 km	neg.	0.19	0.45	0.80
30 km	neg.	0.12	0.37	0.70

[a] Relative to the point of emissions. The approximate distance from this point to the nearest Edwards AFB boundary within the allowable wind corridor is 7.5 km.

[b] Less than 0.01 ppm.

windspeed conditions for Case 1, ground-level HCl concentrations are predicted to diminish to very low levels by the time the plume segment crosses the nearest property boundary of Edwards AFB within the allowable wind corridor.

Because the conditions for Case 4 were formulated to simulate the conditions that existed for the Titan 34D test, it is of interest to compare the predicted concentrations for this case with the HCl monitoring results obtained in conjunction with the Titan 34D test (Appendix B). Based on the wind direction during the test and on visual observations, it appears that the plume would have crossed the Edwards AFB property line slightly south of the northeast corner of the base. While there are some discrepancies between different types of monitoring instruments, the most reliable measurements seem to be a 0.1 ppm 1-min average value at the northeast corner of the base (Askania 1-A site) and a peak value of 0.12 ppm measured by a mobile monitoring van which was placed under the visually estimated plume centerline, approximately 1 mile south of the northeast corner of the base.

The maximum predicted AFTOX value at the distance of the above measurements (approximately 15 km) was 0.6 ppm for the Titan IV simulation. Recall that the AFTOX HCl predictions are peak values, which were conservatively used as 10-min averages. Accounting for the lower Titan 34D HCl emissions, which were approximately two-thirds of the HCl emissions assumed for the Titan IV, the maximum HCl concentration predicted by AFTOX would be 0.4 ppm for the Titan 34D test. This is three to four times higher than the monitor values discussed above. While it is likely that the monitors did not record the actual peak ground-level concentration at the base boundary, the placement of the mobile monitoring unit under the observed plume track probably ensures that the actual peak value was not drastically higher than the monitored value. The apparent overprediction by AFTOX may be due to a number of factors, including possible underestimation of the plume height, underestimation of the degree of dispersion, neglect of initial washout by the water deluge, and downwind HCl removal by surface deposition and by chemical reactions. Regardless of the source of the apparent overprediction, the HCl monitor results seem to indicate conservatism in the AFTOX predictions.

3.2.3.3 Maximum predicted PM_{10} concentrations

Maximum predicted 24-hr PM_{10} concentrations are shown in Table 3.5. Background levels (existing) concentrations of PM_{10} were added to the modeled concentrations in order to estimate maximum potential ambient PM_{10} concentrations.

The background 24-hr PM_{10} concentration used is a very conservative value and is based on the second-highest measured PM_{10} concentration during 1986 at the town of Barstow, approximately 60 km east of the test site. The second highest 24-hr PM_{10} concentration at Barstow was higher than the second highest value at either Victorville (55 km southeast of the test site) or Mojave (48 km northwest). The second highest value was chosen in order to correspond with the federal PM_{10} standard, which allows one exceedance per year at a receptor.

The total PM_{10} concentrations listed in Table 3.5 are below the 24-hr federal PM_{10} AAQS of 150 $\mu g/m^3$ at all distances beyond the Edwards AFB

Table 3.5. Maximum predicted 24-hr PM_{10} concentrations, ($\mu g/m^3$)

Distance[a]	Background conc.	Case 1 (5 kts)		Case 2 (8 kts)		Case 3 (13 kts)		Case 4 (25 kts)	
		Model	Total	Model	Total	Model	Total	Model	Total
1 km	92	<12	<104	neg.[b]	92	neg.[b]	92	neg.	92
2 km	92	278	370	neg.	92	neg.	92	neg.	92
4 km	92	21	113	neg.	92	neg.	92	neg.	92
6 km	92	13	105	5	97	neg.	92	neg.	92
10 km	92	1	93	23	115	3	95	2	94
15 km[c]	92	neg.	92	22	114	7	99	5	97
20 km	92	neg.	92	20	112	11	103	9	101
25 km	92	neg.	92	16	108	13	105	10	102
30 km	92	neg.	92	10	102	14	106	11	103

[a] Relative to the point of emissions. The approximate distance from this point to the nearest Edwards AFB boundary within the allowable wind corridor is 7.5 km.

[b] Less than 0.5 $\mu g/m^3$.

boundary. The only exceedance is for Case 1 at a distance of 2 km, but this is well within the base boundary, regardless of the wind direction assumed. Total PM_{10} concentrations are well over the more stringent California 24-hr PM_{10} AAQS of 50 $\mu g/m^3$. However, it should be noted that the existing concentrations of PM_{10} are well over the standard. The maximum additional impact of the Titan IV tests is predicted to be only 10-20% of the total PM_{10} loading for 5 days out of 14 months and, therefore, is not a significant impact.

The California and federal PM_{10} AAQS for the annual averaging period are 30 $\mu g/m^3$ and 50 $\mu g/m^3$, respectively. With only five Titan IV tests over approximately a 14-month period, the incremental annual PM_{10} impact based on the off-base worst-case (Case 2) and assuming the plume centerline for each test crossed the same receptor, the maximum incremental annual PM_{10} concentration would be only 0.3 $\mu g/m^3$. This is insignificant relative to the state and federal AAQS.

3.2.4 Worst-Case Scenarios

3.2.4.1 Rocket failure

The consequences of a rocket failure are explained and analyzed in the EA for the Titan 34D solid propellant rocket motors (Appendix A, Sect 3.2.6). The results of that analysis indicated that the downrange (off-base) pollutant concentrations would be much lower than for a normal firing. The main reason for this result would be that the exhaust would spread radially from the rocket, resulting in very little contact with the deluge water. Because of the higher exhaust cloud temperature, the plume would rise much more than for a normal firing.

A failure of a Titan IV rocket during firing is expected to produce a similar effect to that described for the Titan 34D. Plume rise would probably be somewhat greater than for the Titan 34D scenario due to a larger heat release. However, even if the Titan IV plume rise was assumed to be the same as for the Titan 34D, the concentrations would only increase linearly according to the increased Titan IV emissions. According to the results of the earlier analysis (p. 3-18 of Appendix A), these impacts would be much lower than for a normal firing.

3.2.4.2 Nonbuoyant exhaust cloud

The scenario of a nonbuoyant exhaust cloud was analyzed in the EA for the Titan 34D rocket. Apparently this was considered due to concern that the heat of vaporization from the deluge water might consume all of the exhaust heat, resulting in a nonbuoyant plume. The Titan 34D rocket motor test results provide assurance that this will not occur for the Titan IV test. Although the deluge water total flow rate during ignition for the Titan IV test is expected to be 11% greater, this will be more than offset by the approximately 50% greater propellant mass to be burned. Thus, no further analysis of the nonbuoyant exhaust scenario was conducted for the Titan IV test.

3.2.5 Plume Visibility and Acid Deposition off Edwards AFB

Based on experience with the Titan 34D rocket testing, visibility impacts will be limited primarily to Edwards AFB and will be very brief. Observations by USAF personnel (Reinhart) indicated that the Titan 34D plume dispersed very rapidly and was very difficult to discern as it crossed the Edwards AFB property boundary. Since emissions from the Titan IV will be only moderately (less than a factor of two) larger, they are not expected to cause significant visibility impacts.

Given the comparatively low HCl concentrations expected off-base and the brief period of exposure (generally under 15 minutes per test), the amount of HCl deposition at locations off Edwards AFB is expected to be quite small. Since rain in the vicinity is precluded by meteorological constraints during the tests, any HCl deposited in the region around Edwards AFB is likely to be in the form of gas or small aerosols.

A facility of particular concern with regard to visibility and acid deposition is the Luz Engineering solar mirror electric generating complex just north of Kramer Junction, at the northeast corner of Edwards AFB. The nature of expected impacts from the Titan IV testing was discussed with a representative of Luz Engineering (Robert Cimburg, Luz Engineering, personal communication with E. J. Liebsch, ORNL, April 18, 1988) to receive any concerns with regard to the proposed tests. Visibility impacts were mentioned by Mr. Cimburg as an area of concern. Based on the observations during the Titan 34D test, however, visibility impacts are expected to be minimal. Another possible impact discussed with Mr. Cimburg was acid deposition on the surface of the mirrors. The sensitivity of the mirrors to acid deposition is unknown at this time. If Luz Engineering determines that acid deposition is a significant concern, a washing of the mirrors will be conducted at the expense of the USAF immediately after exhaust cloud passage, in the event that the cloud passes over the solar mirror generating facility. This would not be an extraordinary measure, since according to Mr. Cimburg, the mirrors are washed periodically as part of the normal operating procedure.

3.2.6 Summary of Air Quality Impacts

The five Titan IV rocket motor static firing tests will generate Al_2O_3 (assumed to be in the form PM_{10}), HCl, relatively small amounts of CO and NO_2, and very minor quantities of other air pollutants. A reasonable and conservative worst-case dispersion modeling analysis of PM_{10} (AL_2O_3) and HCl emissions has indicated that concentrations of these pollutants beyond the boundaries of Edwards AFB will not adversely affect air quality.

The dispersion modeling analysis, considered to be conservative based on monitoring data during a similar rocket motor test (Appendix B), indicated that the maximum HCl concentration beyond the Edwards AFB boundary would be 0.93 ppm, compared to the NAS guideline of 3.0 ppm over a 10-min period.

The maximum modeled 24-hr concentration of PM_{10} beyond the Edwards AFB boundary was 23 $\mu g/m^3$. This is well below the 24-hr California and federal PM_{10} AAQS of 50 $\mu g/m^3$ and 150 $\mu g/m^3$, respectively. However, the California AAQS of 50 $\mu g/m^3$ is frequently exceeded in the region, probably due to the dry surface soil conditions prevalent in the desert climate coupled with human activities. While the predicted PM_{10} impact may add a small amount to the existing high levels of PM_{10}, this is not considered a significant impact because of the small number of tests (5) in a fourteen-month period.

The cumulative impacts of the 5 Titan IV rocket motor tests on air quality will be small. PM_{10} concentrations as a result of the tests considered on an annual basis are low. Given the brief period of exposure and the small number of proposed tests, the cumulative impacts from HCl deposition are expected to be small. It is not known, at this time, if other rocket motor tests or other new air pollutant emitting activities at Edwards AFB are proposed during the proposed testing period. If other activities subject to NEPA are proposed during this period, the environmental analyses for these activities will consider the cumulative effects of the new emissions and those for the Titan IV tests if appropriate.

3.3 IMPACTS TO SURFACE WATER AND GROUNDWATER RESOURCES

Each of the static test-firings will require approximately 674,000 gal of deluge water and a few thousand additional gallons for pad washdown. All water will be supplied from existing wells as described in Appendix A, Sect. 3.4. Each firing will produce wastewater from the deluge water system containing byproducts of the test such as the ablative heat shield material in addition to the products of combustion and a few thousand gallons of water from pad washdown. This material will be collected and treated as described in Appendix A, Sects. 1.2.5.2 and 3.4, ensuring no discharges of this material to surface water or groundwater recharge areas. Of the 674,000 gallons of water used, approximately 330,000 gallons (see Table 1.1) are expected to be collected and treated for each Titan IV test. The fate of the remaining water will be fallout from the exhaust plume immediately below the berm, rainout within a few hundred meters of the test stand, and evaporation.

Based on observations from the Titan 34D test, it is expected that there will be some runoff from the hillside around Test Stand 1C. This runoff will be locally heavy below the test stand, causing some erosion. More moderate liquid deposition will likely occur over an area within a few hundred meters of the test stand, due to wind-carried mist and splash from the deluge water. Three collection sites in the vicinity measured amounts of up to 1 cm of rainout during the Titan 34D test (see Appendix B). Because of the rocky nature of the ridge on which the test stand is located, this deposition is expected to quickly run off in a manner similar to what occurs during a brief, heavy thunderstorm. Based on observations from the Titan 34D test, this runoff is expected to have a pH under 3, due to washout of HCl from the exhaust plume. However, because of the alkaline nature of the Mojave desert soils surrounding the ridge, the moderate acidity of this runoff is expected to be quickly neutralized as the water soaks into the soil.

The cumulative impacts of the 5 Titan IV rocket motor tests on surface water and groundwater resources are expected to be small since no surface or groundwater resources in the area will be affected by any of the tests and the timing of the tests is such that no long-term accumulation will not occur. It is not known, at this time, if other rocket motor tests or other new water discharging activities at Edwards AFB are proposed during the proposed testing period. If other activities subject to NEPA are proposed during this period, the environmental analyses for these activities will consider the cumulative effects of the new discharges and from the Titan IV tests if appropriate.

3.4 IMPACTS TO ECOLOGICAL RESOURCES

The testing would take place at an existing test area that has been used for similar tests for many years. In general, disturbance to habitat has already occurred including an area near the test stand where plants show damage in the form of plant cell necrosis, and significant impacts to existing habitat from the test are not anticipated. In addition to the actual test of the Titan rocket motors, an existing railroad spur will be modified, a flat concrete pad approximately 4950 ft^2 will be built, and an asphalt parking area and rail spur will be refurbished. Areas to be affected by these activities have been previously disturbed but do continue to support natural vegetation (Appendix C).

An EA of a previous test (Appendix A) concluded that no significant impacts to biota would occur. Because the proposed test involves the use of more propellant than the previous one, the possibility of additional effects has been evaluated.

An acidic mist of pH 3.0 or lower (Appendix B) will be formed by contact of the deluge water with the rocket exhaust during ignition and will fall within approximately 1 mi of the area near Test Stand 1-C (Appendix A, Sect. 3.2). The potential effect on vegetation and wildlife species of the Mojave Desert is discussed below.

The testing of the Titan rocket motors at Test Stand 1-C is not expected to significantly impact the vegetation of the AFAL area if assumptions regarding the extent and intensity of the deluge water rainout impact area are valid. However, uncertainties are associated with estimates of the size of the impact area. Also, due to the increased size of the rocket motor, the associated increase in volume of propellant consumed, and the resulting increased exhaust cloud size, the extent of the impacted area may be greater than that of previous tests. If so, the potential would exist for the loss of some, probably small, additional area of habitat.

Another uncertainty associated with the estimation of potential biotic impacts results from the poor estimates available for the expected acidity of the deposition of the deluge water in the vicinity of the test stand. Deposition of deluge water associated with the launch of the shuttle from Cape Canaveral would suggest that solutions significantly more acidic than pH 3.0 have been common over a major portion of the impact area. A recommended measure is to continue carefully monitoring deposition using a systematic manner in order to resolve this uncertainty.

Research performed on numerous plant species common to the area indicates that pH 2.5 hydrochloric acid treatments did not cause significant short-term injury to those species. However, pH 1.7 solutions caused significant amounts of injury (Granett and Taylor 1977, Granett 1984). Damage appeared as necrosis (death) of cells located in the vicinity of the stomata, pores in the leaf surface through which gas exchange occurs. Agriculturally important and ornamental species were found to be the most sensitive, being primarily broadleaved species. Literature reviews of the effects of HCl (NAS 1976) report large differences in species sensitivity to the gas and acid mist. Cell wall thickness and amount of intercellular space seem to influence the severity of symptom expression. A pH of 3.0 would be considered relatively acidic, especially for agricultural and horticultural species. However, xerophytic (desert or dry environment adapted species) plants are generally more resistant to acid exposure due to (1) the presence of thick layers of epicuticular wax, which both protect from acid and reduce the wetability of the surface, and (2) modified or reduced numbers of stomata; both features are adaptations to reduce water loss by the plants in the harsh desert environment.

Reviews of the Titan 34D EA (Appendix A) by the California Department of Fish and Game (DFG) (letter dated February 9, 1987, to R. Mason, USAF, from G. D. Nokes, DFG) and the USFWS (letter dated February 10, 1987, to Elaine M. Archibald, Brown and Caldwell Consulting Engineers, from Gail C. Kobetich, USFWS, Sacramento, California) concluded that no significant effects on fish and wildlife or their habitat would occur from the proposed action.

Increased personnel activity and elevated noise levels associated with the modifications to the test stand and the test-firings will temporarily disturb wildlife in the immediate vicinity. In addition, it can be anticipated that wildlife in the vicinity would continue to be impacted by irritation due to revolatilization of HCl gas for some period of time after the firings. However, these impacts are not expected to be significant.

Additional information developed by the USAF since the Titan 34D EA (Appendix C) indicates that desert tortoises (a Category 2 candidate species of the USFWS) have been observed within the area where vegetation has been affected by previous rocket motor tests. An unknown number of tortoises may be in the area and could be adversely affected by noise and acidic deposition that would occur during the proposed tests. The USAF, in consultation with DFG and USFWS will monitor potential impacts to the desert tortoise before and after each proposed test.

Observations by USAF personnel have indicated that the Mojave ground squirrel (a Category 2 candidate species of the USFWS) may be present near the railroad siding (Appendix C). USAF staff, in consultation with the DFG and USFWS, will conduct surveys and determine whether these species are present and would be affected by the test. The fact that the site has been used for testing in the past suggests that any effect on the ground squirrel populations would be temporary.

A population of desert cymopterus (a Category 2 candidate species of the USFWS) has been discovered approximately 2 miles north northeast of the Test Stand 1-C, and the desert floor north of Leuhman Ridge is a likely habitat for this species (Appendix C). Again, the presence of the species in an area that has already been subjected to testing suggests that no significant impacts to the existing known populations would occur from the proposed action. However, USAF staff will conduct additional surveys in consultation with DFG and USFWS to locate this species and other plant species discussed in Sect. 2.1.4.3 in areas potentially affected by rocket motor testing. Populations will be monitored to determine if the plants are affected.

A prairie falcon (Falco mexicanus) was recently observed within 1/4 mile of Test Stand 1-C on Leuhman Ridge (Appendix C). Several areas in the vicinity may represent potential falcon nesting sites. Discussions between USAF and DFG personnel (reported in personal communication between M. V. Phillips, USAF, and D. M. Evans, ORNL, March 30, 1988) have indicated that this species would probably be temporarily frightened from any nearby nest during the tests, but no long-term effect, such as abandonment of the nest, should occur due to noise. Any adverse effects of acidic deposition on the prairie falcon are unknown, but if they occurred, they would probably be indirect effects on habitat and food sources. Long-term monitoring of this species and its habitat will be conducted to determine effects of the rocket motor tests on existing populations.

3.5 IMPACTS TO POPULATION AND SOCIOECONOMIC RESOURCES

The proposed testing of the Titan IV rocket motors is expected to create no significant impact on population and housing in the region around Edwards AFB (Sect. 2.2.2) based on the experience of the 34D test. Impacts during construction may be smaller than experienced for the 34D tests since modifications proposed for the Titan IV tests are relatively minor. The local economy of the region may receive some short-term additional income from construction-related expenditures (e.g., payments associated with temporary housing or miscellaneous construction materials) that will positively impact the economy.

3.6 NOISE IMPACTS

Assessment of noise impacts associated with the proposed rocket testing are based on actual measurements of noise produced by static tests of the 5-1/2 segment Titan 34D rocket motors (personal communication, S. Burrell, USAF, Edwards AFB, and D. M. Evans, ORNL, March 31, 1988). The proposed Titan IV rocket motor has been evaluated for expected increases in noise levels with respect to the noise produced by the 5-1/2 segment Titan rocket motor on the basis of increased thrust and exit velocity. It is estimated that the Titan IV motor may produce an increase of approximately 1 dB in overall sound pressure level. The spectral distribution is expected to be about the same. Since humans cannot, on the average, detect differences of 1 dB(A) (EPA 1974) no differences in human impacts are anticipated relative to those determined for the 5-1/2 segment motor. Noise level peak amptitudes at frequencies of 0 to 20 kHz at selected distances (0.75 mi, 1.25 mi, 2 mi, and 4 mi) from the test site have been measured to be less than 80 dB in all cases.

It is expected that even as near as 0.75 mi the noise levels will be less than 80 dB at any frequency from 0 to 20 kHz. It is anticipated that overall measures reflecting an integration of the octave bands from 2 to 8000 Hz will yield sound pressure levels of 85 dB(A) or less for distances of 3/4 mile or greater. This estimate is substantially below the levels shown in Appendix A which used an efficiency factor for mechanical to acoustical energy of 0.3%. Current methods for use of deluge water decrease this factor considerably (as reflected in the actual measurements). Since the nearest residences are beyond 3/4 mile and inhabitants have experienced such noises routinely, no adverse effects are anticipated for the proposed static tests.

3.6.1 Impacts - Planned Test Conditions

Measurements indicate no risk of structural damage to residential buildings. Personnel at AFAL will not be in danger of suffering hearing damage nor will residents experience levels sufficient to result in speech interference, or possibly even perception. Nighttime tests are not planned, thus precluding most sleep interference. There is no reason to expect a startle reaction for automobile drivers in the immediate vicinity of Desert Lakes and the highway rest stop although as a safety precaution, the Air Force will display warning signs in the appropriate areas.

3.6.2 Impacts - Failure/Abort Conditions

In the event that it becomes necessary to terminate a test firing by splitting the motor case, a high amplitude pressure wave will be generated. Overall sound pressure levels could be high enough to cause slight aural pain for persons at Desert Lake. Persons closer could possibly experience slight hearing damage. Startle reaction of automobile drivers is also possible.

3.6.3 Mitigation Measures

The potentially significant impacts of rocket motor testing include hearing damage to personnel outside the bunker room at the test site. Mitigation measures for both controlled and uncontrolled populations should include an evacuation within 1 mile of the test stand.

3.7 IMPACTS TO ARCHAEOLOGICAL AND CULTURAL RESOURCES

Due to the absence of archaeological and paleontological resources noted during the December 1986 survey of the area around Test Stand 1-C (Appendix A, Sect. 2.2.4) and consultation with the state historic preservation office (personal communication, Elaine M. Archibald, Brown and Caldwell, and Bob Mason, USAF, Feb. 26, 1987) and the subsequent survey of the railroad spur area in March 1988 (Appendix D), the proposed construction and testing of Titan IV motors will not directly or indirectly affect any archaeological or paleontological resources in the area. There will be no affect on properties included in or eligible for the National Register of Historic Places. If project design changes requiring disturbance of larger land areas or changes in areas to be disturbed, additional cultural resource surveys and evaluations may be necessary. If cultural resources are encountered during the construction, work shall be stopped and the base archaeologist or his representative will be contacted immediately to inspect the material.

3.8 SAFETY

The rocket motor segments to be used for the test-firings will be transported to AFAL by common-carrier rail service from the Hercules Bacchus Works Plant 1 rocket motor manufacturing facilities approximately 25 miles east of Salt Lake City, Utah, to AFAL. The Titan IV motors will be transported in Titan IV railroad cars. Motor segments will be hoisted onto an open car and locked into a restraint system. An environmental cover, which has been grounded, will then be placed over the segment and an attached environmental-control unit will be used to provide temperature and humidity control within the cover. The process will be reversed to unload the segment. The storage facilities and transportation routes are not identified in this EA for security reasons. Regulations of the U.S. Department of Defense (DOD), and the U.S. Department of Transportation (DOT) will be observed to ensure compliance in transport, movement, and handling of all Titan IV rocket motor segments. Segments will be stacked and mated according to Hercules, Inc.'s standard procedures and safety regulations. Following each test, the spent rocket motors will be disassembled and transported off-site for detailed examination.

All safety procedures described in Appendix A, Sect. 3.9 including a Safety Procedures and Contingency Plan and a Pre- and Post-Test Contingency Plan will be adhered to, with the following changes:

1. As a requirement for testing, there will be no thunderstorms within 25 nautical mi.

2. All areas within Edwards AFB in the wind corridor will be evacuated during the test firings.

3. The posting of warning signs on highways 58 and 395 will be required as a safety precaution.

4. A 1-mile clear zone where personnel will be evacuated will be established around Test Stand 1-C during the firings due to the potential for explosions.

5. Comprehensive realtime meteorological and dispersion monitoring, analysis, and refinement of the rocket exhaust dispersion model will be conducted to determine if the conservative meteorological conditions could be relaxed to an expanded wind corridor and lowered wind direction height requirements. These measures will ensure that if firings are conducted under alternate meteorological conditions, the testing would not expose the general public to HCl concentrations above the recommended standards or reduce the level of protection provided by the current conditions.

3.9 ENVIRONMENTAL MONITORING

In order to document the environmental effects of the proposed Titan IV tests and develop appropriate mitigation measures, several types of monitoring will be conducted. The aspects to be monitored include meteorology, air quality, liquid deposition, noise, vegetation, and wildlife. Mitigating measures resulting from monitoring can be developed to address individual rocket motor tests as well as the potential cumulative impacts before the entire series of tests is completed. As a minimum, the environmental monitoring plan will contain the following elements:

1. HCl monitors. HCl concentrations will be monitored at several points near the perimeter of the base within the allowable wind corridor. At least one mobile HCl monitor will be placed near the estimated plume

centerline beneath the exhaust cloud as it exits the base. Infrared HCl monitors will be employed to observe the cross-section of the plume as it passes off the base.

2. PM_{10} monitors. A PM_{10} monitoring plan will be developed in order to document the regulatory compliance of the tests. It is expected that several PM_{10} monitors will be used, including one mobile unit to be placed beneath the exhaust cloud as it exits the base.

3. Noise monitors. Although noise was not observed to be a problem for the smaller Titan 34D test, only limited measurements were made. Noise monitors will be employed at least for the first Titan IV test. If, as expected, noise levels are quite small at the distances of concern, no noise monitoring will be conducted for subsequent tests.

4. Liquid deposition monitoring. Several wet deposition collection sites (pans) will be employed to determine the extent and strength of acidic deposition in the test stand vicinity. The number of collection sites and the area covered will be at least as extensive as for the Titan 34D test (see Appendix B).

5. Ecological monitoring. Surveys will be undertaken prior to the first test firing to establish in some detail the baseline conditions of vegetation and wildlife. Particular care will be taken to adequately identify and characterize the presence of the Mojave ground squirrel, the desert tortoise, desert cymopterus, as well as the general condition of vegetation near the test stand. Post-firing monitoring will be undertaken after each test to determine any adverse effects and to form the basis of any recommended mitigation. Baseline and post-test monitoring efforts and any resultant mitigation will be conducted in coordination with USFWS and DFG.

6. Meteorological monitoring. These efforts will be at least as extensive as described in the EA for the Titan 34D testing (Appendix A, p. 3-21). However, additional monitoring techniques such as realtime SF_6 tracer monitoring and acoustic sounders for measurement of winds aloft may be employed to ensure that the exhaust plume trajectory will remain within the allowable wind corridor.

7. Occupational Safety Monitoring. The monitoring used to ensure occupational safety at AFAL for the Titan 34D tests was quite effective. Those procedures, described in Appendix A, Sect. 3.9, will be repeated for the proposed test with any changes from those procedures described in the Safety Procedures and Contingency Plan and Pre- and Post-Test Contingency Plan.

3.10 SUMMARY OF IMPACTS AND MITIGATION MEASURES

The environmental impacts of the Titan IV solid propellant rocket motor testing at Edwards AFB are summarized in Table 3.6. Mitigation measures which will reduce the impacts are also identified in the table.

Table 3.6. **Summary of impacts and mitigation measures**

Environmental resource	Impacts	Mitigation measures
Geology and soils	Some erosion and acidic deposition near the test stand, but no significant impacts.	Pre-firing efforts to include erosion control measures such as recontouring, the addition of riprap, or the construction of check-dams. Post-firing efforts to include recontouring, mulching, and revegetation of affected areas.
Air quality	Existing levels of PM_{10} frequently exceed CA 24-hr standard of 50 $\mu g/m^3$. Rocket tests will add up to 23 $\mu g/m^3$ beyond boundary of Edwards AFB. HCl maximum off base of 0.93 ppm, compared to a 3.0 ppm NAS guideline.	AFAL weather conditions (no thunderstorms within 25 nautical miles, wind speed greater than 5 knots, and no inversions) will be met. In addition, the tests will be conducted only when the wind is blowing from 260 to 310 degrees azimuth up to 10,000 ft AGL unless comprehensive research determines testing conducted under alternate conditions would not reduce the level of protection provided by the current conditions. This will prevent the exhaust cloud from blowing over any nearby inhabited areas.
	Possible slight acid deposition at Luz Engineering solar mirror generating complex.	Wash mirrors if exhaust cloud passes over Luz Engineering facility.
Surface water and groundwater	Moderate to heavy rainout of acidic deluge water causing some runoff and erosion on hillside near test stand. Acidic runoff will soak into and be neutralized by alkaline soil.	Deluge water contained in the channel and basin will be evaporated. pH of rainout will be moderated by sodium carbonate buffering.

Table 3.6. Continued

Environmental resource	Impacts	Mitigation measures
Ecological Resources	Acidic mist may threaten the health of plants and animals in the area and contribute to the continued degradation of habitat in the immediate vicinity of the test.	Large quantities of deluge water with sodium carbonate additive should result in a deposition pH between 1 and 3. Systematic monitoring of vegetation and wildlife before and after the tests will be done to document any adverse effects to plant and animal populations and habitat and provide direction for further mitigation.
	Noise from the rocket motor tests may temporarily frighten sensitive animal species including the desert tortoise, prairie falcon, and Mojave ground squirrel. Noise may pose a hearing problem to the reproduction of the desert tortoise in the vicinity of the rocket motor tests.	Systematic monitoring of populations of these sensitive species will be done to determine if any adverse effects will occur and provide direction for further mitigation.
Population and Socioeconomics	No significant impacts.	None required.
Noise	Noise levels at nearest residential area will not be significant.	Warning signs will be posted on highways 58 and 395.
	Potential high noise levels in AFAL area with rocket failure event.	Evacuate AFAL area within 1 mile of test stand.
Archaeology and cultural resources	No impacts expected.	None required. Base archaeologist will be notified in the event of discovery of archaeological or cultural resources during construction.

Table 3.6. Continued

Environmental resource	Impacts	Mitigation measures
Safety	Deposition of acidic material near the test stand and revolitization of HCl.	All regulatory agencies' safety procedures will be followed. Safety monitoring will be conducted during tests. Telephone hotline fire and medical personnel will be available. Warning signs will be posted on highways 58 and 395. Clear zone of 1 mile will be established. No one will be allowed into the immediate downwind area within the base boundaries. Roads will be closed in clear zone. Essential test personnel will be located in protected concrete bunker. Realtime air supply monitoring will be performed.

4. REGULATORY REVIEW

4.1 AIR QUALITY

An overview of air quality regulatory requirements of the Kern County Air Pollution Control District (APCD) is given in Appendix A, section 4.1. As with the Titan 34D testing, a research exemption will be requested from the Kern County APCD for the Titan IV tests. The only facilities connected with the Titan IV testing program that are expected to require air pollution permits from the Kern County APCD are a spray painting booth in the receiving and inspection building 1D and a small backup generator to supply emergency power to monitoring instruments at Test Stand 1C. The ambient air quality impact of these facilities is expected to be negligible.

4.2 WATER QUALITY

The California Regional Water Quality Control Board, Lahontan Region issues monitoring and reporting board orders for the Edwards AFB region for discharges of wastes to surface waters and waste discharge requirements for discharges of waste that may affect groundwater quality. USAF will submit a report describing the waste discharge of the project to the Board for consideration of a waiver of waste discharge requirements.

4.3 ENDANGERED SPECIES

As described in Sect. 2.4, the static testing of the Titan IV rocket motors will not affect any federal- or state-listed threatened or endangered species. The USFWS and DFG will review the EA. A description of the protection of threatened and endangered species is contained in Appendix A, Sect. 4.3.

4.4 SOLID AND HAZARDOUS WASTES

The testing of the Titan IV rocket motors at Edwards AFB will generate a very small amount of solid and hazardous wastes. It is estimated that the solid wastes generated will include approximately 50 gal of waste oil, 5 gal of waste grease and 20 gal of waste hydraulic fluid. Each firing will produce hazardous waste in the form of approximately 150 lb of solvent contaminated rags and 5 lb of Alodine contaminated rags (personal communication, David A. Holtgraves, Hercules, Bacchus, and John R. Edwards, USAF, Los Angeles Air Force Base, March 31, 1988). The sludge produced by the water recycling system will be chemically analyzed and disposed of in accordance with all federal, state, and local regulations, laws, and policies including the Hazardous Materials and Hazardous Waste Management Plan for Edwards AFB. The proposed electrical upgrades for test buildings may require changing transformers. Appropriate measures for identifying, handling, and disposing of transformers containing PCBs will be undertaken by USAF or its contractors, if necessary. Section 4.4 of Appendix A contains a summary of the regulation of solid waste management in the Edwards AFB area.

4.5 HISTORIC AND CULTURAL PRESERVATION

The National Historic Preservation Act requires that USAF assess the impact of the project on properties included in, or eligible for, the National Register of Historic Places. The purpose of this is to ensure that an adequate evaluation of potential conflicts with archaeological and historical sites is completed and that appropriate mitigation measures are implemented. A field survey is required to assess the impact of each project at Edwards AFB on these cultural and historic resources.

A field survey has been completed by USAF for the Titan IV rocket motor testing at AFAL which did not identify any historic or cultural resources in the potentially affected area. A report on the cultural and historic impacts of this project will be coordinated with the California State Historic Preservation Office.

4.6 TRANSPORTATION AND SAFETY REGULATIONS

A summary of the transportation and safety regulatory system is described in Sect. 4.6 of Appendix A.

4.7 NOISE STANDARDS

Normal testing of the Titan IV rocket motors will not violate established noise standards. A summary of noise standards is contained in Sect. 4.7 of Appendix A.

5. LIST OF AGENCIES AND INDIVIDUALS CONTACTED

The following individuals were contacted during the preparation of this EA.

U.S. Air Force
    Sam Burrell, AFRPL
    John Edwards, SD/DEV
    MAJ Gary Fishburn, AFFTC/DEV
    B. A. Kunkel, USAF Geophysics Lab.
    Mike Phillips, AFFTC/DEV
    LT Graham Rinehart, AFRPL/SEH
    CAPT Steve Taylor, SD/CLV
    Thomas Troyer, AFRPL/SEH

U.S. Fish and Wildlife Service
    Endangered Species Office, Sacramento, CA
    Ted Rado

Aerospace, Corp.
    Dr. Ken Herr

California State Historic Preservation Office
    Nick delCioppio

Hercules, Inc.
    R. L. Griffin
    David A. Holtgraves

Kern County Air Pollution Control District
    Tom Paxson

Luz Engineering
    Michael Furina
    Robert Cimburg

NASA - Cape Canaveral
    Raoul Ciami

6. LIST OF PREPARERS

Clay E. Easterly (Ph.D., Physics).
Fifteen years experience in areas including health effects, epidemieology, and noise impacts.

Daniel M. Evans (M.S., Urban and Regional Planning; B.A. Political Science).
Six years experience in environmental impact assessment including socioeconomic impacts and project coordination.

Edward J. Liebsch (M.S., Meteorology).
Seven years experience in air pollution, dispersion modeling, data base management and environmental assessment.

Kenneth H. McCorkle (B.S., M.S., Ph.D., Chemical Engineering).
Nineteen years experience in radiochemical processing, six years experience in chemical process thermodynamics and design, six years experience in teaching and research in chemical engineering, two years research in water supply and water pollution control.

Robert M. Reed (A.B., Botany; Ph.D. Botany/Plant Ecology).
Twenty years teaching and research experience in botany, ecology, and environmental sciences. Twelve years experience preparing environmental impact analyses of terrestrial ecosystems and managing environmental assessment projects.

David S. Shriner (Ph.D., Plant Pathology).
Twenty years experience in air pollution effects research, including effects on vegetation of hydrogen chloride, sulfur and nitrogen oxides, and ozone. Seventeen years of research experience on the effects of acidic precipitation on terrestrial ecosystems. Six years experience in regional-scale environmental assessment.

J. Warren Webb (B.A., Zoology; Ph.D., Insect Ecology).
Twelve years experience in ecological research and ecological effects associated with energy production in a variety of terrestrial ecosystems.

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APPENDIX A

ENVIRONMENTAL ASSESSMENT FOR THE TESTING OF TITAN SOLID PROPELLANT ROCKET MOTORS AT EDWARDS AIR FORCE BASE, CALIFORNIA

MCMXLVII

Environmental Impact Analysis Process

ENVIRONMENTAL ASSESSMENT

TESTING OF TITAN
SOLID PROPELLANT ROCKET MOTORS
EDWARDS AIR FORCE BASE, CA
DEC 1986

DEPARTMENT OF THE AIR FORCE

ENVIRONMENTAL ASSESSMENT FOR THE TESTING OF TITAN SOLID PROPELLANT ROCKET MOTORS AT EDWARDS AIR FORCE BASE, CALIFORNIA

December 1986

Prepared For: Department of the Air Force
Headquarters, Space Division
El Segundo, California

Prepared By: Brown and Caldwell Consulting Engineers
723 "S" Street
Sacramento, California 95814

FINDING OF NO SIGNIFICANT IMPACT (FONSI)
TITAN SOLID PROPELLANT ROCKET MOTOR TESTS
EDWARDS AIR FORCE BASE, CALIFORNIA

DESCRIPTION OF THE PROPOSED ACTION

INTRODUCTION

To support the U.S. Department of Defense (DOD) Space Program, and to ensure access to space through the continued use of Titan solid propellant rocket motors, the U.S. Air Force (USAF) proposes to test fire Titan rocket motors at Test Stand IC, located at the Rocket Propulsion Laboratory (RPL), Edwards Air Force Base (AFB), California, during the period of February to December 1987.

PROPOSED ACTION

The proposed action calls for the renovation of an existing rocket motor test stand (Test Stand IC) located on Leuhman Ridge at RPL to conduct the static test firings. Test Stand IC was used to test F-1 liquid rocket engines until the early 1970s. Test stand renovation includes refurbishment and changes in structural, mechanical, and electrical systems, addition of a heat shield to protect the steel deflector plate, water collection basin improvements, and addition of instrumentation, control, and monitoring equipment.

Following renovation of the test stand facilities, one 5-1/2-segment and possibly one 2-segment Titan solid propellant rocket motor will be test-fired. In addition, up to six short-burn 2-segment tests will be conducted. The tests will be conducted to:

1. Evaluate revised launch criteria.
2. Monitor the structural dynamics of the motors during each test firing.

SUMMARY OF ENVIRONMENTAL IMPACTS

NATURAL ENVIRONMENT

Air Quality

The proposed Titan rocket motor test firings will not significantly impact air quality at Edwards AFB or surrounding areas. Primary constituents of the rocket exhaust emissions will be aluminum oxide

(Al_2O_3), hydrogen chloride (HCl), carbon monoxide (CO), and oxides of nitrogen (NO_x). Afterburning in the atmosphere oxidizes some of these constituents, particularly CO. Modeling of the Titan motor exhausts indicates that the general population will not be exposed to HCl concentrations greater than the National Academy of Sciences recommended limit for short-term public exposure (limit of 3 parts per million HCl in a 10-minute average). Maximum downwind concentrations of Al_2O_3 (as suspended particulates), CO, and NO_x will be within applicable federal and state standards.

The maximum downwind concentration of particulate matter less than 10 microns in diameter (PM_{10}) from the test firings will be significantly less than the state standard of 50 micrograms per cubic meter. However, ambient air quality data indicate some exceedences of the state standard occurred in 1985.

Soils

Implementation of the Titan testing program involves lowering of the water containment berm by 5 feet at Test Stand IC. Neither the lowering of the berm or the subsequent Titan tests will significantly affect the soils at Edwards AFB or the surrounding area.

Hydrology

No significant impacts to groundwater or surface water hydrology will result from the Titan motor tests. All water used for the Titan tests will come from the municipal groundwater supplies. Most of the deluge (cooling) water used in the tests will be conditioned with a carbonate buffer to mitigate the effects of HCl absorption and low pH. Some deluge water will precipitate as acid mist (pH of about 3) from the exhaust plume and exhaust cloud onto the ground surface. The amount of precipitation is estimated to be 0.01 inch in the test stand vicinity. The remainder of the deluge water not entrained into the exhaust gas stream will be collected and recycled or evaporated in concrete-lined channels and a basin located near Test Stand IC.

Water Quality

No impacts on water quality will result from the Titan tests. All deluge water contained in the channels and basin will be recycled and/or evaporated. The amount of mist that will precipitate from the exhaust onto the rocks and soil nearby is limited and will evaporate within about 1 hour, leaving inert nonhazardous compounds (mostly aluminum oxide and sodium chloride) on the ground surface. These compounds will become part of the desert soil. The amount of HCl deposition will be small and have no significant impact on ground or surface waters.

Biota

No significant impacts on the biota of Edwards AFB or surrounding areas are expected as a result of the Titan motor tests. Vegetation and habitat impacts from acidic mist will be extremely limited. No critical habitat for threatened or endangered species will be lost due to the Titan test program. Aquatic organisms will not be impacted. Limited ground animals in this area will be unaffected by the mist fallout. Birds will leave the area when the rocket is fired.

MAN-MADE ENVIRONMENT

Population

The renovation of Test Stand IC and the subsequent test program of the Titan rocket motors will have no significant impacts on population and housing at Edwards AFB or within surrounding communities. The Titan test program will utilize existing personnel at RPL and Edwards AFB. Temporary staff from the USAF Space Division, United Technologies-Chemical Systems Division, and their contractors will be on-site during renovation work and motor testing periods.

Socioeconomics

Test Stand IC was constructed in 1965. The proposed Titan test program is compatible with the surrounding land use, will require no land purchase and no construction work beyond the boundaries of the test stand area, and will not require new utility services, new transportation access, or additional employment. No significant impacts on the socioeconomics of Edwards AFB or Kern County California, are anticipated.

Safety

All regulatory agency safety procedures and guidelines will be followed. Safety monitoring will be conducted during the tests. For the large 2-minute test firings, a protective clear zone of about 1 mile will be established around the test stand and no one will be allowed into the immediate downwind area (approximately 10 miles downwind). A wind corridor has been established to minimize the chances of the exhaust cloud proceeding over housing areas. Essential test personnel will be located in a protected concrete bunker near the test stand. Exhaust cloud monitoring will be conducted.

Noise

Noise levels associated with the Titan test program will not significantly affect the general public due to the distance between the test site and the nearest unregulated area (3 miles). Noise produced during the test firings will be of short duration (2 minutes or less for each event), and at worst, will be a nuisance on two occasions. Portions of the RPL will be evacuated to minimize noise impacts on site.

Archaeology and Cultural Resources

The Test Stand IC area contains no unique archaeological or historic resources. As a result, the Titan test program will have no effect on archaeological or cultural resources.

FINDINGS

Based on the above, a finding of no significant impact is made. Copies of an Environmental Assessment of the proposed action, dated December 1986, can be obtained from:

HQ Space Division
Post Office Box 92960
Worldway Postal Center
Los Angeles, California 90009
ATTENTION: Mr. Robert C. Mason, SD/DEV

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LIST OF ACRONYMS AND ABBREVIATIONS

Act	Federal Endangered Species Act of 1973
AFB	Air Force Base
Al_2O_3	Aluminum oxide
APCD	Air Pollution Control District
C	Centigrade
Caltrans	California Department of Transportation
CHP	California Highway Patrol
Cl	Chloride
CO	Carbon monoxide
CO_2	Carbon dioxide
CSD	United Technologies Corporation-Chemical Systems Division
CWMB	California Waste Management Board
dB	Decibels
dB(A)	Decibels measured on A weighting scale
DFG	California Department of Fish and Game
DOD	United States Department of Defense
DOT	United States Department of Transportation
$Dyne/cm^2$	Dynes per square centimeter
EA	Environmental Assessment
EPA	United States Environmental Protection Agency
F	Fahrenheit
fps	Feet per second
gpm	Gallons per minute
H_2	Hydrogen
H_2CO_3	Carbonic acid
H_2O	Water
HCl	Hydrogen chloride
KSC	Kennedy Space Center
Lb	Pounds
Lb/ft^2	Pounds per square foot
Na	Sodium
$NaCl_3$	Sodium chloride (salt)
Na_2CO_3	Sodium carbonate
N_2	Nitrogen
NASA	National Aeronautics and Space Administration
NO_2	Nitrogen dioxide

NO_x	Nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
O_2	Oxygen
O_3	Ozone
OSHA	Occupational Safety and Health Administration
PIRA	Precision Impact Range Area
ppm	Parts per million
PM_{10}	Particulate matter less than 10 microns in diameter
Regional Board	California Regional Water Quality Control Board, Lahontan Region
RPL	Rocket Propulsion Laboratory
State Board	California State Water Resources Control Board
TSP	Total suspended particulates
ug/m^3	Micrograms per cubic meter
um	microns
USAF	United States Air Force
USFWS	United States Fish and Wildlife Service

1.0 PROPOSED ACTION AND ALTERNATIVES

The U.S. Air Force (USAF), Headquarters Space Division, El Segundo, California, is proposing to perform static test firings of Titan solid propellant rocket motors at the USAF Rocket Propulsion Laboratory (RPL), Edwards Air Force Base (AFB) in eastern Kern County between February and December 1987. In April 1986, a Titan 34D space launch vehicle experienced an in-flight failure several seconds after liftoff from Vandenberg AFB, California. At liftoff the Titan 34D is powered by two 5-1/2-segment solid propellant rocket motors. The cause of the failure may have originated in the solid propellant rocket motor. The manufacturer of the Titan solid propellant rocket motors, United Technologies Corporation-Chemical Systems Division (CSD), has researched and evaluated the potential causes of the misfiring and determined that it was probably due to one of the following:

1. Insulation separated from the steel casing.
2. The restrictor, which acts as a seal between the propellant in adjoining segments, separated from the propellant allowing it to burn through the insulation and casing.
3. Void space within the propellant which would lead to rapid, uneven burning.

Static test firings are proposed as follows:

1. One 5-1/2-segment Titan rocket motor with its normal 2-minute burn time.
2. One 2-segment Titan rocket motor with its normal 2-minute burn time (optional test).
3. Up to six short-burn tests (each about 2 seconds burn time) on a 2-segment Titan rocket motor.

Static tests are conducted on motors that are held down on the test stand rather than being launched. The rocket motors are manufactured in segments for ease of transportation. Each segment is about 10 feet in diameter and about 11 feet high. The segments will be stacked and mated on the test stand. Instrumentation will be attached to the rocket motors to monitor the tests. The motors will fire while being held to the test stand.

This Environmental Assessment (EA) addresses the environmental impacts associated with the proposed static test firings of the Titan solid propellant rocket motors. The EA documents the compliance of the static test program with applicable federal, state, and local environmental regulations and identifies mitigation measures which shall be implemented to minimize the environmental impacts of the proposed test program.

1.1 BACKGROUND

CSD is now using X-ray equipment to scan the propellant, casing, and liner of each Titan solid propellant rocket motor segment. Thus far, no problems have been found with the casings or the liners in any of the Titan segments examined. It appears that the Titan segment which misfired at Vandenberg AFB contained a flaw that other Titan segments do not have. However, CSD is continuing to inspect the fleet of Titan rocket motor segments.

1.2 PROPOSED ACTION

The USAF and CSD intend to conduct static test firings at Edwards AFB to determine:

1. If the acceptance criteria used by CSD are adequate. The Titan propellant and each Titan segment are subjected to a variety of tests. CSD has developed criteria for these tests to determine if each batch of propellant and each motor segment is acceptable.

2. If the placard temperature is correct or if it should be adjusted for the Titan propellant. The placard temperature is the ambient temperature range prior to ignition over which the Titan propellant functions properly.

3. If there are problems with the clevis joint. The clevis joint includes all connecting devices located where two Titan segments are joined together.

The motors will be tested with the nozzle pointing down. Testing in this configuration will provide better test results than the more conventional horizontal test firings or nozzle-up tests. The rocket segments that will be used in the tests at Edwards AFB will be X-rayed to determine that there are no flaws in the propellant, casings, or liners.

The proposed action consists of four major tasks: (1) modifications to the existing test stand, (2) transport and setup of rocket motor segments and necessary test equipment, (3) testing of the Titan rocket motors, and (4) operation of a deluge water recycling and treatment system. Each task is described in the following sections.

1.2.1 Project Location

Edwards AFB is located at the eastern edge of Kern County in the Mojave Desert at an elevation of approximately 2,300 feet. RPL is located in the northeast corner of Edwards AFB about 11 miles east of the main base. RPL is a research and development facility responsible for planning, formulating, and executing the USAF technology programs for rocket propulsion and related space technology. Both solid and liquid rocket motors are tested at a number of test stands located at RPL. Figure 1.1 shows the general location of Edwards AFB and RPL. Figure 1.2 shows the test stands and major areas of RPL. Test Stand IC, which will be used for the proposed tests, is located on top of Leuhman Ridge at an elevation of approximately 3,200 feet, or about 900 feet above the flat desert terrain west of Leuhman Ridge. The location of Test Stand IC is shown on Figure 1.3. The main buildings of the RPL are located about 1 mile south of this test stand. The nearest town is Boron, located approximately 3.5 miles north-northeast of the test site. The Desert Lakes housing area is approximately 3 miles north of the test site. The main base at Edwards AFB is about 11 miles west-southwest of the test site, and Death Valley is approximately 80 miles to the northeast.

1.2.2 Renovation of Test Stand IC

This test stand was previously used for the testing of liquid propellant motors. The liquid propellant testing structures and equipment have been removed, and the test stand is currently being modified to accommodate the Titan solid propellant rocket motors. Modifications include the removal of two tanks from the top of the test stand, buildup of the superstructure to support the Titan rocket motors, installation of a pylon adaptor to receive the 10-foot-diameter Titan rocket motors, and construction of a bonnet to restrain the motors during firings. The electrical and water supply systems have been completely overhauled.

Special equipment has been added to Test Stand IC to conduct and monitor the test firings. A silicon-phenolic heat shield material is being added to the steel deflector plate in the area where the high temperature exhaust will strike it. This material is designed to slowly wear away during the test to protect the steel deflector plate. A deluge water recycling and treatment system has been established to provide mitigation of low pH mist and control of solids disposal. Instrumentation, monitoring, and control equipment is being added to conduct the tests successfully and in accordance with up-to-date safety and reliability standards.

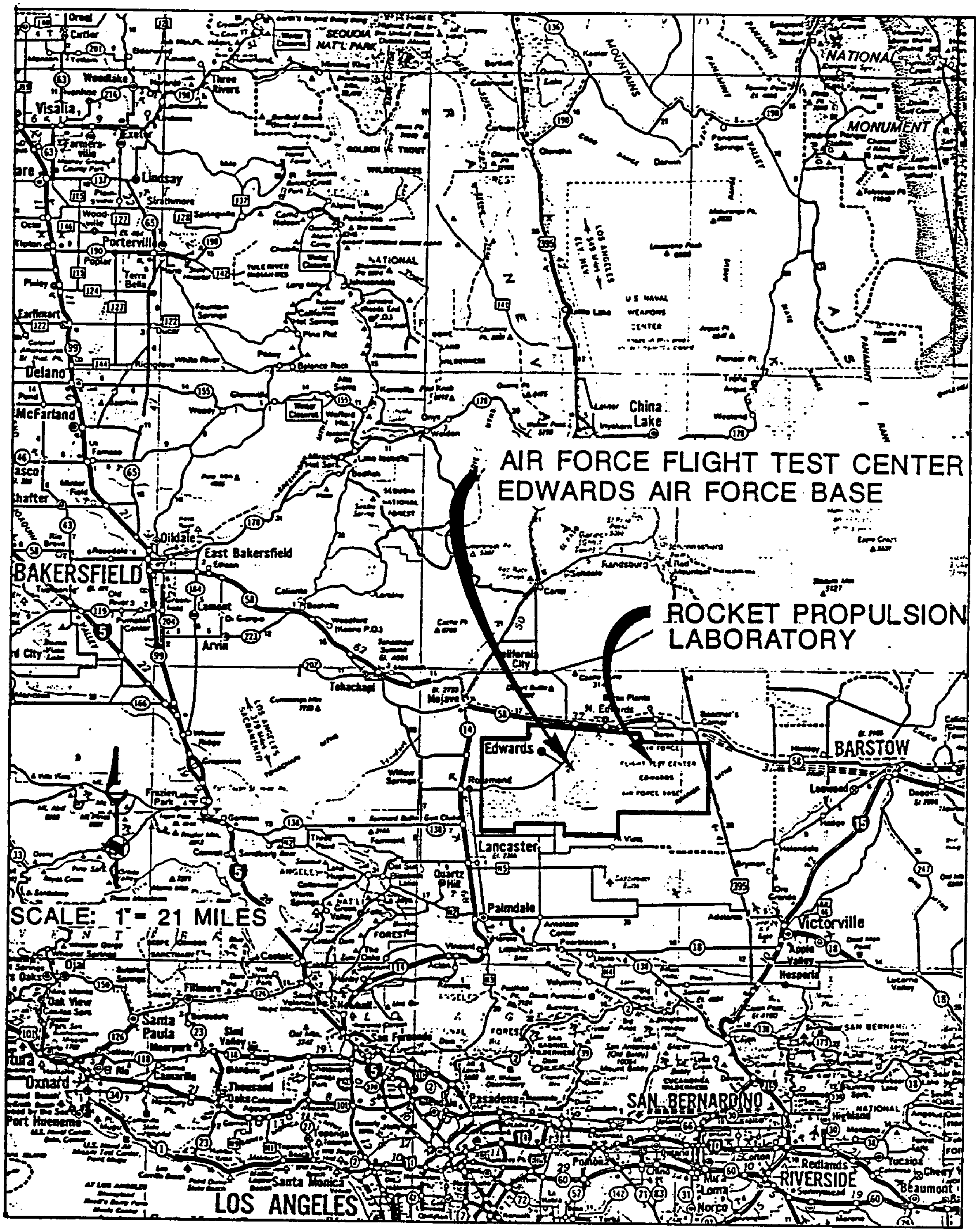


Figure 1.1 Location of Edwards Air Force Base

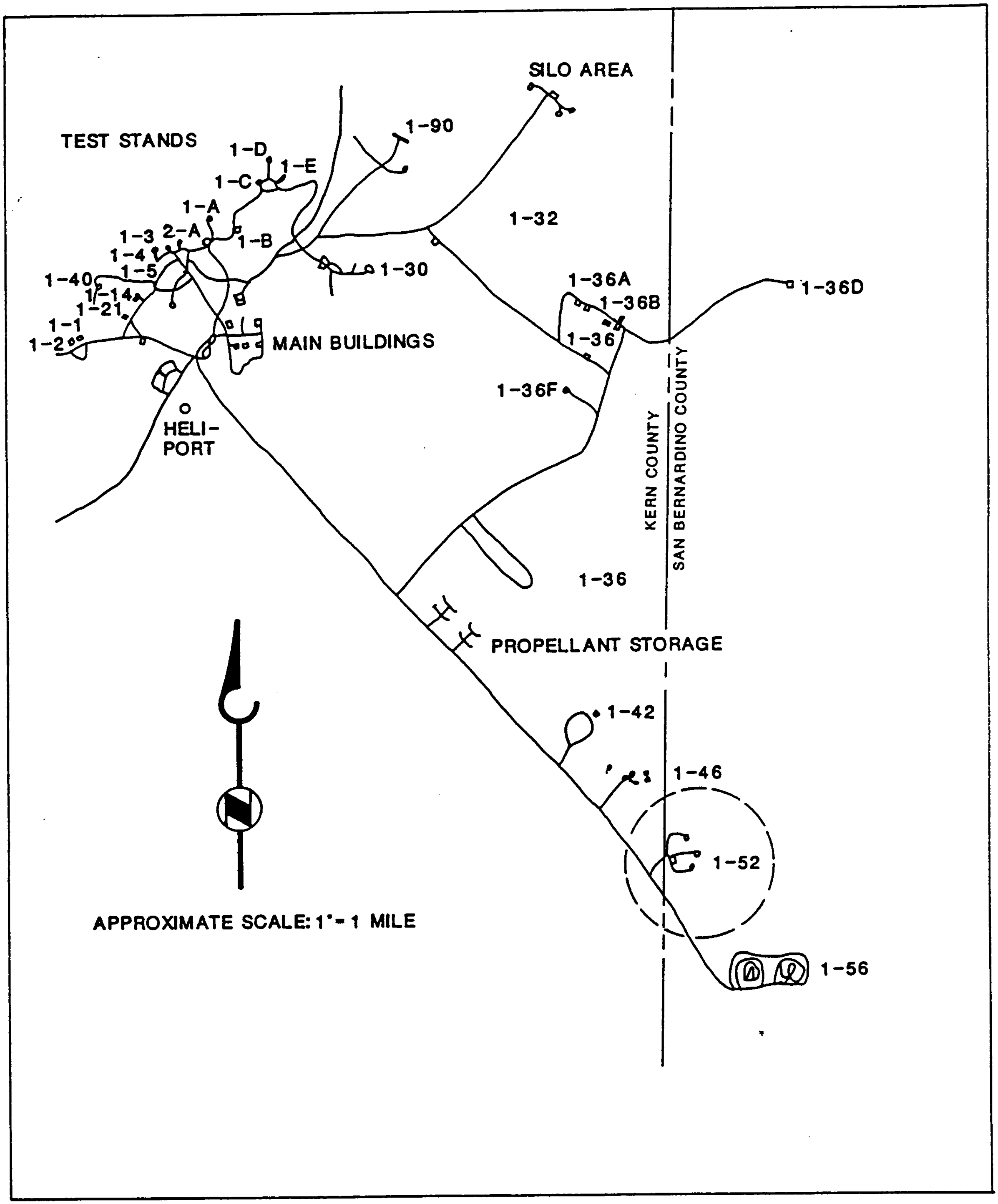


Figure 1.2 Rocket Propulsion Laboratory

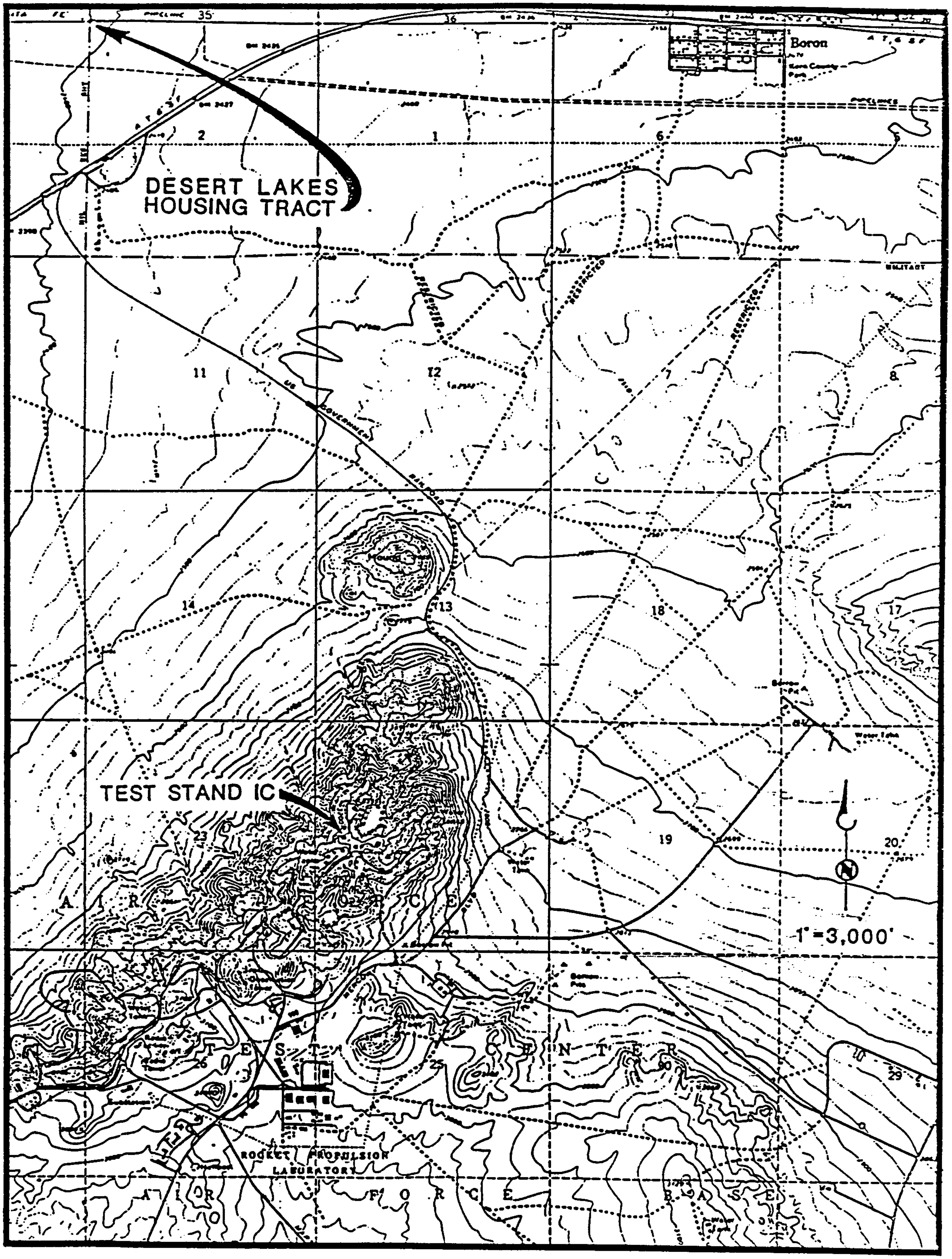


Figure 1.3 Location of Test Stand IC

1.2.3 Test Firing Setup

The rocket motor segments to be used for the test firings will be transported by truck from CSD storage facilities in southern California to RPL. The storage facilities and transportation routes are not identified in this EA for security reasons. Since each motor segment is fairly large, oversize regulations apply to the transport of such material. Regulations of the U.S. Department of Defense (DOD), U.S. Department of Transportation (DOT), and the California Highway Patrol (CHP) will be observed to ensure compliance in transport, movement, and handling of all Titan rocket motor segments. Segments will be stacked and mated according to CSD standard procedures and safety regulations. Following each test, the spent rocket motors will be disassembled and transported off site for detailed examination.

1.2.4 Testing of Titan Rocket Motors

1.2.4.1 Two-Minute Test Firings--

The 5-1/2-segment motor will contain 465,800 pounds (lb) of propellant and the 2-segment motor (if tested) will contain 206,120 lb of propellant. Each of these test firings will last for 2 minutes, during which extensive data regarding rocket performance, structural and thermal loads on the test stand structures and booster rocket, and other critical performance parameters will be obtained. The Titan solid propellant burns at a given rate from the core toward the casing in each segment. It takes 120 seconds for the propellant to completely burn within each segment. Therefore, a 2-segment motor burns for the same amount of time as a 5-1/2-segment motor.

The solid propellant used in the Titan rocket motors consists of ammonium perchlorate oxidizer, aluminized synthetic-rubber binder fuel, and various other additives to stabilize mass and control the burning rate. The combustion products at the nozzle will be particulates, consisting mainly of aluminum oxide (Al_2O_3), hydrogen chloride (HCl), and gaseous hydrogen (H_2), nitrogen (N_2), and carbon monoxide (CO). Various water sprays will be used to quench and cool the rocket and exhaust for the tests of 2-minute duration.

1.2.4.2 Short-Burn Test Firings--

The six short-burn tests will be substantially different from the 2-minute test firings. The purpose of the short-burn tests is to bring the motor case up to required pressure for about 1 second so that the performance of the joints between the motor segments can be adequately monitored. To do this, a maximum of 500 pounds of propellant will be ignited for each test within a 2-segment rocket motor. The motor will be filled with inert propellant-like material to provide weight and structural characteristics similar to a 2-segment motor full of solid propellant. The 500 pounds of propellant will burn in a maximum of 2 seconds to provide the pressure needed. The deluge water system is not required for these tests.

The air emissions and the exhaust plume will be much smaller for the short-burn tests than for the 2-minute test firings. Noise and other effects are also greatly reduced. Therefore, these tests are described in less detail than the 2-minute test firings.

1.2.5 Deluge Water Handling System

The 2-minute Titan rocket motor tests will require an extensive deluge water system since the exhausts will have a very hot, high-velocity gas stream, and the tests will be undertaken with the nozzle of the motor pointing down. A large deflector shield, called the flame bucket, will divert the exhaust to the horizontal. The deluge water system, which is primarily used to cool the flame bucket, is described in the following sections.

1.2.5.1. Water Quantity--

Each of the 2-minute test firings will require approximately 570,000 gallons of cooling (deluge) water. Table 1.1 shows the derivation of this number by test period. For both the 5-1/2- and 2-segment tests, it is estimated that 280,000 gallons will be lost to evaporation and dispersive spray during rocket motor ignition and the remaining 290,000 gallons will be collected.

Table 1.1. Water Flow Rates and Volumes for Each 2-Minute Test

Test period	Average flow rate, gpm	Duration, minutes	Water supply volume, gallons	Water volume collected, gallons
Start-up	70,000	2	140,000	140,000
Ignition	140,000	2	280,000	0
Shutdown	70,000	2	140,000	140,000
Quench	1,000	10	10,000	10,000
Total	-	-	570,000	290,000

No deluge water is needed to cool the flame bucket for the short-burn tests. A small amount of rocket motor quench water and washdown water will be used. At maximum, 10,000 gallons of water could be used for each of the short-burn tests. All of this water would be collected in the water channel containment system.

1.2.5.2 Water Containment and Treatment System--

The deluge water will be supplied from two existing storage tanks. A 3-million-gallon tank supplies a 120,000-gallon-per-minute (gpm) system, and a 400,000-gallon tank supplies a 20,000-gpm system. The larger system supplies water directly to the flame bucket, and the smaller system is for sprays and quench waters used above the flame bucket.

The deluge water will be collected in the basin at Test Stand IC and will flow into the 6-foot high concrete channels that connect Test Stands IC and ID. The collection system is shown on Figure 1.4. Cracks and leaks in these channels have been repaired. The system is scheduled to be tested for water tightness in January 1987. The estimated volume of storage available in these channels is 816,000 gallons. It is estimated that the depth of water in the channels after each 2-minute rocket motor test will be 1-1/2 to 2 feet.

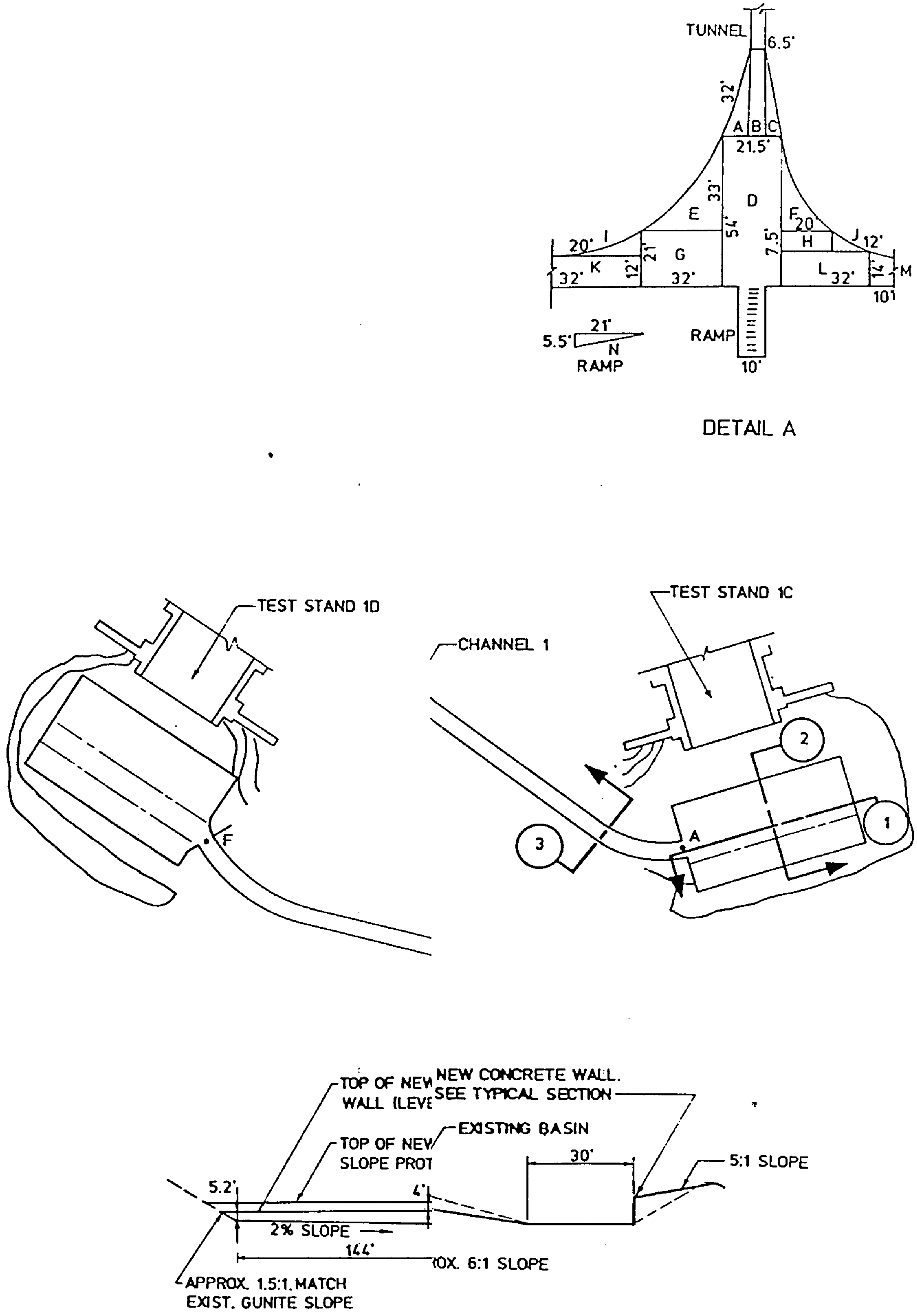
The hydrogen chloride in the rocket exhaust has an affinity for water. When it dissolves in the deluge water, it becomes hydrochloric acid which lowers the pH of the water. The water handling system consists of pretreatment of the water with sodium carbonate to raise the pH to about 11 prior to the test. This is being done to mitigate the low pH which occurs in the mist fallout beneath the exhaust plume. Conditioning of the water will be performed by addition of sodium carbonate in the mixing basin, as noted on Figure 1.4.

1.3 ALTERNATIVE ACTIONS

Alternative actions to the proposed testing of Titan rocket motors at Edwards AFB include alternative types of tests and alternative sites for the tests.

1.3.1 Alternative Tests

Horizontal and nozzle-up static test firings were considered for this program but were rejected by the USAF and CSD because the forces acting on the rocket motors in these configurations are different than the forces in the nozzle-down launch position. The purpose of the proposed tests is to simulate as closely as possible the forces acting on the rocket motors during launch conditions. The nozzle-down tests were chosen for this reason.



SECTION 2
SCALE: 1"=20'–0"

SECTION 1
SCALE: 1"=40'-

Figure 1. Test Stand 1C Deluge Water Capture System

1.3.2 Alternative Sites

The USAF and CSD conducted a nationwide search for the best site to conduct these tests. CSD examined the feasibility of conducting the tests at its Coyote Center facility near San Jose, California, and at one of the USAF launch bases. These sites were rejected because their test stands are designed for horizontal and nozzle-up tests, and launch pads are not adequate for static test firings. An entirely new test stand and flame deflector would be required to conduct nozzle-down tests at these sites. Testing at the National Aeronautics and Space Administration (NASA) Mississippi Space Center and NASA's Marshall Space Flight Center was also evaluated and rejected because of conflicts with other high-priority programs. The USAF evaluated four test facilities at RPL and determined that Test Stand IC was in the best working condition and best suited for these tests. Therefore, Test Stand IC at RPL was chosen for the static test firings.

1.4 NO-ACTION ALTERNATIVE

If the proposed tests are not conducted, the no-action alternative will require that the USAF stop using Titan rocket motors or risk another incident similar to the one at Vandenberg AFB. The no-action alternative is not feasible because the USAF must determine that the Titan solid propellant rocket motors are reliable and can be used to launch critical national defense payloads.

2.0 ENVIRONMENTAL SETTING

2.1 NATURAL ENVIRONMENT

2.1.1 Geology and Soils

Edwards Air Force Base (AFB) is located in the western portion of the Mojave Desert at an elevation of approximately 2,300 feet. Test Stand IC which will be used in the project, is located at the Rocket Propulsion Laboratory (RPL) on Leuhman Ridge at an elevation of 3,200 feet, about 900 feet above the desert floor to the west of Leuhman Ridge. This portion of the desert is dominated by the Antelope Valley, which is bordered to the south by the San Gabriel Mountains, to the northwest by the Tehachapi Mountains, and to the east by low hills. Layers of eroded material from the surrounding mountains have built up over bedrock to form alluvial fans. These layers of rock, sand, and alluvium are shallow along the base of the mountains, rock outcroppings, and butte formations, and become deep in the dry lakes or playas. The major playas within Edwards AFB are Rosamond Lake and Rogers Dry Lake. Rogers Dry Lake lies about 5 miles west of the test site. Rock outcroppings, ranging from small single rocks to small mountain or ridge formations spot the surface of the base. The test site is located on the Leuhman Ridge rock formation.

Soils in the test site area (below Leuhman Ridge) consist of a surface layer of blown sand covering sandy soil mixed with clay. Most of the soil layer is impermeable, and most of the rainfall washes down to the dry lake beds. The soils of the area are slightly alkaline with the pH ranging from 7.4 to 8.4 (U.S. Department of Agriculture, 1981). The slopes of Leuhman Ridge have shallow surface soils which cover bedrock. The top of the ridge is essentially rock, with little soil material.

Mountains to the north and south which form the west side of the Antelope Valley follow major faults. These include the San Andreas and Garlock faults which intersect at Gorman, approximately 70 miles west of the test site area. In addition to these major faults, several minor fault lines fan out across the Edwards AFB area (see Figure 2.1).

2.1.2 Meteorology

The climate at Edwards AFB is characterized by long, dry summers and mild, relatively dry winters. The mean seasonal and annual temperatures, precipitation, wind speeds, and wind directions are shown in

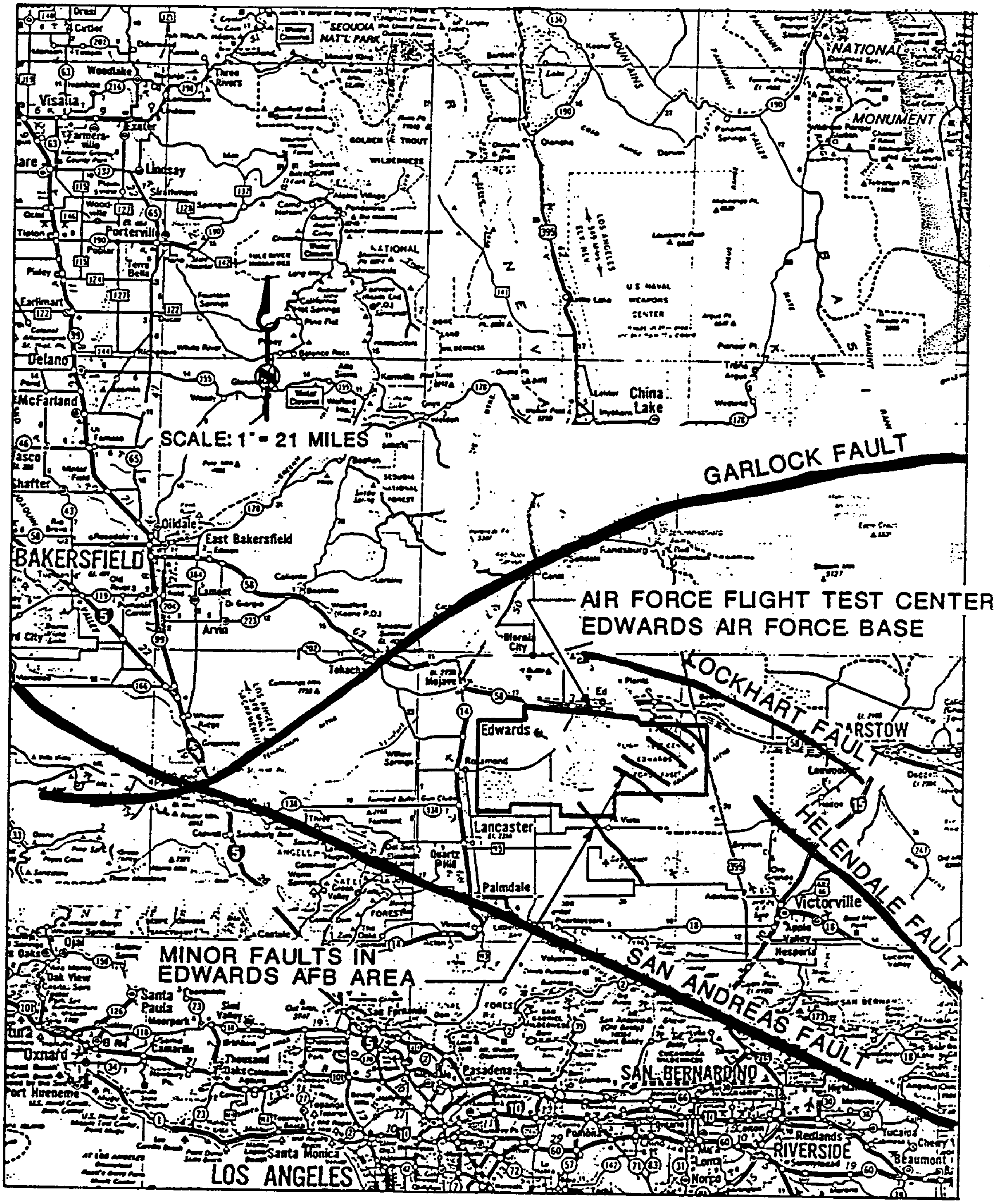
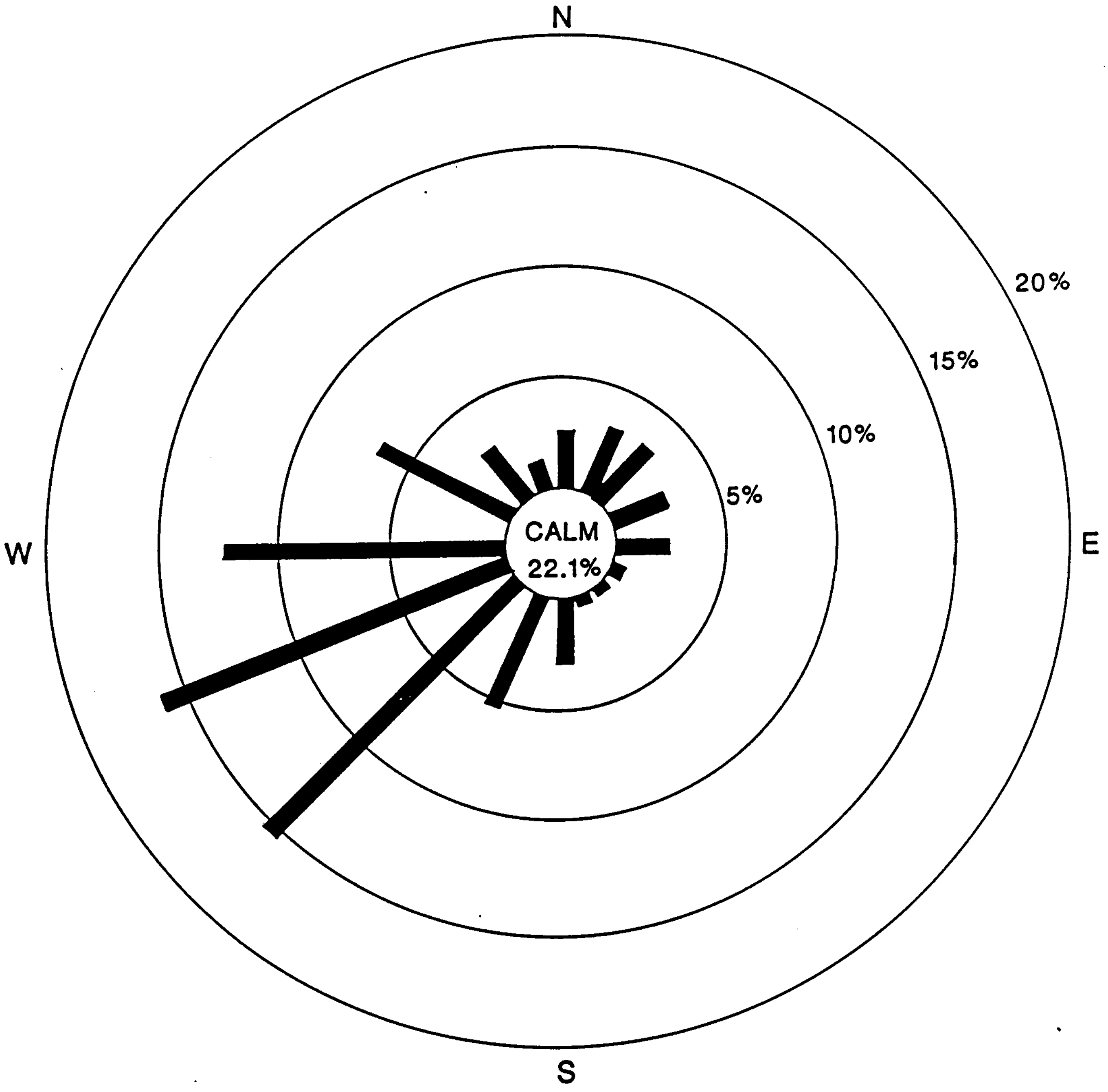
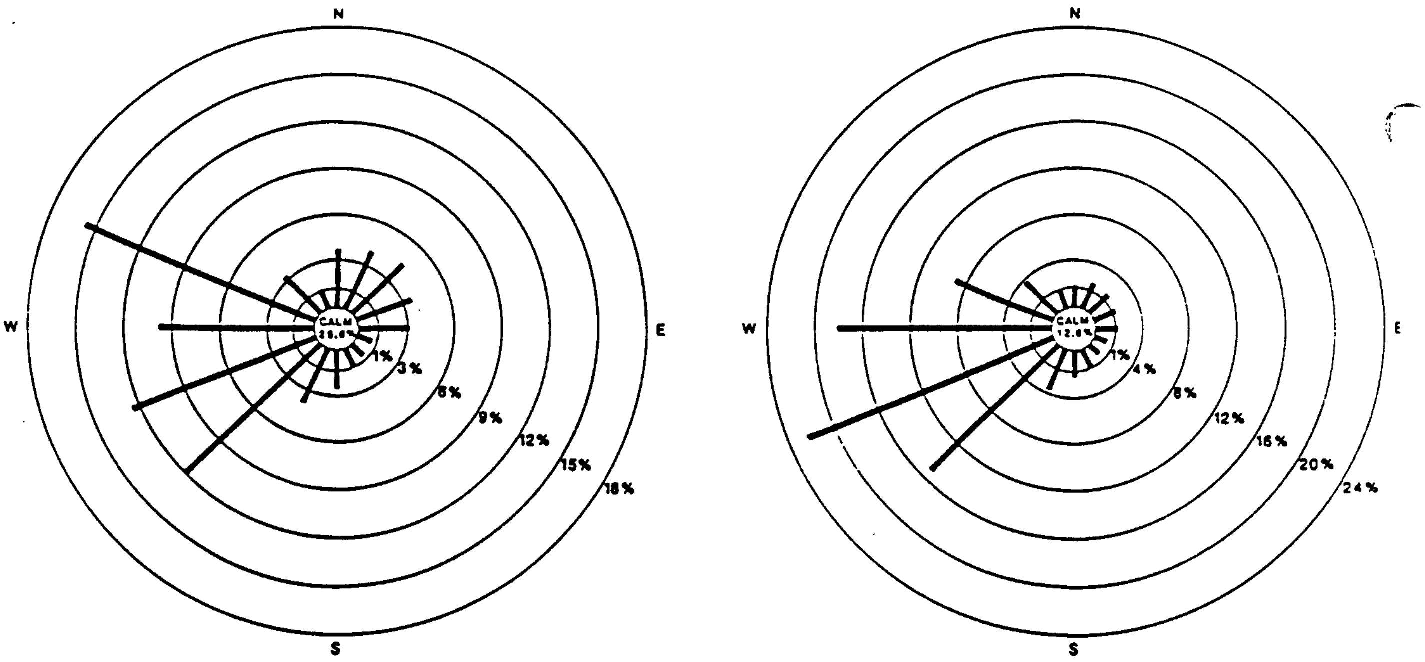


Figure 2.1 Geologic Faults in the Edwards Air Force Base Area



Note: Percentages Indicate Frequency By Direction of Surface Winds.
Source: LISOCS DOR Sep. 1974 - Aug. 1984

Figure 2.2 Annual Wind Rose



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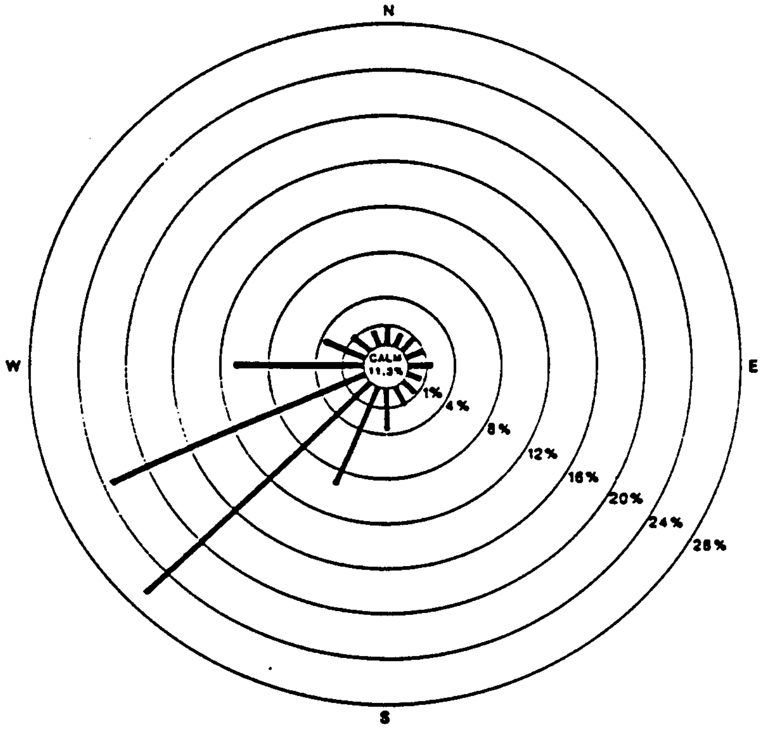


JULY

Note: Percentages Indicate Frequency By Direction of Surface Winds.

Source: LISOCS for Sep. 1974– Aug. 1984.

Figure 2.3 Representative Seasonal Wind Roses

Table 2.1. Figures 2.2 and 2.3 show the annual wind rose and specific months, respectively. As shown on Figure 2.2, the wind blows from the west, southwest, or west-southwest most of the time.

Table 2.1 Climate for Edwards AFB

Parameter	Winter	Spring	Summer	Fall	Annual
Temperature, degrees F					
Mean temperature	48	66	79	53	61
Mean daily maximum	60	81	95	67	76
Mean daily minimum	35	51	63	37	46
Precipitation					
Mean relative humidity, percent	52	37	31	45	42
Seasonal mean precipitation, inches	2.69	0.37	0.42	1.42	4.86
Surface winds					
Prevailing direction, degrees azimuth	250	240	240	240	250
Mean speed, knots	7	11	9	6	9
Mean speed, mph	8.0	12.7	10.3	6.9	10.3

Source: Published data, Office of Staff Meteorologist, Edwards AFB, Data Base 1943-1984.

During the winter and spring months, a strong radiation (surface) inversion usually exists in the early morning. The radiation inversion is typically about 1,000 feet thick and generally disperses about 10 a.m. Pacific Standard Time (California Air Resources Board, 1979). Subsidence inversions occur infrequently during the winter months and are typically fairly weak with a base about 5,000 to 6,000 feet above the desert surface. During the summer months, high-pressure zones increase the number and strength of the subsidence inversions.

2.1.3 Air Quality

Edwards AFB is located within a portion of the Southeast Desert Air Basin which has limited air quality data. The states and the U.S. Environmental Protection Agency (EPA) designate the attainment status of air basins throughout the country for each pollutant. There are four designations possible for national air quality standards:

1. Does not meet primary standards.
2. Does not meet secondary standards.

3. Cannot be classified.
4. Better than national standards.

For the Kern County portion of the Southeast Desert Air Basin, EPA has concurred in the following designations (Code of Federal Regulations, Title 40, Part 81):

1. Total Suspended Particulates--Cannot be classified.

2. Sulfur Dioxide--Cannot be classified.

3. Nitrogen Dioxide--Cannot be classified or better than national standards.

4. Carbon Monoxide--Cannot be classified or better than national standards.

5. Ozone--Cannot be classified or better than national standards.

Ambient air quality data from 1980 to 1985 from monitoring stations in the Southeast Desert Air Basin are summarized in Table 2.2. Detailed air quality information is shown in Appendix A, and the most appropriate data for the RPL area are shown in Table 2.2. Ambient air quality standards are shown in Table 2.3.

Table 2.2 Worst Case Ambient Air Quality

Pollutant	Monitoring station location	Averaging time, hours	Estimated representative maximum in RPL area	Strictest standard
Ozone	Lancaster	1	0.19 ppm	0.12 ppm
Carbon monoxide	Lancaster	1	12.0 ppm	20 ppm
Nitrogen dioxide	Lancaster	1	0.11 ppm	0.25 ppm
Total suspended particulates	Lancaster	24	176 ug/m^3	260 ug/m^3
Particulate matter <10 microns in diameter	Barstow/ Mojave	24	82 ug/m^3	50 ug/m^3

Source: See Appendix A for detailed data.

Table 2.3 Ambient Air Quality Standards

Pollutant	Averaging time	Concentrations		
		California standards[b]	National standards[a]	
			Primary[c]	Secondary[d]
Oxidant[e]	1 hour	0.10 ppm (200 ug/m^3)	-	-
Ozone	1 hour	-	0.12 ppm (235 ug/m^3)	Same as primary standard
Carbon monoxide	8 hours	9 ppm (10 mg/m^3)	9 ppm (10 mg/m^3)	Same as primary standard
	1 hour	20 ppm (23 mg/m^3)	35 ppm (40 mg/m^3)	Same as primary standard
Nitrogen dioxide	Annual average	-	100 ug/m^3 (0.05 ppm)	Same as primary standard
	1 hour	0.25 ppm (470 ug/m^3)	-	-
Sulfur dioxide	Annual average	-	80 ug/m^3 (0.03 ppm)	-
	24 hours	0.05 ppm[f] (131 ug/m^3)	365 ug/m^3 (0.14 ppm)	- -
	3 hours	-	-	1,300 ug/m^3 (0.5 ppm)
	1 hour	0.25 ppm (655 ug/m^3)	-	-
Suspended particulate matter	Annual geometric mean	-	75 ug/m^3	60 ug/m^3
	24 hours	-	260 ug/m^3	150 ug/m^3
Suspended particulate matter (PM$_{10}$)[g]	Annual geometric mean	30 ug/m^3	-	-
	24 hours	50 ug/m^3	-	-

[a] National standards, other than those based on annual averages or annual geometric means, are not to be exceeded more than once per year.

[b] The California standard for oxidant is a value that is not to be equaled or exceeded. The California standards for carbon monoxide, nitrogen dioxide, sulfur dioxide and PM10 are values not to be exceeded.

[c] National Primary Standards: the levels of air quality necessary, with an adequate margin of safety, to protect the public health.

[d] National Secondary Standards: the levels of air quality necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

[e] Measured as ozone.

[f] At locations where the state standards for oxidant and/or suspended particulate matter are violated. National standards apply elsewhere.

[g] The California Air Resources Board has adopted an "inhalable" particulate standard.

Note: ppm - parts per million by volume; ug/m^3 - micrograms per cubic meter; mg/m^3 - milligrams per cubic meter.

Concentrations are expressed first in units in which standards were promulgated. Equivalent units given in parentheses are based upon a reference temperature of 25 degrees C and a reference pressure of 760 milligrams of mercury.

Source: California Air Resources Board.

The existing air quality, as shown in Table 2.2, is within air quality standards for carbon monoxide (CO) and nitrogen dioxide (NO_2). The peak ozone (O_3) concentration of 0.19 parts per million (ppm) is greater than the federal 1-hour standard of 0.12 ppm. The low population density of the area indicates that the violation of the O_3 standard is probably due to transport of O_3 from the Los Angeles Basin and possibly the San Joaquin Valley Basin. The representative peak total suspended particulate (TSP) concentration (176 micrograms per cubic meter (ug/m^3)) is greater than the federal secondary standard (150 ug/m^3) but not the federal primary standard (260 ug/m^3). The peak concentration for particulate matter less than 10 microns in diameter (PM_{10}) is greater than the state standard of 50 ug/m^3. However, there are limited PM_{10} data since PM_{10} measurements were only started in late 1984.

2.1.4 Surface Water Resources

The general drainage pattern in the area is from the mountains toward the dry lakes. There are no major surface water resources in the area. The Amargosa Wash, Littlerock Creek, and Big Rock Creek flow from the southern mountains across the valley to Rosamond and Rogers Dry Lakes. Amargosa Wash and Big Rock Creek are dry except during rainstorms.

In the vicinity of the test site, runoff from the eastern slope of Leuhman Ridge flows east to flat terrain. Runoff from the western slope of Leuhman Ridge flows into Rogers Dry Lake. Rogers Dry Lake generally contains water from February to May and is dry the remainder of the year.

2.1.5 Groundwater Resources

The principal aquifer of Antelope Valley is contained in the unconsolidated Tertiary-age alluvial and lacustrine deposits overlying pre-Tertiary-age basement rocks. These deposits consist of arkosic gravel, sand, silt and clay, and reach a thickness of 2,000 feet at the center of the basin. Where saturated, the alluvial and lacustrine deposits yield large quantities of water to wells. In addition to these deposits are the unconsolidated Pleistocene-age alluvial fan and windblown sand deposits. The fan deposits consist of graded gravels and sand of granitic origin. They are generally unsaturated. The windblown sand is stabilized and very fine- to fine-grained. The windblown sand lies above the groundwater table, but may contain small amounts of perched groundwater.

The principal aquifer is broken into a series of subunits. Edwards AFB draws water from the Lancaster and North Muroc subunits. The pattern of groundwater movement in the area is complex. Groundwater in the Lancaster subunit generally moves toward two large pumping depressions, one located south of Edwards AFB and the other located west of Lancaster.

Groundwater recharge to the area is primarily from subsurface inflow from adjoining areas. Recharge from infiltration of precipitation and from percolation of infrequent stream runoff is minor. Due to the low annual precipitation and high evaporation rate, recharge of underground aquifers from sources other than subsurface inflow is minimal (DMA Engineering, 1986).

Edwards AFB obtains its potable water exclusively from wells. All water production wells for RPL are located on the west slope of Leuhman Ridge and on the east margin of Rogers Dry Lake. The well nearest Test Stand IC is approximately 3 miles away. There are 15 existing wells within the general area (T. 10 N., R. 8 W., and T. 10 N., R. 9, W., SBM). Of these, seven have groundwater quality data available. Water quality data from groundwater samples collected between 1947 and 1958, were obtained from USGS Bulletin No. 91-6, 1962. These data are shown in Table 2.4. Regionally, groundwater quality is characteristically good. Locally, however, groundwater can be highly mineralized, relatively hard, and have a high sodium concentration. Total dissolved solids and electrical conductivity of some groundwater samples exceed the recommended drinking water standards for those parameters.

2.1.6 Biota

2.1.6.1. Vegetation--

Three plant community types have been observed in areas around the test site. These plant communities are the Joshua tree woodland, creosote bush scrub, and alkali sink. Vegetation in these plant communities are common to the desert environment and are characterized as an intermixture of the dominant species and species of abutting communities.

Joshua trees (*Yucca brevifolia*) exist in relatively open stands, becoming more dense on the alluvial fans above and around the dry lake beds. Scattered Joshua trees are found throughout the RPL area. Undergrowth shrub species common to the Joshua tree woodland include the burrobush (*Hymenoclea monogyra*), Mormon tea (*Ephedra* spp.), creosote bush (*Larrea divaricata*), cholla (*Opuntia* spp.), and several species of saltbush (*Atriplex* spp.). Herbaceous species existing in the Joshua tree woodland occur throughout the other major plant communities. These species include Mojave spineflower (*Chorizanthe spinosa*), desert cymopterus (*Cymopterus deserticola*), wild buckwheat (*Erigonum* spp.), fiddleneck (*Amsinckia* spp.), forget-me-not (*Myosotis* spp.), red stem filaree (*Erodium texanum*), desert candle (*Caulanthus inflatus*), brome grasses (*Bromus* spp.), and Indian rice grass (*Oryzopsis hymenoides*).

Table 2.4 Groundwater Quality in the Vicinity of RPL

Constituent[a]	Groundwater concentrations								Drinking water standards	
Well number	9/13-23B1	10/8-4A1	10/9-4D1	10/9-4D2	10/9-36G1		10/9-7A1[b]	10/9-7A2[c]		
Date of collection	4-17-52	4-2-52	2-8-57	8-9-58	1-?-47	7-22-47	b	c	Primary	Secondary[d]
Silica	36	42	—	7	40	37	33-40	33-42		
Iron	1.2	1.6	—	0	0.22	0.04	0-0.20	0-0.08		0.3
Calcium	86	44	4.3	3.0	18	16	7.5-14	14-23		
Magnesium	17	5.6	0.4	2.0	7.9	8.5	1.6-3.9	4.7-7		
Sodium	70	197	119	129	328	329	231-300	310-384		
Potassium	2.5	4.8	0.6	—	—	—	2.0-3.6	2.4-4.5		
Bicarbonate	187	115	213	188	351	360	298-330	275-302		
Carbonate			0	13	0	0	0	0		
Sulfate	178	162	58	70	195	191	95-109	132-146		250
Chloride	65	210	24	31	204	206	102-246	258-400		250
Fluoride	0.7	0.5	1.2	1.0	2.7	1.9	1.2-3.1	2.0-3.5	2.0	
Nitrate	5.2	1.1	—	1.0	8.0	1.7	0.3-3.3	1.2-2.1	45	
Boron	0.31	1.1	—	0	—	—	0.5-0.59	0.7-0.72		
Dissolved solids calculated	554	727	255	350	979	968	653-852	886-1,130		500
Hardness as $CaCO_3$	284	133	12	16	78	75	28-43	55-84		
Percent sodium	35	76	95	95	90	91	92-95	90-92		
Specific conductance, micromhos at 25°C	847	1,200	549	—	1,570	1,580	1,040-1,470	1,480-1,980		900
pH	7.8	8.1	7.7	8.3	7.9	7.4	7.4-8.1	7.1-7 9		
Temperature, (°F)	68	72	70	—	—	—	66	66-69		
Depth of well, feet	290	—	502	500	93.5	93.5	200	200		

Source: Bulletin No. 41-6 "Data on Wells in the Edwards Air Force Base Area, California," prepared by U.S. Department of the Interior, Geological Survey, June 1962.

[a] All data are in mg/l unless indicated otherwise.

[b] Samples were collected on 7-22-47, 5-6-48, 11-20-50, 4-10-53, and 1-7-58. The range of concentrations detected on these dates is shown.

[c] Samples were collected on 1-?-47, 4-10-53, 1-7-58, and 4-9-58. The range of concentrations detected on these dates is shown.

[d] Recommended maximum contaminant levels.

The creosote bush scrub plant community is generally distributed on the slopes, hills, and well-drained sandy flats and washes throughout the RPL area. Perennial species often associated with the creosote bush (*Larrea divaricata*) include the burrobush (*Hymenoclea monogyra*), Mormon tea (*Ephedra* spp.), brittlebush (*Encelia farinosa*), snakeweed (*Gutierrezia* spp.), shadscale (*Atriplex canescens*), winterfat (*Eurotia lanata*), cheesebush (*Hymenoclea salsola*), and rabbitbrush (*Chrysothamnus mohavensis*). Herbaceous species common to the creosote bush scrub community are similar to those discussed for the Joshua tree woodland, with the addition of the desert evening primrose (*Oenothera deltoides*) and the alkali mariposa lily (*Calochortus striatus*).

The alkali sink vegetation often referred to as saltbush scrub community covers low depressions and margins of dry lakes throughout Edwards AFB. Important shrub species of this community include Parry saltbush (*Atriplex* sp.), wedgescale (*Atriplex truncata*), shadscale (*Atriplex* sp.), four-wing saltbush (*Atriplex* sp.), and burrobush (*Hymenodea monogyra*). Scattered Joshua trees may also be found. Herbaceous species common in the alkali sink community are the same as for the Joshua tree woodland, but are less abundant. The alkali mariposa lily (*Calochortus striatus*) is also found in this community.

2.1.6.2 Wildlife--

Wildlife in the area consists mostly of small mammals, reptiles, and birds. Feral burros (*Equus asinus*) are the only large mammals currently known to utilize the Edwards AFB area. Domestic sheep (*Ovis aries*) are known to forage outside AFB boundaries. Other mammals known or expected to utilize habitats in the area are the desert kit fox (*Vulpes macrotis arsipus*), coyote (*Canis latrans*), black-tailed hare (*Lepus californicus*), cottontail rabbit (*Sylvilagus audubonii*), badger (*Taxidea taxus*), antelope ground squirrel (*Ammospermophilus leucurus*), mice (*Peromyscus* spp.), kangaroo rats (*Dipodomys* spp.), desert woodrat (*Neotoma lepida*), California ground squirrel (*Citellus beecheui*), and Mojave ground squirrel (*Spermophilus mohavensis*). Seed-eating small mammals are particularly abundant due to ephemeral growth during the winter and spring.

Reptiles are common throughout the study area. The desert tortoise (*Gopherus agassizi*) uses most of the habitat areas. Lizard species are abundant and include the collared lizard (*Crotaphytus collaris*), desert horned lizard (*Phrynosoma platyrhinos*), and side-blotched lizard (*Uta stansburiana*). The Mojave green rattlesnake (*Crotalus scutulatus*), garter snakes (*Thamnophis* spp.), and coachwhips (*Masticophis flagellum*) are also expected in the area.

Predatory birds common to the area include the ferruginous hawk (*Buteo regalis*), harrier (*Circaetus* spp.), red-tailed hawk (*Buteo jamaicencis*), rough-legged hawk (*Buteo lagopus*), American kestral

(Falco sparverius), turkey vulture (Cathartes aura), burrowing owl (Athene cunicularia), and the great-horned owl (Bubo viginianus). Other common birds in the area include the horned lark (Eromophilia alpestris), common raven (Corvus corax), roadrunner (Geococcyx californianus), white-crowned sparrow (Zonotrichia leucophrys), western meadowlark (Sturnella neglecta), and the cactus wren (Heleodytes brunneicapillus). The mourning dove (Zenaida macroura) and Gambel's quail (Lophortyx gambelii) are game birds which have also been observed in the area.

2.1.6.3 Threatened, Endangered, and Special Status Species--

The following list of potential special status plants and animals has been developed based on previous biological studies of the Edwards AFB area (USFWS, 1984 and Personal Communication, Mike Phillips, 1986) and from information obtained from the Natural Diversity Data Base, (California Department of Fish and Game (DFG), 1986).

Alkali mariposa lily (Calochortus striatus)
Mojave spineflower (Chorizanthe spinosa)
Desert cymopterus (Cymopterus deserticola)
Mojave ground squirrel (Spermophilus mohavensis)
Desert tortoise (Gopherus agassizi)

Alkali mariposa lily--Alkali mariposa lily is a small, smooth, perennial herb, 4 to 18 inches high. The flowers are lavender with purple veins and generally appear between April and June in the Mojave Desert. The plant is typically found in alkaline meadows and springy areas at elevations of 2,500 to 4,300 feet. The plant is associated with the creosote bush scrub habitat (Munz and Keck, 1959). All known populations of alkali mariposa lily on Edwards AFB are located on the southern and western margins of Rogers and Rosamond Dry Lakes. Alkali mariposa lily is a candidate for federal protection. It is in the U.S. Fish and Wildlife Service (USFWS) Category 2, species that may warrant listing but for which substantial biological information is not available.

Mojave spineflower--Mojave spineflower is a prostrate annual. During April through July, small flowers with three white, petal-like sepals appear. This plant occurs in sandy and gravelly places at elevations of 2,500 to 3,500 feet. It is associated with the creosote bush scrub and Joshua tree woodland habitats in the Mojave Desert (Munz, and Keck, 1959). Mojave spineflower has been found approximately 3 to 7 miles east of RPL in San Bernardino County. It is in USFWS Category 3C, plants which are more abundant or widespread than was previously believed and/or plants that are not subject to any identifiable threat.

Desert cymopterus--Desert cymopterus is a dwarf, stemless, smooth perennial herb, 4 to 6 inches high. The flowers are purple and generally appear in April in the Mojave Desert. The plant is typically found in sandy or gravelly areas at elevations of 2,500 to 3,100 feet. It is rare even in its preferred habitat. The plant is most often associated with creosote bush scrub and Joshua tree woodland habitats (Munz and Keck, 1959). It has been found approximately 3 to 7 miles east of RPL in San Bernardino County. Desert cymopterus is a candidate for federal protection. It is in USFWS Category 2.

Mojave ground squirrel--The Mojave ground squirrel is a small, brownish-gray, desert-dwelling ground squirrel. It is found in desert habitats at elevations of 1,800 to 5,000 feet. The animal is torpid from August to March, remaining underground in burrows. It is listed as a candidate species, Category 2, by the USFWS (FR 50:181, pp 37965) and as threatened by DFG.

Desert tortoise--The desert tortoise is a terrestrial desert turtle found in the cresote bush scrub habitat of the Mojave desert. It is active in April and May and aestivates during the cold winter months. It was listed as a candidate species, Category 2, by the USFWS (FR 50:181, pp 37965). On December 5, 1985, the USFWS "determined that listing the tortoise as an endangered species throughout its range is warranted, but precluded by other pending proposals of higher priority." (FR 50:235, pp 49868-49870.)

In addition to the species described above, the feral burro is a protected species under the wild horse and burro act, and the desert kit fox (Vulpes macrotis arsipus) is listed by DFG as a special animal. Special animals are not legally protected in California but they are of concern because they are associated with a habitat that is declining rapidly in California. There are several species of eagles and falcons which overwinter in the area that are listed as special animals by DFG. The bald eagle (Haliaeetus leucocephalus) and the peregrine falcon (Falco peregrinus) are both state and federally listed endangered species. The golden eagle (Aquila chrysaetos) is a fully protected species in California. Protected species cannot be hunted or collected for any purpose without a permit from DFG. The prairie falcon (Falco mexicanus) is not legally protected but it is listed by DFG as a species of special concern because its population is thought to be declining.

2.2 MAN-MADE ENVIRONMENT

2.2.1 Population

As shown on Figure 1.1, the test site lies in the southeast corner of Kern County which borders San Bernardino County on the east and Los Angeles County on the south. The site is about 90 miles northeast of downtown Los Angeles. The nearest cities are Lancaster, approximately 30 miles to the southwest, and Mojave, about 30 miles to the west-northwest.

Nearby communities include Rosamond, California City, North Edwards, and Kramer Junction. The closest community is Boron, located approximately 3.5 miles north-northeast of the test site with a population of about 2,000 people. In addition, a small housing area, Desert Lakes, is located approximately 3 miles north of the test site. The main base at Edwards AFB is about 11 miles west-southwest of the test site.

2.2.2 Socioeconomics

Geographically, Edwards AFB lies at the intersection of three counties, but its primary economic ties are with Kern and Los Angeles Counties. No direct access exists from population centers in San Bernardino County to Edwards AFB. Consequently, few base employees live in that county and little income is spent there. Base procurements from merchants in San Bernardino County are relatively insignificant, and do not contribute appreciably to the county's economy.

The economy of northern Los Angeles County is dominated by the airplane and aerospace industry. This area is sensitive to fluctuations in federal spending for military aerospace activities. The Palmdale-Lancaster area serves as a manufacturing, trade, and services center. In the past, this area has been fairly rural and isolated, but it has become rapidly urbanized and industrialized. Edwards AFB civilian employees tend to live in this area and base procurements from merchants in the area are common.

The southeastern Kern County economy, on the other hand, is based on agriculture and mining, with relatively few industries related to aerospace. The main Edwards AFB community and RPL are located in Kern County, and the economic benefits to Kern County are derived from the spending of disposable income generated at Edwards AFB and from base procurements.

RPL is located in the northeast corner of Edwards AFB about 11 miles east of the main base. RPL is a research and development facility responsible for planning, formulating, and executing the USAF technology programs for rocket propulsion and related space technology. Both solid and liquid rocket motors are tested at a number of test stands located in both Kern and San Bernardino Counties. Most of the RPL buildings are located about 1 mile from the proposed test stand on Leuhman Ridge.

2.2.3 Noise

Noise is generated by pressure fluctuations in the air. The human ear reacts to changes in sound pressure so that each doubling of sound pressure represents equal increases in loudness. The same type of relationship also applies to the human ear's frequency sensitivity. Therefore, both sound pressures and frequency are commonly expressed in logarithmic scales, where these relationships are linear with respect to loudness.

The common measure of sound pressure level is decibels (dB), with zero dB being the threshold of hearing. Examples of sound pressure levels are 40 to 50 dB in an office, 70 dB inside a car at highway speeds, 80 to 85 dB 50 feet from a highway with truck traffic, and 100 dB or more near an airport during aircraft flyovers.

At approximately 120 dB, the sound will be felt as a gentle pressure in the ear. At 140 dB, there will be a painful sensation in the ear and, at the lower frequency ranges, feelings of pressure on the body or vibrations of the rib cage. Sound pressures of 160 to 170 dB (typical of rifle shots at close range) may lead to permanent hearing damage after short exposure. Structural damage to dwellings will occur in the range of 130 to 140 dB for the predominately low frequency range, typical of rocket noise.

The ear does not hear all frequencies with equal acuity. Low frequencies are attenuated, while those essential for human speech are slightly amplified. Noise levels measured with the A-weighting network provide a good correlation of human reactions to noise levels and are useful for estimating audibility of sounds. Units for A-weighted pressure levels are listed in dB(A).

Criteria for noise intrusion and annoyance are generally based on integration of the noise events over time, including multiple events. Therefore, they are of questionable value for assessing a program such as that proposed for the Titan test firings, where the noise events will be of very short duration, and where the total test program is limited to approximately three events, and where the noise is so disproportionately weighted toward low frequencies.

Common community noise descriptors include the Community Noise Equivalent Level, (CNEL), the Day-Night Average Sound Level (Ldn), and different statistical descriptors, including levels exceeded for certain percentages of the time. The Kern County Noise Element of the General Plan uses L_{50} (the level exceeded for 50 percent of the time, or the "median level") as the criterion for acceptability of different land uses. This descriptor is appropriate for relatively continuous noise environments, such as near a roadway, but is practically meaningless in assessing rocket test noise. Since the rocket test lasts only 2 minutes, the L_{50} would be unaffected by it unless the measuring period were to be less than 4 minutes long, in which case it would be equal to the rocket noise level.

The Ldn is an energy-based average sound level for the entire 24-hour day, where nighttime noise levels occurring between 10 p.m. and 7 a.m. are adjusted by 10 dB to account for the additional sensitivity of people at that time. CNEL is a very similar descriptor with the exception that evening noise events, occurring between 7 a.m. and 10 p.m. are penalized by 5 dB. For the rocket testing, these descriptors would normally be equivalent, unless the testing occurs during the three evening hours, in which case the CNEL would be 5 dB higher.

Hearing loss criteria have been developed by the Occupational Safety and Health Administration (OSHA) for working environments, where workers are exposed to continuing high levels of noise. The highest noise level allowed at any time in a workplace under OSHA standards is 115 dB(A). A criterion which has been used by the National Aeronautics and Space Administration (NASA) and the U.S. Air Force (USAF) for "uncontrolled populations" is that the overall level shall not exceed 120 dB, corresponding to the approximate onset of pressure sensations in the ear and a general feeling of concern. At this level, and with low frequency noise dominating, gentle rattling of windows and walls may also be experienced.

Noise levels in the vicinity of the test site have not been measured. However, noise levels can reach 100 dB or more during aircraft testing on the nearby Precision Impact Range Area (PIRA). The Edwards AFB area is subject to frequent overflights of high-powered military aircraft that often fly faster than the speed of sound, creating "sonic booms."

2.2.4 Archaeology and Cultural Resources

The Edwards AFB area is rich in archaeological resources due to the centralized position of the Antelope Valley to geologic features in southern California and to the shallow lakes which once existed in the area. The margins of these now dry lakes are rich repositories of archaeological remains. As of November 1986, there are approximately 400 recorded prehistoric sites and 450 historic sites on Edwards AFB (Norwood, 1986).

Known prehistoric archaeological sites span at least 6,000 years and represent a variety of functions, including habitation, food procurement, quarrying, manufacturing, and burial of the dead. Historic resources consist of homesteads and associated features dating from the early part of the 20th century. No comprehensive study or synthesis of either paleontological or archaeological resources for the entire Air Force Base has yet been completed. The references "Cultural Resources Overview for Edwards Air Force Base" (Greenwood and McIntyre, 1980) and "Cultural Resources Management Plan for Edwards Air Force Base" (Greenwood and McIntyre, 1981) provide the most comprehensive background information on the history, prehistory, and ethnology of Edwards AFB in addition to excellent summaries of relevant geological, biological, and paleontological information.

Although no comprehensive survey of Leuhman Ridge has yet been attempted, various surveys have been completed in the general area, and at least one prehistoric archaeological site is known on the ridge itself (Personal Communication, Richard Norwood, December 1986). No archaeological or paleontological sites are known to exist sufficiently close to the project site to be of particular concern. A survey of the test site area was conducted in December 1986 and no cultural or paleontological resources were found (Robinson, 1987).

2.2.4.1 Test Stand History--

The six large existing rocket test stands on Leuhman Ridge were used primarily in the 1960s to support NASA's Saturn V program with its manned Apollo missions to the moon. The F-1 liquid fuel engines, used in the first stage of the Saturn V, were tested on these stands.

The first test stand to be built, Test Stand IA, was originally constructed for the USAF in 1956 for the Atlas rocket program. Following an Atlas rocket engine explosion on this test stand in 1958, Test Stand IA was modified under NASA direction by Rocketdyne for research and development testing on the F-1 engine. Test Stand IB was constructed in 1960, also for F-1 research and development testing. Test Stand IIA was built in 1959. This test stand was constructed to perform near-horizontal testing (rather than vertical nozzle-down testing on the other five test stands) for development of thrust chambers and injectors for the Saturn V. Test Stand IIA was operated up to the mid-1960s. Test Stands IA and IB were operated into the late 1960s.

Test Stands IC, ID, and IE were constructed for production testing of F-1 engines. IC was placed in operation in the spring of 1965, ID in the summer of 1965, and IE in the fall of 1965. The last F-1 test firing on these stands was in 1974. Test Stand IE was used primarily for qualification testing under environmental extremes and has the necessary facilities for cold and hot temperature conditions. Rocketdyne operated all six test stands through its contract with NASA (Personal Communication, Frank Will, 1986).

The test stands were constructed to safely handle 2 million pounds of thrust. Although each F-1 engine was designed for 1.5 million pounds of thrust, actual peak thrusts in excess of 1.8 million pounds were measured on these test stands occasionally. Due to the conservative design of the test stands, they are probably capable of handling thrusts well in excess of 2 million pounds. The USAF is considering the use of these stands for test firing rocket engines for a heavy-payload Saturn-class rocket currently under investigation (Personal Communication, Frank Will, December 1986; Pete Van Splinter, December 1986).

3.0 ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

3.1 GEOLOGY AND SOILS

The proposed rocket motor tests at Edwards Air Force Base (AFB) will not adversely affect the geologic resources of the area. The tests will be conducted on an existing test stand (IC) that has been modified for the static tests of Titan rocket motors. The deluge water containment basin at Test Stand IC was recently repaired as part of the modifications to the test stand. This required regrading a berm of the water containment basin near Test Stand IC. This will not result in significant soil erosion.

3.2 AIR QUALITY--2-MINUTE TEST FIRINGS

The large quantity of combustion products that will be produced by the 2-minute rocket motor tests are potentially a significant source of emissions. The potential air quality impacts of the proposed testing program and measures to be implemented by the U.S. Air Force (USAF) to minimize those impacts are described in this section. The air quality impacts of the short-burn tests are described in Section 3.3.

3.2.1 Rocket Motor Emissions

This section describes the emissions, deluge water system, and afterburning reactions for the 2-minute test firings. The 2-segment test firing is fully described here, although it may not be conducted.

3.2.1.1 Emissions at the Rocket Nozzle--

The propellant used in the Titan motor consists of ammonium perchlorate oxidizer, aluminized synthetic-rubber binder fuel, and various other additives to stabilize mass and control the burning rate. The combustion products at the nozzle will consist of particulates (consisting mainly of aluminum oxide (Al_2O_3)), hydrogen chloride (HCl), hydrogen (H_2), nitrogen (N_2), water (H_2O), carbon dioxide (CO_2), and carbon monoxide (CO). The combustion process within the rocket motor will release oxygen (O_2). The O_2 released is then used to continue the combustion process. No O_2 is assumed to exist in the exhaust at the nozzle. Total emissions expected at the nozzle (or, more specifically, at the nozzle exit plane) are shown in Table 3.1. The location of the nozzle and the nozzle exit plane are shown on Figure 3.1.

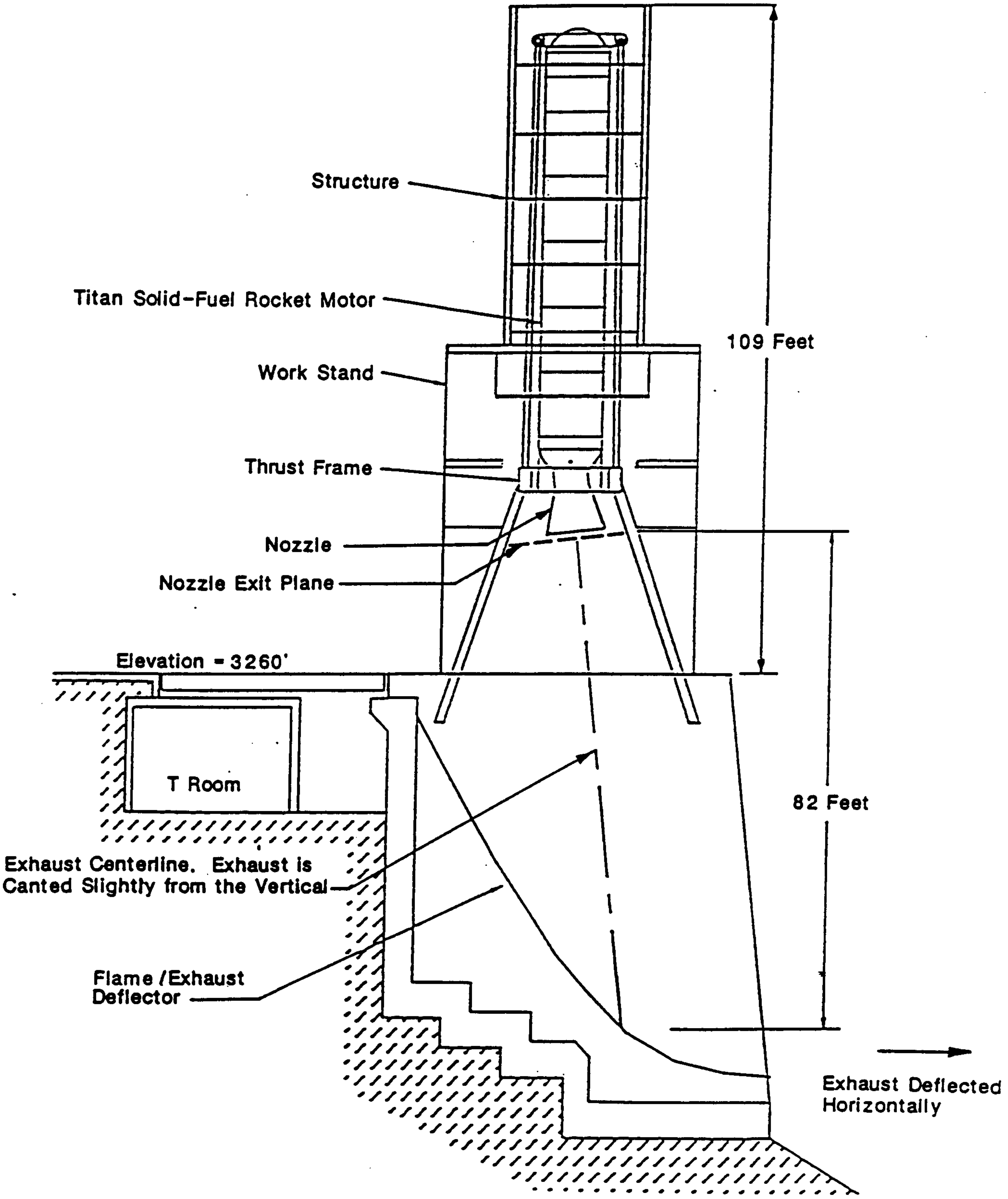


Figure 3.1 Side View of 5-1/2 Segment Motor

Source: Wyle Laboratories, August 6, 1986 ,Modified by Brown and Caldwell

The estimated emissions listed in Table 3.1 are based on years of technical development of the Titan solid propellant and its combustion characteristics. Specifically, these numbers are derived from a set of five volumes evaluating reaction products, completed in 1984 for the USAF (Lamberty and Hermsen, 1984). These documents describe the chemical reactions and equilibrium equations which apply during combustion in a Titan motor case. A computer program was developed as part of Lamberty and Hermsen's work to assess the possible reactions and determine which ones are predominate.

Table 3.1 Emissions at Nozzle

	Emissions, pounds per test						
Rocket motor	Al_2O_3[a]	HCl	H_2	N_2	CO	CO_2	H_2O
5-1/2-segment	140,514	96,080	11,330	38,950	129,510	13,026	32,436
2-segment[b]	62,178	42,516	4,880	17,235	57,310	5,733	14,353

[a] Assumed to be particulate matter.
[b] The 2-segment test is optional.

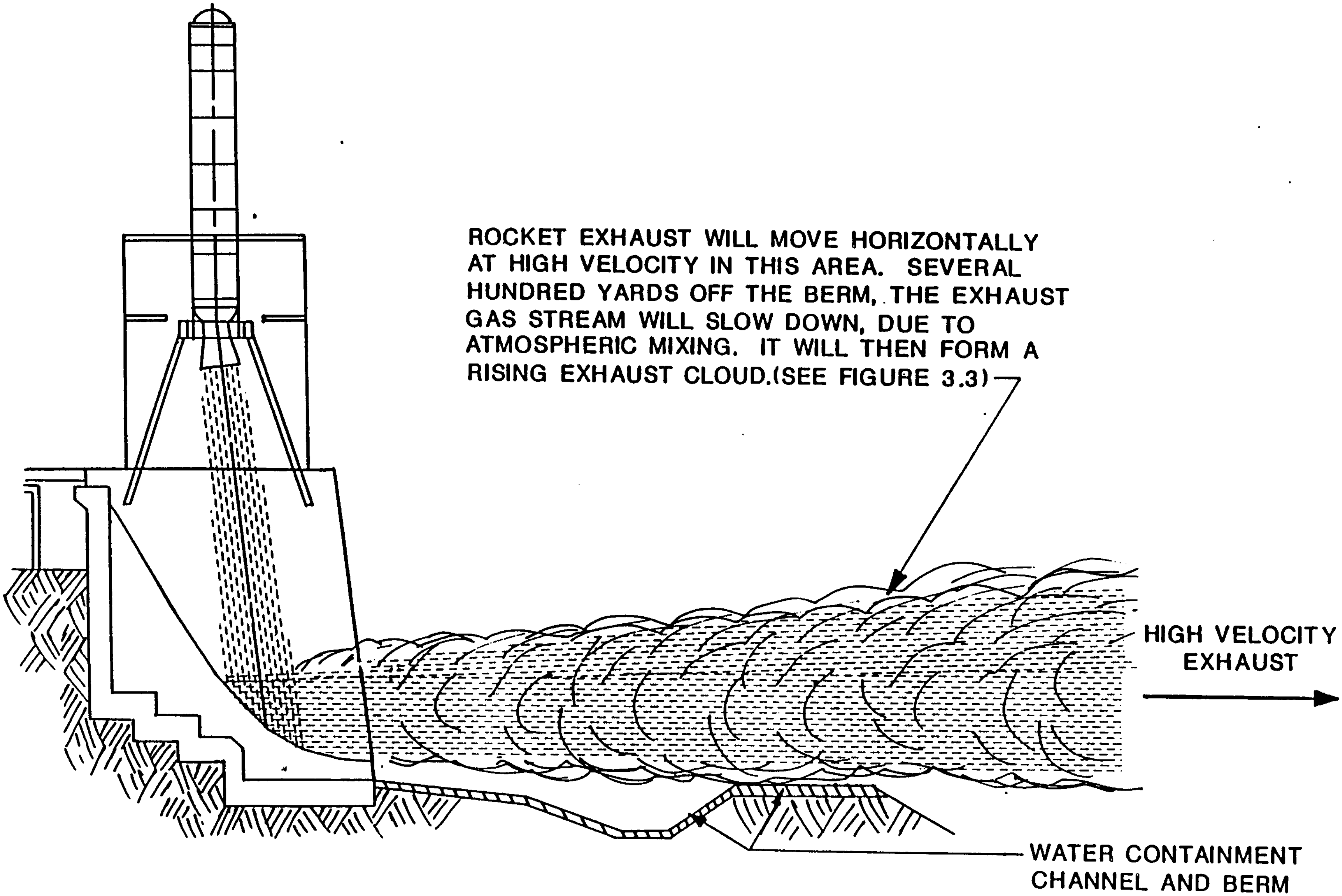
Note: Each test will be 2 minutes in duration because it takes 2 minutes for the propellant to burn from the core to the casing in each segment.

During the test, the exhaust will leave the rocket nozzle vertically downward (see Figure 3.1) at a temperature of about 3,330 degrees Fahrenheit (F). The exhaust velocity at the nozzle for the 5-1/2-segment motor is about 8,100 feet per second (fps) and for the 2-segment motor the exhaust velocity is about 6,200 fps.

The exhaust stream will strike a deflector plate mounted directly below the nozzle and will be deflected horizontally away from Leuhman Ridge in a west-northwesterly direction (see Figure 3.2). Because of the volume of exhaust and the velocity with which it leaves the rocket nozzle, the exhaust cloud is expected to extend up to 1/4- to 1/2-mile beyond the base of the test stand. Various water sprays will be used to cool the exhaust, provide sound suppression, and quench the motor case. These sprays total about 140,000 gallons per minute (gpm).

3.2.1.2 Afterburning Emissions--

The conversion of H_2 to H_2O, CO to CO_2, and N_2 to nitrogen oxides (NO_x) is assumed to take place in the afterburning process occurring in the exhaust cloud. This section describes the afterburning process.



ROCKET EXHAUST WILL MOVE HORIZONTALLY AT HIGH VELOCITY IN THIS AREA. SEVERAL HUNDRED YARDS OFF THE BERM, THE EXHAUST GAS STREAM WILL SLOW DOWN, DUE TO ATMOSPHERIC MIXING. IT WILL THEN FORM A RISING EXHAUST CLOUD.(SEE FIGURE 3.3)

Figure 3.2 Side View of Test Stand During 2-Minute Test (Water Deluge System Not Shown)

The conversion of H_2 to H_2O is an exothermic reaction that requires a small amount of activation energy. Therefore, it is assumed that all the H_2 is converted to H_2O.

The conversion of CO to CO_2 was estimated from measured values obtained from in-cloud measurements of Titan launches in 1977 at the USAF Eastern Test Range in Florida. The in-cloud measurements indicate only trace amounts (less than 1 part per million (ppm) of peak exhaust concentrations) of CO in the stabilized exhaust cloud (Bendura and Crumbly, 1977; Gregory et. al, 1978; Woods et al., 1979; and Wornom et al., 1979). Modeling the launch exhaust, assuming no CO afterburning, results in in-cloud CO concentrations that are much higher than actual measurements. The modeling work implies a reduction in CO of about 98.8 to 99.4 percent. Therefore, it was assumed that 99 percent conversion of CO to CO_2 will occur in the afterburning process for the Titan tests.

Nitrogen conversion (N_2 to NO_x) in the rocket exhaust is a complex process not entirely understood. It is clear, however, that some nitrogen is oxidized, based on exhaust cloud measurements from Titan launches. A conservatively high estimate of NO_x formation of 22,000 pounds has been made based on field information from Titan launches. The quantity of NO_x produced by the 2-segment rocket motor tests is assumed to be the same as for the 5-1/2-segment test. This assumption is conservative due to the lower velocities and lower amount of thermal energy released by the 2-segment tests. The lower exhaust velocities will entrain less O_2 from the ambient air. This will reduce the availability of O_2 for the conversion of N_2 to NO_x. In addition, the lower amounts of thermal energy released will reduce the size of the exhaust plume where the N_2 to NO_x reactions occur rapidly.

The estimated quantities of exhaust pollutants following afterburning are shown in Table 3.2. For more information on nitrogen and CO afterburning, see the Air Pollution Control District exemption support document (Brown and Caldwell, 1986).

Table 3.2 Rocket Exhaust Products Following Afterburning

	Atmospheric exhaust products, pounds per test						
Motor segment	Al_2O_3	HCl	N_2	NO_x[a]	CO_2[b]	CO	H_2O[c]
5-1/2	140,514	96,080	29,203	22,000	215,247	1,295	32,436
2	62,178	42,516	7,488	22,000	95,219	573	14,353

[a] Assumes 90 percent of the NO_x compounds is NO and 10 percent of the NO_x compounds is NO_2 (Cole and Sommerhays, 1979).
[b] Assumes 99 percent of the CO is converted to CO_2 during the afterburn.
[c] Does not include water entrained or vaporized from water deluge system.

3.2.1.3 Emissions From Deluge Water--

Section 3.2.2.2 describes the amount of deluge water vaporization expected and the amount of mist formed. Since the deluge water contains sodium carbonate, reactions with exhaust HCl will occur in the mist particles entrained in the exhaust plume. These reactions are described in Section 3.2.5 and are summarized here with respect to their impact on downwind air quality predictions.

In addition to the direct rocket exhaust emissions listed in Table 3.2, the deluge water and its chemical constituents entrained in the exhaust plume will add the following to the exhaust plume for each test:

1. Water vapor and water mist totaling 280,000 gallons.
2. Sodium chloride (common table salt) dissolved in the mist. The sodium carbonate added to the deluge water is largely transformed to sodium chloride due to the reaction with HCl.
3. Minor amounts of other dissolved salts and compounds contained in the deluge water.

These constituents are not considered "emissions" for air quality modeling purposes since they will largely settle or fall out of the exhaust cloud in the vicinity of the test stand or in the immediate downwind area. In summary, for purposes of air quality modeling of the exhaust cloud, the deluge water emissions are not significant and are not considered. The fallout of mist, particulates, and HCl is described separately (Section 3.2.5) and evaluated in Sections 3.4 and 3.5.

3.2.1.4 Exhaust Temperature--

The rocket exhaust temperature will be about 3330 degrees F at the nozzle. The water deluge system will help cool the exhaust to protect the test stand structure. The deluge water that vaporizes will lower the temperature of the exhaust at the flame bucket and help protect it. The remainder of the deluge water will be a mist entrained around the edges of the exhaust gas stream and will provide additional cooling of radiant heat around the exhaust stream. The exhaust gas stream will be projected immediately above the concrete berm located approximately 100 feet from the flame bucket. The berm is expected to experience an increase in temperature. However, the ground surface drops rapidly beyond the berm (essentially a talus pile) for 100 to 200 feet. The exhaust temperatures will be reduced rapidly as the exhaust plume projects beyond the berm due to the entrainment of large quantities of ambient air from turbulent mixing. At the point where the exhaust cloud begins to rise, the temperature within the cloud will be within a few degrees of the ambient air temperature.

3.2.2 Model Description

The air quality model and results for the 2-minute test firings are described in this section.

3.2.2.1 Meteorological Scenario--

Cold-temperature-induced stresses on the rocket motor are of most interest to the USAF and United Technologies Corporation-Chemical Systems Division (CSD). However, these stresses can be analyzed in warm-weather periods by cooling the rocket motor to the required temperature for analysis. Therefore, the test firings can be undertaken in summer as well as other seasons. It would be easier and less costly to complete the tests in cooler weather, and it is likely that the 2-minute tests will be completed prior to the summer of 1987. However, there are no specific limitations on the test firings due to air temperature and, therefore, the modeling work has assumed a variety of ambient air temperatures likely to occur in the daytime periods over all seasons at Edwards AFB. The meteorological parameters associated with these test periods are shown in Table 3.3.

Table 3.3 Meteorological Parameters for Rocket Motor Test Modeling

Parameter	Late morning/early afternoon
Temperature, degrees F	40 to 100
Wind speed, knots	5, 7, 9[a]
Radiation inversion	No
Subsidence inversion	No
Atmospheric stability	Unstable

[a] Modeling at 20 knots is being conducted to determine if downwind concentrations would be higher than predicted at 5, 7, and 9 knots.

3.2.2.2 Modeling Methodology--

The dispersion modeling used to estimate downwind concentrations from the 5-1/2-segment rocket motor test is briefly described in this section. The model (box model described below) that was used to estimate the downwind concentrations involves a conservative (worst-case) approach. Since this model and approach showed no air quality problems, more detailed modeling was not necessary.

A box model that assumes a trivariate Gaussian distribution in the vertical and horizontal (x, y, and z) directions was selected to estimate the maximum ground level pollutant concentrations at various receptors. The trivariate Gaussian distribution model is given in EPA's Workbook of Atmospheric Dispersion Estimates AP-26, (Turner, 1970). The trivariate Gaussian distribution is also used in the following EPA models:

1. Mesopuff
2. Mesopuff 2.0 (Scire et al., 1983)
3. Inpuff 2.0 (Peterson and Laudas, 1986)

The quasi-instantaneous dispersion parameters (sigma (x), sigma (y), and sigma (z)) given in AP-26 were used for the Titan exhaust cloud modeling. The quasi-instantaneous dispersion parameters were used instead of the Pasquill-Gifford (P-G) (Turner, 1970; Hanna et al., 1982) dispersion parameters because of the short averaging time required for the downwind concentrations and the short rocket exhaust release time (2 minutes). A comparison of the maximum estimated ground-level concentrations for the quasi-instantaneous and P-G dispersion parameters indicate that the quasi-instantaneous dispersion parameters predict higher maximum peak ground-level concentrations by factors ranging from 2.2 to 2.4. Therefore, to be conservative, the quasi-instantaneous dispersion parameters were used. A representation of exhaust cloud formation is shown on Figure 3.3.

The exhaust cloud stabilization height was determined using Briggs buoyant plume rise equation modified for a plume only slightly inclined from the horizontal (Dumbauld and Bjorkland, 1972). In addition, the energy due to afterburning and the energy required to vaporize a portion of the deluge water was considered in estimating the exhaust cloud rise. The range of exhaust cloud heights estimated for the 5-1/2-segment Titan test at the Rocket Propulsion Laboratory (RPL) is 3,500 to 4,900 feet above the test stand. The height range for the 2-segment test is 2,930 to 3,540 feet above the test stand.

The amount of deluge water vaporized by the rocket exhaust was estimated using the conservation of energy principle and the location of the deluge water jets. The conversion of the initial chemical energy of the solid rocket fuel to thermal and kinetic energy was approximated using the mass of the rocket exhaust, the exhaust exit velocity, and assuming an adiabatic process. The maximum amount of water that could be vaporized in 2 minutes by the exhaust gas stream is estimated at 104,000 gallons assuming all energy was used to vaporize water.

However, the estimated amount of water that will be in direct contact with the core of the exhaust plume is about 32,500 gallons for the 5-1/2-segment test. The external deluge water jets are not expected to significantly penetrate the core of the plume due to the large

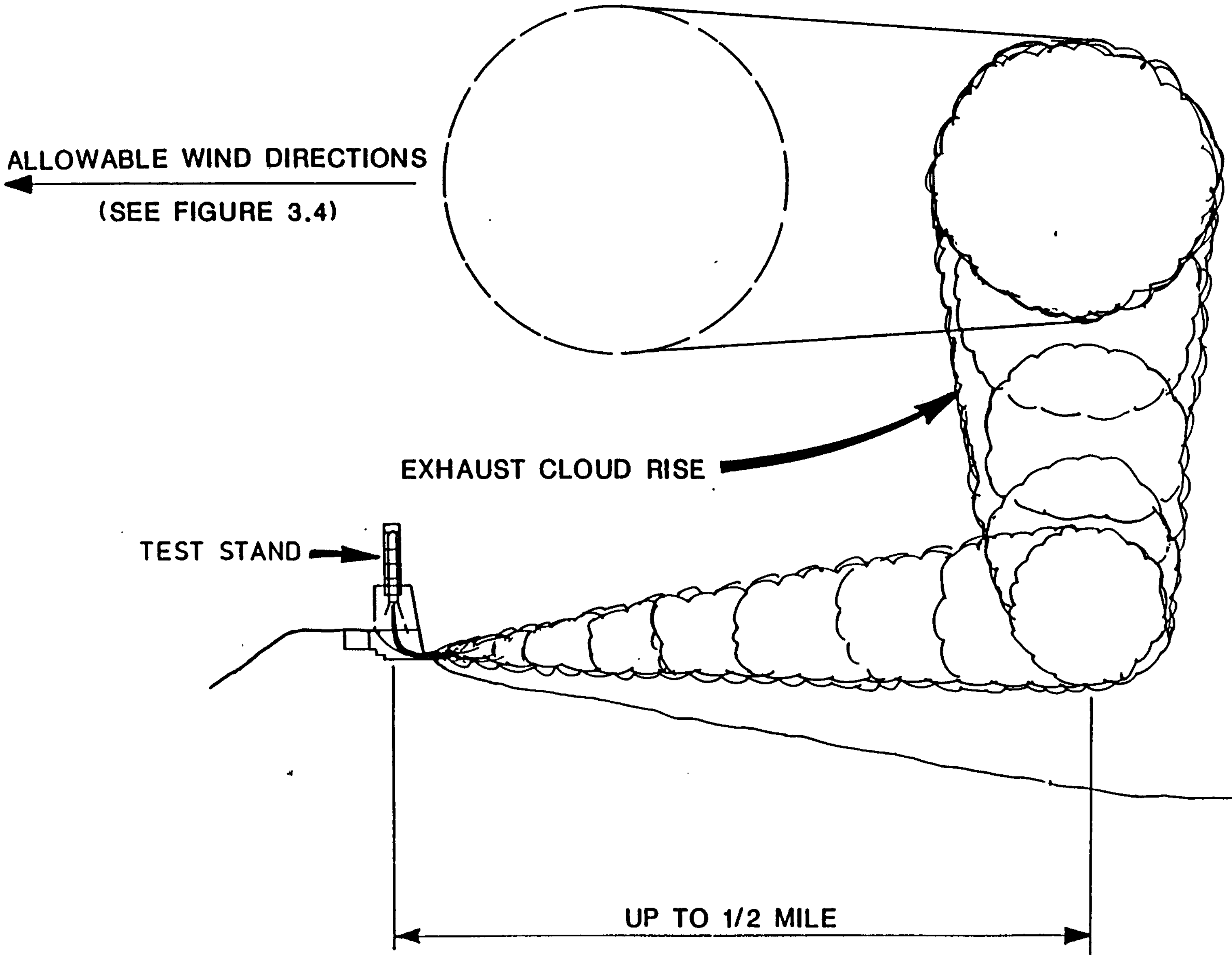


Figure 3.3 Exhaust Cloud Formation and Rise -- 2-Minute Test Firing

differences in velocity and momentum. However, some of this deluge water will be vaporized. To be conservative, an additional 27,500 gallons of water is assumed to be vaporized for a total of 60,000 gallons or 22 percent of the total amount of deluge water applied. Due to the lower total energy in the 2-segment exhaust, less deluge water is expected to be vaporized. It is estimated that approximately 8 percent (22,400 gallons) of the total amount of deluge water will be vaporized.

Visual observations of scale model rocket test firings in November 1986 at Norco, California, and full-scale F-1 liquid rocket test firings at RPL from the 1960s, indicate that a large amount of the deluge water is entrained in the exhaust cloud as a fine mist. A portion of the fine mist will evaporate and the rest will precipitate.

An energy balance of the exothermic and endothermic afterburning reactions (CO to CO_2, H_2 to H_2O, and N_2 to NO_x) discussed previously was incorporated into the cloud rise modeling.

3.2.2.3 Model Assumptions--

The assumptions used when estimating the downwind concentrations of the rocket exhaust cloud are listed below. A short explanation of their effect on the estimated concentrations is also included.

1. The total amount of exhaust emissions is assumed to be released into the atmosphere. No losses of HCl or Al_2O_3 are assumed. (However, the water deluge system will remove a portion of the HCl exhaust emissions by absorption into water droplets, and will have the capability of neutralizing much of the HCl in the exhaust, see Section 3.2.5.)

2. The wind speed is assumed constant with altitude through the exhaust cloud. This is a conservative assumption with respect to downwind pollutant concentrations.

3. Gravitational settling was not included in the modeling process. The size distribution of the Al_2O_3 particles within the exhaust cloud is uncertain. Particles range in size from 0.05 micron (um) to 40 um with an estimated 50 to 75 percent of the particles less than 10 um. The particles that are 10 um or less will have dispersion characteristics similar to gases. The 40-um particles have a settling velocity of approximately 0.6 fps. At this settling velocity, about half of the 40-um particles will settle within 8 miles downwind from the 5-1/2-segment motor test at a wind speed of 5 knots. Therefore, gravitational settling will reduce the predicted downwind ground-level particulate concentrations slightly.

4. The conversion of N_2 to NO_x is assumed to be the same as monitored Titan launches. The amount of deluge water to be applied to the exhaust of the proposed Titan tests at Edwards AFB is significantly larger than the amount of deluge water applied to the Titan launches monitored in 1977. Therefore, there will be less conversion of N_2 to NO_x for the proposed Titan tests. To be conservative, this reduction in the conversion rate of N_2 to NO_x was not considered in the modeling process.

3.2.3 Model Results

3.2.3.1 Maximum Concentrations From Rocket Exhaust--

The maximum ground level concentrations and the distance downwind at which the maximum concentrations of Al_2O_3, HCl, and NO_2 occur due to the Titan tests at RPL are shown in Tables 3.4, 3.5, and 3.6. The 2-segment test results in higher downwind concentrations than the 5-1/2-segment test due to the lower stabilized exhaust cloud height of the 2-segment test. In addition, the estimated ground level concentrations at sites located 3.5 and 3.0 miles downwind, respectively, are also shown in Tables 3.4, 3.5, and 3.6. These values assume the exhaust cloud passes directly over Boron or the Desert Lakes housing tract. It should be noted that the predicted maximum ground level concentrations occur at a greater distance downwind than either the Desert Lakes housing tract or Boron. The exhaust cloud will not have dispersed sufficiently from its final stabilized height to produce maximum downwind concentrations at Boron or the Desert Lakes housing tract, assuming the wind blows the exhaust directly toward these areas.

3.2.3.2 Maximum Downwind Concentrations--

The estimated maximum ground-level concentrations due to the proposed Titan tests at RPL are added to the ambient air monitoring data presented in Table 2.2. The total estimated maximum downwind concentrations are shown in Table 3.7.

Table 3.4 Maximum Downwind Concentrations of Al_2O_3

Distance downwind, miles	Wind speed, knots	Averaging time, hours	5-1/2-segment concentration, ug/m^3	2-segment concentration, ug/m^3
7.5[a]	5	24	27.7	31.3
6.8[a]	7	24	22.9	27.2
5.6[a]	9	24	21.8	9.2
3.5	5	24	9.5	12.3
	7	24	9.4	12.2
	9	24	7.6	3.7
3.0	5	24	6.5	8.7
	7	24	6.7	8.9
	9	24	7.4	3.5

[a] Distance downwind where the maximum concentration occurs.

Note: Assumes test conducted late morning to afternoon (after 10 a.m. PST).

Table 3.5 Maximum Downwind Concentrations of HCl

Distance downwind, miles	Wind speed, knots	Averaging time, minutes	5-1/2-segment concentration, ppm	2-segment concentration, ppm
7.5[a]	5	10	1.04	1.27
6.8[a]	7	10	1.21	1.40
5.6[a]	9	10	1.28	1.43
3.5	5	10	0.50	0.65
	7	10	0.59	0.75
	9	10	0.57	0.79
3.0	5	10	0.30	0.46
	7	10	0.42	0.54
	9	10	0.41	0.58

[a] Distance downwind where the maximum concentration occurs.

Note: Assumes test conducted morning to afternoon (after 10 a.m. PST).

Table 3.6 Maximum Downwind Concentrations of NO_2[a]

Distance downwind, miles	Wind speed, knots	Averaging time, hours	5-1/2-segment concentration, ppm	2-segment concentration, ppm
7.5[b]	5	1	0.055	0.064
6.8[b]	7	1	0.050	0.055
5.6[b]	9	1	0.041	0.050
3.5	5	1	0.018	0.026
	7	1	0.019	0.025
	9	1	0.017	0.025
3.0	5	1	0.011	0.019
	7	1	0.014	0.019
	9	1	0.012	0.019

[a] The concentrations assume an initial distribution of 90 percent NO and 10 percent NO_2 and an oxidation rate equal to a peak ozone concentration of 0.19 ppm (Cole and Sommerhays, 1979).

[b] Distance downwind where the maximum concentration occurs.

Table 3.7 Estimated Total Maximum Downwind Concentrations

Pollutant	Averaging time, hours	Ambient air maximum[a]	Maximum concentration due to rocket test	Total maximum downwind concentration	Standard[b]
O_3, ppm	1	0.19	0	0.19	0.12
CO, ppm	1	12.0	0	12.0	20
NO_2, ppm	1	0.11	0.026	0.136	0.25
TSP, ug/m^3	24	176	31	207	260
PM_{10}, ug/m^3	24	82	16–23	98–105	50
HCl, ppm	1/6	0	1.43	1.43	3[c]

[a] See Table 2.2.

[b] Most stringent standard from Table 2.3.

[c] NAS criteria.

The modeling results presented in Table 3.7 show the cumulative impacts of the rocket motor tests and the maximum ambient air quality concentrations. Table 3.7 indicates that the impacts due to the rocket motor tests will not increase the maximum measured values above the state or federal standards except for particulate matter less than 10 um in diameter (PM_{10}). The measured ambient air concentration of PM_{10} presently exceeds the state standard. The impact due to the rocket motor tests is to increase the maximum air concentration of PM_{10} for 2 days between February and December 1987. This is not considered significant.

The maximum estimated 10-minute average HCl concentrations are 0.58 ppm at 3 miles downwind and 0.79 ppm 3.5 miles downwind. The maximum downwind concentration of HCl is predicted to be 1.43 ppm. There is no state or federal short-term standard for HCl; however, the recommended short-term public exposure limit put forth by the National Academy of Sciences is 3 ppm average for 10 minutes (1980).

Acidic precipitation will occur near the test site due to two conditions:

1. A portion of the deluge water is expected to reach the outer surface of the exhaust stream and be atomized on contact due to the large differences in momentum and velocity between the exhaust gas stream and the deluge water stream. The water mist will entrain HCl from the outer edges of the exhaust plume and become acidic. Measurements of the pH for Titan launches indicate a range of 0.5 to 1.0 with the mist settling to the ground in the vicinity of the launch site. Since the water at RPL will be buffered with sodium carbonate, the pH of the mist is expected to be about 3 (see Section 3.2.5).

2. The exhaust plume will entrain a significant amount of the deluge water due to vaporization and turbulent gas mixing. As the cloud entrains air and the exhaust cools, a portion of the entrained water vapor will condense onto the Al_2O_3 particles and precipitate from the cloud. This amount will be small (less than 1 percent of the water vapor) when compared to the precipitation due to the mist as discussed in Section 3.2.5.

3.2.4 Summary of Air Quality Impacts

The Titan rocket motor tests will not cause established air quality standards or criteria to be exceeded in the surrounding area for NO_2, HCl, CO, and TSP. The representative peak ambient air PM_{10} concentration was estimated to be 82 micrograms per cubic meter (ug/m^3). This PM_{10} concentration currently exceeds the state standard of 50 ug/m^3. The addition of the estimated PM_{10} impacts due to the rocket tests (16 to 23 ug/m^3) would increase the estimated peak PM_{10} concentration. Due to the lack of monitoring data available for PM_{10}, the small number of rocket tests (3), and the short duration of each test (2 minutes), the PM_{10} impacts are not considered significant.

3.2.5 Precipitation in the Vicinity of Test Stand

The exhaust gas stream will entrain the deluge water in two different phases:

1. Water vapor--The estimated amount of water vapor in the exhaust plume is a combination of the water vapor present at the nozzle (4,000 gallons for the 5-1/2-segment test and 1,700 gallons for the 2-segment test), and the vaporized deluge water (about 60,000 gallons for the 5-1/2-segment test and 22,400 gallons for the 2-segment test).

2. Water mist--The remainder of the deluge water is assumed to be in the form of mist (220,000 gallons for the 5-1/2-segment test and 257,600 gallons for the 2-segment test).

The mist is produced by a shearing force that occurs due to the large differences in velocity and momentum between the water jets and the exhaust gas stream.

Precipitation near the test stand will occur primarily from the mist entrained into the exhaust cloud. The condensation of the vaporized water onto the Al_2O_3 particulates will be negligible (under 1 percent) due to the large amount of ambient air in the exhaust cloud (greater than 99.9 percent by weight at stabilized height) and the low relative humidity of the ambient air (20 to 50 percent). In addition, a portion of the mist will evaporate due to the low relative humidity. To be conservative, no evaporation of the mist was assumed when estimating the mist precipitation in the vicinity of the test stand.

The mist droplets will collect (scrub) a portion of the HCl and Al_2O_3 in the exhaust cloud. The scrubbing mechanisms are different for the HCl and Al_2O_3, as described below.

For water droplets with low concentrations of aqueous HCl, the equilibrium partial pressure is about two orders of magnitude less than the equilibrium partial pressure of the gas phase HCl (approximately 1 dyne/square centimeter (dyne/cm^2 (aqueous) to 98 dyne/cm^2 (gas phase) at 15 degrees centigrade (C) (Cramer, et al., 1970)). Therefore, essentially all gas phase HCl that comes in contact with the water droplets will be absorbed down to a pH of about 1 (Cramer, et al., 1970).

The amount of HCl scrubbed out is estimated to be about 30 percent of total HCl rocket emissions. This removal percentage was estimated from monitored Titan launches and is approximate due to the error involved in determining the volume of the Titan launch exhaust clouds at relatively long downwind distances (4 to 27 miles) (Gregory, et al., 1978 and Wornon, et al., 1979). The removal percentage was estimated by comparing the total mass of HCl in the exhaust at the nozzle to the total mass of HCl in the exhaust cloud, as it traveled downwind. The total mass of HCl in the exhaust cloud was calculated from the average concentration measured in airplane fly-throughs and from the estimated cloud volume at the time of the sampling fly-throughs.

The water droplets scrub the Al_2O_3 by impingement of the Al_2O_3 particles onto the water droplets as the water droplets settle. This scrubbing mechanism requires an impact between the Al_2O_3 particles and the water droplets. This is a less efficient scrubbing process than the HCl absorption process. The amount of Al_2O_3 removed is estimated to be about 5 to 20 percent of total Al_2O_3 rocket emissions. This range was estimated by comparison of the HCl/water droplets and Al_2O_3/water droplets scrubbing mechanisms. The monitored Titan launches are inconclusive in determining a removal percentage of Al_2O_3 due to the large amounts of debris entrained in the exhaust cloud. However, some removal of Al_2O_3 particles does occur (Bendura, et al., 1977, Gregory, et al., 1978, Woods, et al., 1978, and Wornom, et al., 1979).

The deluge water will be buffered with sodium carbonate (Na_2CO_3) and will have an initial pH of about 11. Therefore, the water mist produced by the shearing action of the rocket exhaust velocity and momentum will also have a pH of about 11.

When the mist absorbs HCl in the exhaust cloud, the HCl will dissociate and react with the Na_2CO_3 in the following reaction:

$$2HCL + Na_2CO_{3\,(aq)} \longrightarrow 2Na_{(aq)}^{+} + 2Cl^{-}_{(aq)} + H_2O + CO_{2\,(g)}$$

Note that at a low pH (pH <3) the aqueous carbonic acid (H_2CO_3) changes to water (H_2O) and carbon dioxide (CO_2) gas. (Morel, 1983). Therefore, the final concentration of carbonates in the mist will be small (approximately 10^{-5} Molar). The aqueous sodium ions (Na^+) and aqueous chloride ions (Cl^-) will combine to form common salt (NaCl) when the mist evaporates. The final pH of the mist after the reactions between the HCl and the Na_2CO_3 take place, should be about 3.

The maximum amount of precipitation that could occur from the test was estimated by assuming that all 220,000 gallons of the mist deluge water precipitated within 1 mile. This assumption is conservative due to the following reasons:

1. The smallest droplets (less than 10 um) will behave as a gas and disperse as the exhaust cloud disperses.

2. The large amount of ambient air at a low relative humidity (at initial stabilized height, 99.9 percent ambient air by weight at a relative humidity between 20 and 50 percent) will cause a portion of the mist to evaporate.

Assuming the 220,000 gallons of deluge water precipitates within 1 mile, the amount would be about 0.01 inch of precipitation average. This will be a thin moisture film that will evaporate within about 1 hour under the average annual evaporation rate of 80 inches per year in the Mojave Desert (Linsley and Franzini, 1979). This would be typical in late winter, daytime conditions. Summer daytime conditions would evaporate this water in less than 1 hour.

The maximum amount of Al_2O_3 (20 percent) that could precipitate is about 28,000 pounds or about 0.001 pounds per square foot (lb/ft^2). The maximum amount of NaCl that could precipitate and form upon evaporation is approximately 20,000 to 46,000 pounds. If this settled within 1 mile of the test stand, it would form about 0.001 $lb/sq\ ft^2$ of NaCl.

3.2.6 Worst-Case Analysis

3.2.6.1 Rocket Test Abort/Failure--

If problems arise during the 2-minute Titan test firings, the rocket motor case will be ruptured and propellant combustion will proceed faster than normal. This analysis addresses the air quality impacts if a rocket failure or rupture were to occur during the 2-minute test firings.

The modeling methodology used to estimate the maximum downwind concentrations for a Titan test failure is similar to the approach used to model a successful Titan test except for the changes listed below. It should be noted that the entire propellant does not detonate instantaneously in any failure scenario. There is a sudden release of pressure when the motor case is ruptured. This causes propellant pieces to be ejected from the case and allows much faster and uncontrolled combustion of propellant.

1. Differences Between a Successful Test and a Failure. The physical differences in the rocket exhaust release are as follows:

   a. The combustion products will be released over a very short time period for a rocket failure.

   b. There will be no cooling from the deluge water for a failure.

c. The combustion products will be released radially for a failure.

d. A rocket failure would spread the exhaust radially with a depth roughly equal to the height of the Titan rocket. This would allow for the initial entrainment of large amounts of ambient air (O_2). Therefore, to be conservative, the conversion of N_2 to NO_x is assumed to proceed to completion.

2. Cloud Rise. Due to the large heat release in a short time and the absence of water cooling, the cloud is predicted to rise to about 8,200 to 9,800 feet, depending on the wind speed. This maximum cloud rise assumes the absence of or a weak subsidence inversion.

3. Impacts Due to a 5-1/2-Segment Titan Failure. The maximum concentrations due to a Titan failure would occur about 14 to 18 miles downwind. The increase in pollutant maximum concentrations due to a rocket failure are shown in Table 3.8. These numbers are extremely small, have no significant effect on downwind air quality, and would not violate any standards.

Table 3.8 Estimated Maximum Downwind Concentrations With a Rocket Failure

Pollutant	Concentration				
	Wind speed, knots	Ambient air maximum[a]	Maximum due to failure	Maximum downwind	Standard[b]
Al_2O_3,[c] ug/m^3 (TSP)	5	176	3.8	180	260
	7	176	3.1	179	—
	9	176	2.8	179	—
HCl,[d] ppm	5	0	0.14	0.14	3.0
	7	0	0.16	0.16	—
	9	0	0.17	0.17	—
NO_2,[e] ppm	5	0.11	0.04	0.15	0.25
	7	0.11	0.04	0.15	—
	9	0.11	0.03	0.14	—

[a] See Table 2.2.
[b] Most stringent standard or criterion.
[c] Averaging time is 24 hours.
[d] Averaging time is 10 minutes.
[e] Averaging time is 1 hour.

3.2.6.2 Nonbuoyant Exhaust Cloud--

A worst-case scenario assumes that all of the thermal energy within the rocket exhaust plume vaporizes deluge water. If this occurs, there will not be a significant difference between the internal temperature of the exhaust cloud and the ambient air temperature. Therefore, there would be no buoyant cloud rise. This is not expected to occur, but has been calculated for safety reasons in the event deluge water is able to penetrate the core of the exhaust plume to a greater extent than predicted.

The 2-segment test was used to determine the downwind concentrations for a nonbuoyant exhaust cloud because the heat release from the 2-segment motor is less than the heat release of the 5-1/2-segment motor; therefore, the 2-segment motor will have a greater probability of forming a nonbuoyant exhaust cloud.

The drop in temperature would probably not allow the afterburning reactions (H_2 to H_2O, CO to CO_2, and N_2 to NO_x) to proceed to completion. To be conservative, the afterburning reactions were assumed not to occur. Table 3.9 shows the estimated downwind concentrations due to the rocket exhaust from the 2-segment test. Table 3.10 shows the cumulative downwind concentrations due to the rocket exhaust and the existing ambient worst-case concentrations.

The concentrations shown in Table 3.10 exceed the state standards for total suspended particulates (TSP) and PM_{10}. The HCl concentrations exceed the standards set by the National Academy of Sciences. While a nonbuoyant exhaust cloud is considered very unlikely, this worst-case scenario was used in determining the required direction of the prevailing winds at the time of the test to minimize the potential impact on downwind populations. The receptor located 9.5 miles from the test stand is the eastern boundary of RPL at U.S. Highway 395. The location of this receptor assumes the cloud is directed by a westerly wind.

The maximum ground-level concentrations for the exhaust emissions at U.S. Highway 395 (Table 3.10) are below the strictest standards or criteria with the exception of PM_{10}. However, the particulate concentrations were averaged over a 24-hour period to be comparable to the federal and state particulate standards. The peak concentrations (1 minute averaging time) are significantly higher. The estimated peak concentrations of Al_2O_3 at the U.S. Highway 395 receptor for the nonbuoyant cloud scenario is about 6,200 ug/m^3. The entire cloud would pass the receptor within a period of 20 to 30 minutes, depending on the wind speed.

Table 3.9 Downwind Pollutant Concentrations From the Nonbuoyant Exhaust Cloud of a 2-Segment Motor

Pollutant	Distance downwind, miles	Wind speed, knots		
		5	7	9
Al_2O_3[a], ug/m^3 (TSP)	3	246	184	123
	3.5	183	137	116
	9.5	56	40	31
CO,[b] ppm	3	4.6	3.3	2.6
	3.5	4.0	2.9	2.2
	9.5	1.1	0.8	0.6
HCl,[c] ppm	3.0	15.3	11.3	8.9
	3.5	12.8	9.7	7.7
	9.5	2.4	2.2	1.9

[a] Twenty-four hour averaging time.

[b] One-hour averaging time.

[c] Ten-minute averaging time.

Table 3.10 Cumulative Concentrations for Nonbuoyant Plume Rise and Worst-Case Ambient Air

Pollutant	Downwind distance, miles	Wind speed, knots			Standard[a]
		5	7	9	
AL_2O_3,[b] ug/m^3 (TSP)	3	422	360	299	260
	3.5	359	313	292	
	9.5	232	216	207	
PM_{10},[b] ug/m^3	3	205-266	174-220	144-174	50
	3.5	174-219	150-185	140-169	
	9.5	110-124	102-112	97-105	
CO,[c] ppm	3	16.6	15.3	14.6	20
	3.5	16.0	14.9	14.2	
	9.5	13.1	12.8	12.6	
HCl,[d] ppm	3	15.3	11.3	8.9	3
	3.5	12.8	9.7	7.7	
	9.5	2.4	2.2	1.9	

[a] Most stringent standard or criteria.

[b] Averaging time is 24 hours.

[c] Averaging time is 1 hour.

[d] Averaging time is 10 minutes.

Due to the high peak concentrations of Al_2O_3, visibility along U.S. Highway 395 may be impaired and could cause a safety hazard. To be safe, coordination with the California Highway Patrol (CHP) and possibly California Department of Transportation (Caltrans) is needed so that short-term road closure plans and/or signs warning motorists of the dusty air can be prepared.

3.2.7 Mitigation Measures

The RPL has a sophisticated meteorological monitoring system using 19 instrumented towers. This system collects data on wind speed, wind direction, air temperature, and air temperature difference between 6 and 54 feet above the ground. This information is automatically updated every 5 minutes. These data and other meteorological observations are used to determine if the requirements established by RPL and Edwards AFB for a specific test firing are met. The requirements for the Titan tests are likely to be as follows:

1. No thunderstorms within at least 10 nautical miles.
2. No precipitation in the downwind area.
3. Wind speed greater than 5 knots.
4. Wind direction such that the plume will not blow over an inhabited area--allowable wind direction is 260 to 310 degrees azimuth.
5. A decrease in temperature greater than 1 degree F between 6 and 54 feet above the ground. This condition is not met if a surface inversion is present.
6. Tests in daylight hours only.

The data collection system and criteria are described in detail in the "Air Emissions Inventory for the Air Force Rocket Propulsion Laboratory Operations in Kern County" submitted to the Kern County Air Pollution Control District on September 19, 1986, by RPL. An instrumented balloon will be sent aloft prior to the 5-1/2-segment test to confirm wind speeds and directions and other data at altitudes up to 10,000 feet.

The nonbuoyant exhaust cloud scenario was assumed when determining the wind direction range which directs the exhaust cloud away from inhabited areas. An acceptable wind corridor was established by calculating the estimated ground level concentrations at inhabited areas for different trajectories of the nonbuoyant exhaust cloud. The allowable wind direction range for the Titan tests is 260 to 310 degrees azimuth. The location of the wind corridor is shown on

Figure 3.4. The wind corridor shown on Figure 3.4 indicates that the exhaust cloud will exit the RPL area boundary and pass U.S. Highway 395 at approximately 9-1/2 to 12 miles downwind.

Since the only potentially significant air quality impact in off-site areas will be along U.S. Highway 395, coordination with state highway officials will be undertaken. This coordination is a precaution against the unlikely event of a nonbuoyant plume rise and high dust (Al_2O_3) concentrations at ground level in this area.

The acid mist fallout near the test stand will be mitigated through use of sodium carbonate conditioning of the deluge water. This will keep the mist from reaching the extremely low pH levels experienced near launch sites. Monitoring of the mist pH and HCl concentrations in the mist fallout is planned at least for the first test firing to confirm the estimates and predictions made in the Environmental Assessment (EA).

3.3 AIR QUALITY--SHORT-BURN TEST FIRINGS

The short-burn test firings will emit much smaller quantities of air pollutants and have less potential impact on air quality than the 2-minute firings described in Section 3.2.

3.3.1 Description of Short-Burn Tests

A series of up to six short-burn Titan test firings will be conducted at Test Stand IC sometime between February and December 1987. This series of tests will probably be conducted after the 2-minute, 5-1/2-segment test which is currently scheduled for late winter or early spring, 1987. Each short-burn test will be separated by several days from the next such test.

The short-burn tests will be conducted within a 2-segment Titan rocket motor which will have a small amount of active propellant. The motor will be essentially filled with inert propellant-like material which will not burn during the test. The formulation of this inert material is similar to active propellant, except that the ammonium perchlorate is replaced with salt and other compounds. The purpose of the inert propellant is to provide weight and structural characteristics similar to active propellant.

The motor will be fitted with a small nozzle (about 2 to 4 inches in diameter) to provide the gas pressure needed within the motor case. The active propellant will burn in the motor for less than 2 seconds. However, due to the small nozzle size, combustion products will continue to exit the nozzle after the propellant has burned. The pressure will gradually be reduced within the motor case as exhaust products leave the nozzle. It is estimated that up to 90

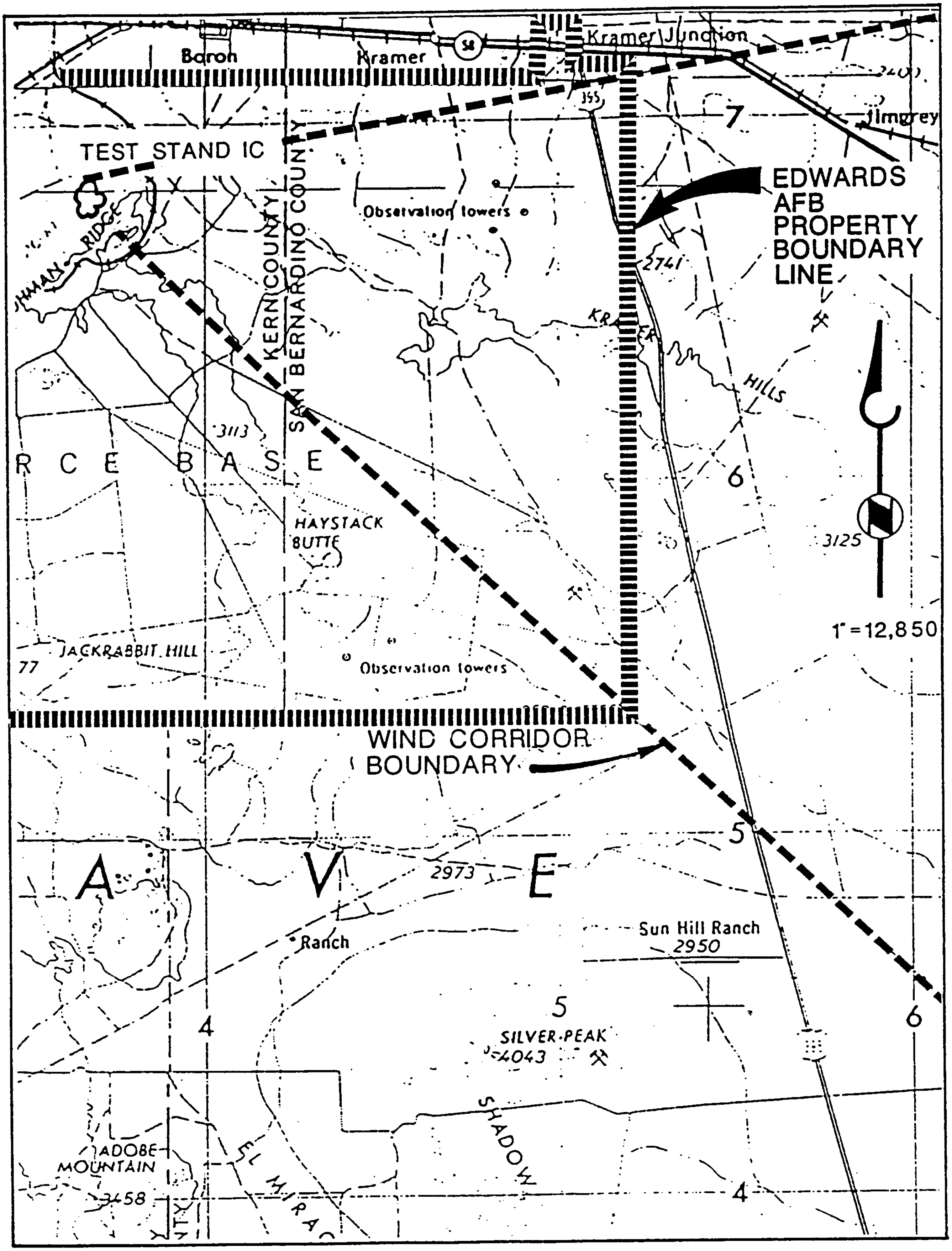


Figure 3.4 Location of Wind Corridor

seconds will be required for the motor case pressure to reach ambient air pressure. The rate of exhaust emissions will gradually drop to zero over this 90-second time period. About 75 percent of the total emissions will be released within the first 20 seconds.

3.3.2 Air Emissions--Short-Burn Tests

Up to 500 pounds of Titan solid propellant will be burned for each test. There is the possibility that the propellant formulation could be slightly different than Titan propellant. However, the propellant will still be Class 1.3 propellant, the exhaust products will not be significantly different than Titan propellant exhaust products, and the emissions will be no greater than indicated in Table 3.11.

Table 3.11 Emissions for Each Short-Burn Test

Constituent	Emissions following afterburning, lbs[a]
Al_2O_3	151
HCl	103
NO_x	95
CO_2	231
CO	1
H_2O	35

Note: Emissions total more than 500 pounds due to atmospheric afterburning.

[a] Assumes Titan propellant.

Afterbrning of H_2, CO, and N_2 is assumed to be essentially complete due to the rapid mixing of air with the exhaust gases. CO conversion to CO_2 is estimated at 99 percent as discussed for the 2-minute tests. It is conservatively assumed that complete conversion of N_2 to NO_x will occur. Complete conversion of H_2 to H_2O is assumed.

3.3.3 Exhaust Cloud Rise--Short-Burn Tests

The exhaust will strike the deflector plate and be directed horizontally. Exhaust velocity will be much less than for the 2-minute tests described previously, and the exhaust cloud will form immediately adjacent to the test stand. The exhaust emitted during the first 10 to 20 seconds will rise in an exhaust cloud about 250 to 370 feet above the deflector plate. The last 50 to 60 seconds of exhaust will rise only 50 to 130 feet due to the reduced quantity of emissions.

3.3.4 Dispersion Modeling--Short-Burn Tests

The dispersion modeling used for the short-burn tests is similar to the modeling used to predict downwind concentrations for the 2-minute test firings with the following exceptions:

1. No restriction on wind direction was assumed; therefore, RPL building areas were considered receptors.
2. Due to the relatively small exhaust cloud rise, terrain effects were estimated.

If the wind is from the northeast, north, northwest, or west, the exhaust cloud will travel over Leuhman Ridge and RPL building areas. Due to the size of Leuhman Ridge and the exhaust cloud heights, downdrafting of the exhaust cloud will probably occur. The dispersion modeling assumes a worst case scenario of exhaust cloud traveling to RPL areas and then brought down to ground level by turbulent eddies. This method is described by Turner (1970).

Other than the immediate test stand area, the RPL areas 1 mile away were considered the worst-case receptors. Concentrations in this area are shown in Table 3.12. Concentrations at off-site locations, such as Boron and Desert Lakes, would be less than the concentrations shown in the table. The concentratons shown in Table 3.12 are very low and will not result in violations of air quality standards.

Table 3.12. Predicted Downwind Concentrations at RPL for Short-Burn Tests[a]

Constituent	Wind speed, knots	Averaging time	Downwind concentrations at RPL with downdrafting
HCl, ppm	5	10 min.	0.09
	7	10 min.	0.13
	9	10 min.	0.08
Al_2O_3, ug/m^3	5	24 hrs.	1.3
	7	24 hrs.	2.1
	9	24 hrs.	1.0
NO_2,[b] ppm	5	1 hr.	0.02
	7	1 hr.	0.02
	9	1 hr.	0.01

[a] RPL is located approximately 1 mile south of Test Stand IC.
[b] Calculated by the ozone limiting method.

There should be little or no acid or particulate fallout since no deluge water will be used. The small amount of fallout that could possibly occur would be in the immediate test stand area. This area will be washed down after the test and the wash water will drain into the containment basin and water channel system (see Figure 1.4).

The stringent meteorological conditions required for the 2-minute tests will not be needed for the short-burn tests. The short-burn tests should not be conducted under inversion conditions or when thunderstorms are in the immediate vicinity. There should be a wind speed of at least 5 knots, although no restrictions on wind direction are needed. RPL's standard safety procedures should be followed. Personnel should remain away from the exhaust cloud while it is in the test stand vicinity and up to about 1 mile downwind to insure that HCl concentrations have dispersed to safe levels.

3.4 SURFACE WATER AND GROUNDWATER RESOURCES

Each of the 2-minute test firings will require about 590,000 gallons of deluge water and a few thousand gallons of additional washdown water. All water will be supplied from existing wells. Fire suppression water, if needed, will also be supplied from existing wells. Each test will generate approximately 210,000 gallons of wastewater from the deluge water system plus a few thousand gallons from washdown operations. The wastewater will be collected in channels, and recycled and evaporated, as described in Section 1.2.5.2, so there will be no discharge to surface waters or recharge of groundwater. The 280,000 gallons that will be carried off in the exhaust will be partially evaporated. The remainder will be small water droplets or mist. Some of this mist will fall out near the test stand and some will be carried long distances in the exhaust plume (see Section 3.2.5).

CSD conducted small-scale (825-lb) rocket motor tests on November 3 and November 20, 1986, at the Wyle Laboratories facility in Norco, California. The purpose of the tests was to simulate as closely as possible the test conditions at Edwards AFB so that information could be obtained on the durability of the ablative material on the flame bucket. The water system was scaled in relation to motor heat release rates. When the small-scale rocket fired, the deluge water was entrained in the exhaust and was carried off in the exhaust cloud. Therefore, no data were obtained on the after-test deluge water quality. No mist or mist fallout was observed and no data were collected on the mist. Data collected on cooling water after Space Shuttle launches at Kennedy Space Center (KSC) show that the pH ranges from 1.6 to 2.0 due to HCl absorption (Fluor Engineers Inc., 1983). The pH of mist in exhaust plumes from Titan launches has been about 0.5 to 1.0 (Bendura and Crumbly, 1977; Gregory, et al., 1978; Woods, et al., 1979 and Wornom, et al., 1979).

Based on these data, the USAF and CSD have decided to install a deluge water treatment system consisting of pretreatment of the water with sodium carbonate to raise the pH prior to each test. This will prevent the after-test pH from dropping if deluge water with HCl in it is trapped in the water collection channels. The primary benefit of the pretreatment step will be to keep the pH of the mist above the low pH values observed in Titan launches.

The collected water will be contained in the concrete-lined channel connecting Test Stands IC and ID. Initially, raw water will be conditioned in the channel with sodium carbonate, then pumped to the 3-million-gallon tank in a temporary pipeline. After the first test, the water will be reconditioned for the next test and the solids will be removed from the channel.

The sodium carbonate will be mixed into the water hydraulically within a portion of the concrete-lined channel (see Figure 1.4). After the water is completely mixed and stabilized (3 to 4 days) the solids will be allowed to settle and the water will be conveyed to the 3-million-gallon tank. If the solids do not settle adequately, they will be filtered using in-line cartridge filters before the water is conveyed to the storage tank. The solids will be removed from the channel, chemically analyzed, and disposed of in accordance with all federal, state, and local regulations and policies. After the first test is completed, the water will be sampled and analyzed to determine the amount of conditioning needed before the second test. After the final test, the water will be left in the channel to evaporate. The solids remaining in the channel after evaporation of the water, will be disposed of in accordance with all federal, state, and local regulations and policies. The solids to be disposed are not expected to be hazardous.

The fallout near Test Stand IC is likely to coat the rocks and soil with a small amount of moisture. The increased buffering capacity of the water, due to sodium carbonate additions, should keep the pH of this precipitated mist to about 3.

Some of the ablative heat shield material will erode and vaporize during each 2-minute test firing. The ablative material is a silicon-phenolic compound. Approximately 5,000 pounds of the material could be eroded during each test. Some of the eroded material may be broken off in small pieces which will either fall into the water collection basin or be blown over the basin and fall on the desert floor. Most of the eroded material, however, is expected to be oxidized. The phenolic material will become either CO or CO_2. These additional CO and CO_2 emissions are small compared to the rocket exhaust emissions. The silicon compounds would likely be emitted as small particles which would become part of the Al_2O_3 exhaust stream. These represent a very small percent of the rocket motor particulate emissions and are not significant enough to be taken into account in the modeling procedure.

For the short-burn test firings, the deluge water system will not be used. There will be some quench water used for rocket motor cooling, and washdown water will be needed after each test for cleaning the test stand structure and the immediate area. Maximum water usage will be 10,000 gallons per test. Water conditioning with sodium carbonate will not be necessary for the short-burn tests. Some acid fallout may occur near the test stand. Therefore, washdown water may be slightly acidic (pH between 3 and 6). The water will all be collected in the water channel system and left to evaporate. Remaining solids after evaporation will be disposed according to all applicable state and federal regulations.

In summary, there will be no discharge to surface waters or groundwater and, therefore, no adverse impacts on these resources are expected.

3.5 BIOTA

The testing of Titan rocket motors at Test Stand IC is not expected to significantly impact the vegetation and wildlife of the RPL area. All activities will be conducted within the existing test stand area and will not result in the loss of any additional habitat. Increased personnel activity and elevated noise levels associated with the modifications to the test stand and the test firings will temporarily disturb wildlife in the immediate vicinity.

As previously discussed in Section 3.2.5, an acidic mist of about pH 3 will be formed by contact of the deluge water with the rocket exhaust during ignition and will fall out over approximately 1 square mile of the area near Test Stand IC. The effect on airborne and terrestrial species of the Mojave Desert is discussed below.

Research performed on numerous plant species indicates that pH 2.5 HCl acid treatments were generally no more injurious than distilled water controls (pH = 4.3), whereas pH 1.7 solutions caused significant amounts of injury (Granett, 1977 and 1984). Damage appeared as necrosis (death) of cells located in the vicinity of the stomata, minute openings in a leaf or stem through which gases pass. Agriculturally important and ornamental species were found to be the most sensitive, being primarily broadleaf species. Literature reviews on the effects of hydrogen chloride (EPA, 1976) report large differences in species sensitivity to the gas and acid mist. Cell wall thickness and amount of intercellular space appear to influence the severity of symptom expression. A pH of 3.0 would be considered a mildly acidic concentration. Xerophytic (desert or dry environment adapted plants) would generally be more resistant to acid exposure due to the presence of thick cutin (waxy epidermal cells) and reduced numbers and protected location of stomata.

Ground animals in the vicinity of the test site may come in contact with the acidic mist for short periods of time. This is not expected to have any significant impact on wildlife because the pH of the mist will be near 3.0, the exhaust cloud will remain over any single point a relatively short time, and any mist settling out of the cloud will evaporate within about 1 hour.

Airborne species that might be exposed by flying through the plume could be exposed to concentrations of HCl that would irritate eye and respiratory tract membranes (greater than 10 ppm HCl). It is unlikely that this will occur because birds will initially be frightened away by the noise of the test. Experience at CSD facilities in San Jose, California, indicates that birds have been observed to fly through downwind exhaust clouds formed from solid rocket propellant burning operations (Titan propellant and other propellants), but avoid direct contact with the most concentrated portions of the plumes, especially if large temperature differences exist between the plumes and ambient air. No observations of adverse effects on avian wildlife have been observed at existing CSD facilities from such plumes and exhaust clouds (Personal Communication, Wayne Warwick, December 1986).

The testing of Titan rocket motors at Test Stand IC will not significantly impact any threatened and endangered species. As discussed in Section 2.1.6, the bald eagle and the peregrine falcon are the only federally listed threatened and endangered species in the area. These birds overwinter in the Mojave Desert. If one of these species happened to come in contact with the plume, it would likely occur after the noise had died down, the plume temperature had cooled to near ambient air temperature, and most of the mist had settled out of the cloud. At worst, there may be some irritation of eye and respiratory tract membranes. This is not expected to be a life-threatening situation.

Populations of alkali mariposa lily are not expected to be impacted at all by the firings. All known habitats are located on the southern and western margins of Rogers and Rosamond Dry Lakes. Suitable habitat capable of supporting these plants to the west and east of Leuhman Ridge is not likely to exist based on topography and local knowledge (Personal Communication, Mike Phillips, December 1986).

Mojave spineflower and desert cymopterus have been found approximately 3 to 7 miles east of the test site in San Bernardino County. As discussed in Section 3.2.7, the plume will travel in this direction. These species are listed as candidate species by the USFWS (see Section 2.1.6.3). These species are not normally in evidence at the surface until the April to May flowering period. The perennial living tissues are 4 to 6 inches underground at this time. It is unlikely that acidic mist from the plume will have any adverse impact on these plants due to their distance from the test area.

3.6 POPULATION

The testing of Titan rocket motors is expected to create no significant impact on population and housing in the test site area. Personnel associated with the tests will be temporarily living in the area. Most staff at RPL are permanent, and the Titan tests have no effect on USAF or RPL staff. There have been between 80 and 120 construction personnel at the test site since August 1986. The repairs to the test stand are nearing completion, consequently the construction staff is being reduced. During the static test firings, there will be about 15 construction personnel to operate various systems and approximately 50 USAF and CSD test personnel.

3.7 NOISE

The noise impacts of the proposed rocket testing are based on previous rocket noise information, literature studies, and on the information on rocket motor parameters, meteorological data, and geometric elements at and near the test stand. The results of this study are presented in a report by Peter Klaveness and Associates (1986) and summarized in this section. The noise levels that humans will be exposed to at the test site, RPL facilities, and nearby residential and employment centers are described in this section. This assessment concentrates on the large 2-minute test firings; the noise from the short-burn tests will be much less than the 2-minute tests.

3.7.1 Noise Levels

The main noise-sensitive receptors included in the study are:

1. Personnel at the test site.
2. Personnel at the RPL.
3. The town of Boron, which is partially shielded from the test stand by Leuhman Ridge, at a distance of 3.5 to 4 miles.
4. The Desert Lakes housing tract west of Boron and directly south of the U.S. Borax mine.
5. The rest stop off Highway 58, west of Boron.

6. The community of North Edwards and scattered residences to the northeast, toward Peerless Valley.

7. Kramer Junction at the intersection of U.S. Highway 395 and Highway 58.

8. The residential community at Edwards AFB.

Noise level contours were calculated to distances beyond 30 miles, with potential receptors at Mojave, Lancaster, and Palmdale.

The exhaust flow from the rocket motor is the source of noise during the static rocket tests. The noise level generated depends on the parameters shown in Table 3.13. During the proposed testing, sound will be generated by shear movements within the exhaust flow at the boundary layer between the high-speed exhaust and the still air.

Table 3.13 Rocket Motor Parameters—2-Minute Tests

Parameter	5-1/2-Segment	2-Segment
Sea level thrust	1.2-1.34 Mlbs[a]	113 Klbs[a]
Nozzle diameter, inches	37.7	27.7
Exit diameter, inches	106.6	78.3
Exit velocity, feet/second	8,144	6,200
Burn time, seconds	120	120
Weight of propellant, Klbs[a]	466	206

[a] M = million K = thousand

The noise levels from the test firing of the 5-1/2-segment rocket motor are shown in the form of noise level contours on Figures 3.5 and 3.6. Figure 3.5 shows the overall levels, while Figure 3.6 shows the A-weighted noise levels. The contours indicate the typical "lobed" distribution of the sound. One lobe extends toward the rest stop on Highway 58, and the other toward Lancaster. The noise level predictions are summarized in Table 3.14. As shown in this table, the Occupational Safety and Health Administration (OSHA) standard of 115 decibels measured on the A-weighting scale (dB(A)) (highest noise level allowed at any time in a work place) is not exceeded in any of the nearby communities. Noise levels for the 2-segment tests are expected to be 12 dB(A) lower than those shown for the 5-1/2-segment test.

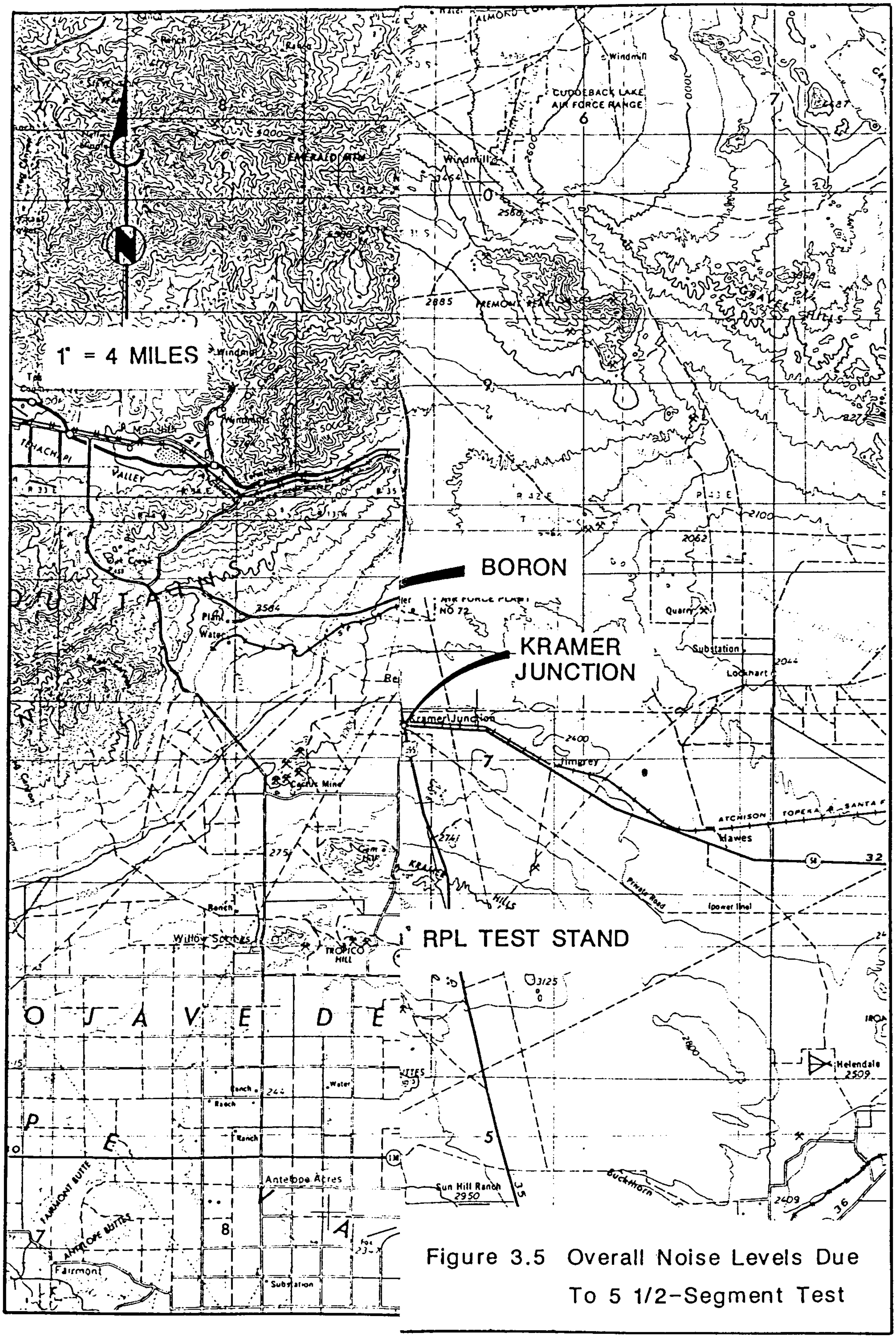


Figure 3.5 Overall Noise Levels Due To 5 1/2-Segment Test

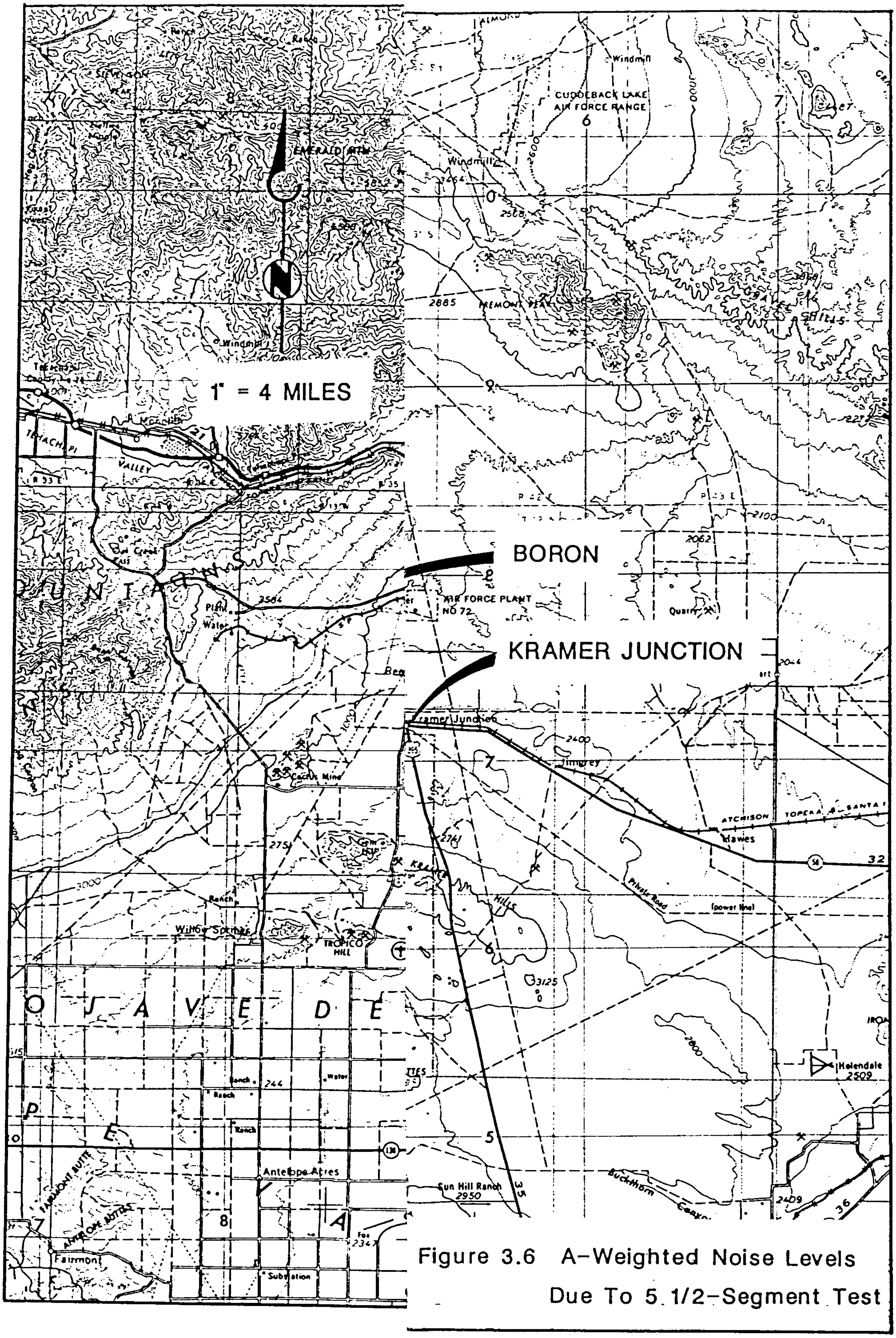


Figure 3.6 A-Weighted Noise Levels Due To 5 1/2-Segment Test

Table 3.14 Predicted Noise Levels Due to 5-1/2-Segment Test

Location	Sound pressure level, dB	A-weighted sound pressure level, dBA
Test Stand IC	193.5	—
Control room		
Outside	130	125
Inside	-	75
RPL	100-110	95-105
Desert Lakes	110	96
Boron	90-102	75-85
North Edwards	95-100	70-75
Edwards Main Base	85	60
Kramer Junction	85	60

The personnel at the test site could be exposed to very high to high sound pressure levels. Exterior sound pressure levels at the control bunker will exceed 130 dB. The control room is constructed underground and built in a manner that could withstand the explosion of a rocket motor. Thus, it is assumed that the sound transmission loss from the exterior to the interior will exceed 60 dB. Interior sound pressure levels will then be less than 75 dB(A).

Personnel at the RPL will benefit by partial shielding from the source since Leuhman Ridge will act as a barrier. Sound pressure levels shown on Figure 3.6 indicate that levels could range between 95 and 105 dB(A) outside.

The maximum noise level at any residential location is predicted to be 110 dB overall and 96 dB(A) at the Desert Lakes housing tract during the 5-1/2-segment motor test. The 2-segment test will generate 98 dB overall and 84 dB(A) at this location. In Boron, the overall noise level will be between about 90 and 102 dB.

The most impacted areas of North Edwards and the scattered residences to the northeast, will experience noise levels between 95 and 100 dB overall and 70 to 75 dB(A). At Edwards, the overall levels will be around 85 and the A-weighted approximately 60 dB(A). The levels at Kramer Junction will be similar to those at Edwards.

Focusing of sound, due to wind and temperature differences at elevations above the test stand, is possible and could increase the predicted noise levels described here. A model predicting these effects is being examined by USAF personnel to determine its applicability and, if used, to determine whether certain meteorological conditions should be avoided. The use of the model does not appear critical to the off-site predictions and the criteria to determine acceptable test conditions.

3.7.2 Impacts

3.7.2.1 Planned Test Conditions--2-Minute Test Firings--

Estimates show no risk of structural damage to residential buildings. Structural damage to dwellings occurs in the range of 130 to 140 dB for octave band noise in the frequency range of the rocket motor tests (Guest, 1973). The probability of damage depends on the test duration. Initial damage normally involves plaster cracking. Window damage should normally not occur for levels below 145 dB and is unlikely below 150 dB.

Personnel at RPL will not be in danger of suffering hearing damage. However, any personnel at the site not within the confines of the control room could suffer hearing damage or at least some pain. The noise levels beyond the Edwards AFB boundaries will be below known criteria for hearing damage, and feeling of physical pressure or discomfort, including ear pain. During the test firing, noise levels will be sufficiently high over a wide area to interrupt outdoor conversations. Indoor conversations and other activities, such as television or radio listening or telephone conversations, will not be disturbed, if windows are kept closed. If windows are open, conversations and other activities will be slightly disturbed for 2 minutes during the test firings.

Nighttime test firings are not planned. If a nighttime test must be conducted, it would cause residents in Boron, Desert Lakes, and parts of the desert community towards North Edwards to awaken. This would be the case for the 5-1/2-segment rocket motor in particular. For the 2-segment motor, awakening due to nighttime firings would be limited to Desert Lakes and the west part of Boron.

There is a minor potential for a startle reaction for automobile drivers in the immediate vicinity of Desert Lakes and the highway rest stop during the firing of the 5-1/2-segment motor. Drivers of automobiles and trucks at cruising speeds on Highway 58 may become aware of the test through the noise, but startle reactions are not expected. No startle reaction is expected during the firing of the 2-segment motor.

3.7.2.2 Failure/Abort Conditions--2-Minute Test--

If it becomes necessary to terminate the 2-minute test firing by splitting the motor case, a high amplitude pressure wave with a short duration will be generated. This sudden change in the form of energy will produce sound pressure levels in excess of those obtained by the normal propellant combustion process and exhaust gas flow. The chances of this failure/abort condition occurring are very low.

Working from the overpressure contours of Class 1.3 propellant, approximations of sound pressure levels for the worst event have been developed (Peter Klaveness & Associates letter, dated December 16, 1986). A-weighted levels have not been predicted because no frequency information is available for a motor failure event.

The maximum noise level at Boron and Desert Lakes would be just below 135 dB overall. At North Edwards, the noise level would be 124 to 126 dB, and at Edwards main base about 123 dB. At RPL, the maximum noise level would be at or above 145 dB, depending on the distance from the test stand. Unlike the noise of the burning rocket motor, the sound of the failure would be omni-directional, without lobes of maximum sound radiation.

According to the 1973 NASA report on the Space Shuttle main engine tests, moderate chest wall vibrations are expected at noise levels above 130 dB and aural pain is likely at levels above 140 dB. For a person at Desert Lakes, therefore, a failure would likely result in feelings of physical pressure and possibly minor pain in the ears. There should be little risk of spontaneous damage to observers' hearing at Boron or Desert Lakes. Structural damage to buildings is unlikely at Boron or Desert Lakes, although not impossible (e.g., for highly stressed, large windows). Significant structural damage due to test failure/abort is unlikely beyond the immediate RPL area. The combined probability of the failure event occurring, and, if it did, damage occurring beyond the immediate area, is very low.

In case of a failure blast of this type, the likelihood of a startle reaction by automobile drivers makes temporary signs on Highway 58 and other local roadways advisable. The sound levels at Desert Lakes are not considered sufficiently high to warrant evacuation. At RPL, evacuation is recommended within 1 mile of the test stand, and between 1 and 3 miles all personnel should be indoors during the tests. Personnel inside buildings within the 1- to 3-mile area need not wear hearing protection. Security and other personnel who are outside buildings yet within 3 miles of the test stand should wear hearing protection during the 2-minute test firings.

3.7.2.3 Noise From Short-Burn Tests--

The noise from the short-burn tests will be significantly less than the 2-minute tests in both intensity and length of time. The peak levels (first few seconds of each test) at RPL will be about 77 to 87 dB, at Desert Lakes 87 dB, and at Boron about 70 to 80 dB. No significant impact will occur in any areas other than the immediate test stand area. Personnel within 1/2 mile of the test stand should wear hearing protection, if not indoors.

3.7.3 Mitigation Measures

The potential significant noise impacts of the rocket motor testing and remote chance of failure of the motor include hearing damage to personnel outside of the bunker room at the test site, speech interference, and possible startle reactions for automobile drivers during tests of the 5-1/2-segment motor.

Mitigation measures for both controlled and uncontrolled populations should include an information program where both populations are informed before the first test of the likelihood of loud sound levels, and of their origin. Signs should be posted along certain roads, as well as at the rest stop, to warn of loud noise levels, to minimize the possibility of driver distraction and possible accidents.

Personnel at RPL should be evacuated within 1 mile of the test stand for the 5-1/2-segment test, and personnel in the 1- to 3-mile area should remain indoors during the test to guard against hearing damage in the unlikely event of a motor failure. Nighttime testing should not be allowed.

3.8 ARCHAEOLOGY AND CULTURAL RESOURCES

Test Stand IC is located on Leuhman Ridge in a highly disturbed area. If archaeological resources were ever present in this area, they were likely destroyed by the excavation for the existing test stands, water channels, storage tanks, and other existing structures.

An archaeological site survey was conducted in December 1986 to determine if there are any archaeological sites in the vicinity of the test stand. There is at least one prehistoric archaeological site on Leuhman Ridge, but there are no cultural or paleontological resources known to be located at or sufficiently near the test site to be of concern (Robinson, 1987). The regrading of a section of the water containment system berm and other construction activities associated with the renovation of Test Stand IC will not affect any archaeological resources.

The rocket tests could indirectly affect archaeological or paleontological resources within the broader area of Leuhman Ridge and the surrounding desert if they cause fires in the surrounding desert. Emergency response vehicles, equipment, and staff could possibly harm archaeological resources, depending on the extent and severity of the fires. This is an unlikely event because the flame bucket and water deluge system at Test Stand IC have been designed to prevent flames from reaching the surrounding area.

No new public viewing areas should be established for the Titan rocket motor tests. If the public are invited to view the tests, the existing Space Shuttle viewing area at the main base should be used. This will prevent any possible impact on archaeological resources due to large crowds of people.

Test Stand IC is not an historically significant structure. It has been modified several times since its construction in 1965, to accommodate various kinds of rocket motor tests. The general area of the test stands may be of historical interest due to the role this area has played in the development of the United States space program.

In summary, the proposed testing of Titan solid propellant rocket motors at Test Stand IC will not directly or indirectly affect any archaeological or paleontological resources in the area. There will be no effect on properties included in or eligible for the National Register of Historic Places. A report describing the site survey and results has been sent to the State Historic Preservation Office.

3.9 SAFETY

The rocket motor segments to be used for the test firings will be transported by truck from CSD storage facilities in southern California to RPL. Shipping approval for all explosives is being obtained from the U.S. Department of Defense (DOD), U.S. Department of Transportation (DOT), and the CHP. Storage and transportation routes are not disclosed for security reasons. Segments will be stacked and mated according to CSD and DOD standard procedures and safety regulations. Following each test, the spent rocket motors will be disassembled and transported off site for detailed examination.

The USAF and CSD will follow the standard safety procedures required by regulatory agencies and conduct safety monitoring during the test firings. There will be a telephone hot line connecting the test control bunker with the operations office at RPL so that potential problems can be quickly communicated. Fire and medical personnel and equipment will be located at RPL and the main base during the test firings.

The USAF has determined that a clear zone with a minimum radius of 1,250 feet around test Stand IC will be required for the 2-minute tests based on the quantity/distance relationship for Titan propellant. A larger clear zone will be required for noise mitigation. All roads will be closed and any RPL offices within the clear zone will be evacuated. Only personnel essential to the operation of the test will be allowed in the clear zone.

A few test personnel will be located in an underground concrete bunker at Test Stand IE, approximately 800 feet from Test Stand IC. The outside air intake will be turned off during and immediately after the test so that no outside air enters the control bunker. Self-contained breathing apparatus will be available in the control bunker. HCl atmospheric monitoring inside the control bunker and outside will be used to provide information for the operating crew's safety.

The staff in the control bunker will receive continuous reports on weather conditions from the Edwards AFB meteorologist. If wind patterns shift to a direction that would carry the exhaust plume for the 2-minute tests over an inhabited area, the test will be delayed. Weather criteria for the 2-minute tests are listed in Section 3.2.7.

When all criteria have been met and the test firing commences, the base meteorological and safety staff will provide continuous visual monitoring of the exhaust plume and exhaust cloud. If a significant ground cloud forms near the test stand (this is unlikely, but theoretically possible), this cloud will be monitored carefully to determine where it will be carried by the wind and an assessment made for any additional on-site or off-site safety needs. No one (other than test personnel in the control bunker) will be allowed within the cone-shaped downwind area shown on Figure 3.4 between the test stand area and U.S. Highway 395, for the 2-minute test firings.

In the event of a ground cloud moving to the east, the most likely requirement is that a portion of U.S. Highway 395 would need to be closed because of poor visibility from dust in the exhaust cloud. The CHP and Caltrans will be alerted on the days of the test firings. Since it will take some time (about 30 to 80 minutes) for the exhaust plume to travel to the highway, depending on wind speed, there will be adequate time to coordinate the plume movement with highway authorities. The CHP and Caltrans may wish to close a section of the highway for a few minutes or otherwise alert motorists to the problem.

The runway at Edwards AFB will be closed during the 2-minute test firings. This will prevent air traffic from encountering the exhaust plume.

There are two fixed tanks of hydrazine located about 2,200 feet from Test Stand IC. Liquid hydrazine is an extremely flammable substance that may explode in the heat of a fire. It is a poisonous substance that may be fatal if inhaled, swallowed, or absorbed through the skin. CSD and the USAF are concerned that a shock wave may affect the fixed tanks in the event of a rocket misfire. CSD and the USAF are evaluating the problem and will determine if it will be necessary to transfer the hydrazine from the fixed tanks or protect the tanks from a shock wave.

3.10 SUMMARY OF IMPACTS AND MITIGATION MEASURES

The environmental impacts of the Titan solid propellant rocket motor testing at Edwards AFB are summarized in Table 3.15. Mitigation measures which will reduce the impacts to insignificant levels are also identified in the table.

Table 3.15 Summary of Impacts and Mitigation Measures

Environmental resource	Impacts	Mitigation measures
Geology and soils	No impacts.	None required.
Air quality—2-minute test firings	PM_{10} standard of 50 ug/m^3 is currently exceeded (82 ug/m^3). Rocket tests will add 16 to 23 ug/m^3. Under worst-case conditions of a nonbuoyant exhaust cloud, the PM_{10} concentration could reach 174 ug/m^3 and the TSP concentration could reach 299 ug/m^3.	RPL weather conditions (no thunderstorms within 10 nautical miles, wind speed greater than 5 knots, and no inversions) will be met. In addition, the tests will be conducted only when the wind is blowing from 260 to 310 degrees azimuth. This will prevent the exhaust cloud from blowing over an inhabited area.
	Acidic mist will be created by contact of deluge water with exhaust stream. Mist will settle to the ground in the vicinity of the test site.	Deluge water will be buffered with sodium carbonate to raise pH of mist to about 3.
	Under worst-case conditions of a nonbuoyant exhaust cloud, visibility may be restricted on U.S. Highway 395.	CHP and Caltrans will be notified of tests so that short-term road closure plans and/or signs warning motorists can be prepared.
Air quality—short-burn tests	No significant impact.	None required.
Surface water and groundwater	No discharge to surface waters or groundwater.	Deluge water contained in the channel and basin will be recycled or evaporated.
	Fallout of acidic mist will coat rocks and soil near test site with a small amount of moisture. There will not be sufficient water to create runoff.	pH of mist should be about 3 due to sodium carbonate buffering.
Biota	Acidic mist will not threaten the health of plants or animals in the area.	pH of mist should be about 3 due to sodium carbonate buffering.
Population	No impacts.	None required.
Noise	Noise levels at nearest residential area (96 dB(A)) should not exceed OSHA standard of 115 dB(A).	None required.
	For 2 minutes during each test, outdoor conversations over a wide area will be interrupted. Indoor conversations and other activities will not be disturbed.	Highway signs will alert motorists to test firing noise.
	Potential high noise levels in RPL area with rocket failure event.	Evacuate RPL area within 1 mile of test stand. Between 1 and 3 miles of test stand, personnel will stay inside buildings during the tests.
Archaeology and cultural resources	No impacts.	None required.
Safety	Possible failure of rocket motors during firing.	All regulatory agencies' safety procedures will be followed. Safety monitoring will be conducted during tests. Telephone hotline. Fire and medical personnel available. Clear zone of at least 1,250 feet will be established. Roads will be closed in clear zone. Essential test personnel will be located in protected concrete bunker.
	Possible effect from rocket failure on liquid hydrazine tanks near test site. Potential release of toxic gas.	Fixed tanks are under investigation by RPL and CSD to define necessary safeguards.

4.0 REGULATORY REVIEW

4.1 AIR QUALITY

Air emissions within Kern County are regulated by the Kern County Air Pollution Control District (APCD). Any person or organization proposing to construct, modify, or operate a facility or equipment that may emit pollutants from a stationary source into the atmosphere must first obtain an Authority to Construct from the APCD. The APCD issues permits and monitors new and modified sources of air pollution to ensure conformance with national, state, and local standards for air quality and to ensure that emissions from such sources will not interfere with the attainment and maintenance of air quality standards.

The APCD determines which emission sources and levels have an insignificant impact on air quality and, therefore, are exempt from permit requirements. Under Rule 202.1, the APCD also exempts experimental research operations from permit requirements if the following requirements are met. Failure to satisfy these requirements will result in the revocation of an exemption and require compliance with other APCD requirements.

1. The purpose of the operation is to permit investigation, experimentation or research to advance the state of knowledge or the state of art of a particular control technology or industrial process.
2. The APCD Control Officer is notified, in writing, of the purpose, goals, and objectives of the project, measures to be taken to minimize the emission of air contaminants, the proposed installation date, the planned start-up date, the expected duration of the test, and test schedules.
3. The cumulative total days of operation will not exceed 180. If the applicant intends to continue operation of the technology or process for more than 180 days, a compliance schedule for obtaining necessary permits is required.
4. Official test results (if the project involves air pollution control devices) are submitted to the APCD, in writing and in final form, no more than sixty (60) days after each test sequence is complete.
5. The APCD Control Officer has granted prior written approval.

The U.S. Air Force (USAF) has been granted a research exemption from the permit requirements under Kern County APCD Rule 202.1 for the testing of Titan solid propellant rocket motors at Edwards Air Force Base (AFB). The rocket motor testing program meets the requirements listed above. Although relatively large quantities of pollutants will be emitted during each test, the tests will be of short duration, and the tests will be scheduled to take place during optimal meteorological conditions to maximize dispersion and minimize the impacts of the testing on downwind air quality. Specific mitigation measures are identified in Section 3.2.7. Appendix C contains the research exemption.

4.2 WATER QUALITY

In the Edwards AFB area, the California Regional Water Quality Control Board, Lahontan Region (Regional Board), issues National Pollutant Discharge Elimination System (NPDES) permits for discharges of wastes to surface waters and waste discharge requirements for discharges of wastes that may affect groundwater quality. A report of waste discharge, describing the project, was submitted to the Regional Board in the fall of 1986. The Regional Board determined that there would be no discharge to surface waters or groundwater so the testing program was exempted from an NPDES permit and waste discharge requirements. Appendix B contains the Regional Board's waiver.

4.3 ENDANGERED SPECIES

The Federal Endangered Species Act of 1973, as amended, (the Act) extends legal protection to plants and animals listed as endangered or threatened by the U.S. Fish and Wildlife Service (USFWS). The Act authorizes the USFWS to review proposed federal actions to assess potential impacts on listed species. In addition to species listed by the USFWS, the California Department of Fish and Game (DFG) protects species listed as threatened and endangered under the California Rare and Endangered Species Act. USAF Regulation 126-1, Conservation and Management of Natural Resources, Chapter 5, paragraph 12, dated March 20, 1984, states that species proposed for or under review for proposed listing should be considered in environmental planning and be provided protection when feasible. Candidate species fall in this category. While the USAF is not obligated by the federal or state Endangered Species Acts to protect state-listed species, it is USAF policy to work cooperatively with DFG to protect state-listed species.

As described in Section 3.4, the testing of Titan solid propellant rocket motors at Edwards AFB will not significantly affect any federal- or state-listed species. The USFWS and the DFG will review this Environmental Assessment (EA).

4.4 SOLID AND HAZARDOUS WASTES

The State Water Resources Control Board (State Board) and the Regional Board, together with the California Waste Management Board (CWMB), are the principal state agencies responsible for nonhazardous solid waste management in the Edwards AFB area. The State Board and Regional Board are responsible for regulating the types of solid waste that can be received at landfills for the purpose of protecting surface water and groundwater resources. The State Board establishes the minimum standards for landfill siting, construction, and closure, while the CWMB is primarily concerned with minimum landfill operating standards. The Kern County environmental health agency acts as the local enforcement agency for the CWMB. The California Department of Health Services (DHS) regulates the storage, treatment, and disposal of hazardous wastes.

As described in Section 3.3, the testing of Titan rocket motors at Edwards AFB will not generate hazardous wastes. The sludge produced by the water recycling system will be chemically analyzed and disposed in accordance with all federal, state, and local regulations and policies. This sludge is not expected to be hazardous.

4.5 HISTORIC AND CULTURAL PRESERVATION

The National Historic Preservation Act requires that the USAF assess the impact of the project on properties included in, or eligible for, the National Register of Historic Places. The purpose of this is to ensure that an adequate evaluation of potential conflicts with archaeological and historic sites is completed and that appropriate mitigation measures are implemented. A field survey is required to assess the impact of each project at Edwards AFB on these cultural and historic resources.

An evaluation has been completed for the Titan rocket testing at RPL and supports a "No Effect" determination. A report on the cultural and historic impacts of this project will be coordinated with the California State Historic Preservation Office in January 1987.

4.6 TRANSPORTATION AND SAFETY REGULATIONS

There are many regulations, guidelines, and criteria issued by several agencies which pertain to the transportation, handling, and firing of solid propellant rocket motors. The Titan propellant is a Class 1.3 propellant (U.S. Department of Defense (DOD) classification). Several safety regulations evolve from this classification to ensure that the risks of fire and other accidents are minimized or eliminated. Agencies which have pertinent regulations include the following:

1. California Department of Health and Safety (Cal OSHA) (safety and working place regulations).

2. California Highway Patrol (transport of hazardous cargoes).

3. DOD (explosive safety standards and transportation regulations).

4. U.S. Department of Transportation (transportation regulations).

In addition, CSD has its own set of standards and criteria for handling its rocket motors. These standards and criteria supplement regulatory agency controls.

4.7 NOISE STANDARDS

The Occupational Safety and Health Administration (OSHA) has established an upper limit of 115 dB(A) as the highest allowable noise level in the workplace. A criterion used by the National Aeronautics and Space Administration and the USAF for uncontrolled populations is that the overall noise level not exceed 120 dB (McClellan, 1968). These levels are not expected to be exceeded in areas off of Edwards AFB.

The Kern County Noise Element of the County General Plan uses noise criteria associated with relatively continuous noise environments. These criteria are not suitable for short-term events such as rocket tests, although technically, the Titan test firing noise will comply with the County Noise Element criteria.

5.0 LIST OF AGENCIES AND INDIVIDUALS CONTACTED

The following individuals were contacted during the preparation of the EA.

U.S. Air Force
- Capt. Emil Barchichat SD/YXT
- Claude Brown, AFFTC/JA
- Sam Burrell, AFRPL
- Capt. Steven Clift, SD/YXT
- Lt. John Coho, SD/SGX
- Lt. Col. Herman Cole, SD/DEE
- John Edwards, SD/DEV
- Maj. Gary Fishburn, AFFTC
- Lt. Col. Frank Gayer, SD/YXT
- Lt. Bryant Hafen, AFRPL/SEH
- Robert Johnstone, AFFTC/CVE
- Lt. Suzanne Komyathy, AFRPL/WE
- Gerald Lawson, 6510 TESTW/TE
- Robert Mason, SD/DEV
- Maj. Mark Mondl, SD/DEV
- Maj. Robert Noonan, AFFTC/WE
- Richard Norwood, AFFTC/CVE
- Mike Phillips, AFFTC/CVE
- Dan Pilson, SD/DEE
- Larry Plews, AFFTC/XR
- Lt. Col. R. M. Riccardi, SD/SGX
- Lt. Graham Rinehart, AFRPL/SEH
- Raphael Roig, SD/DEV
- Lt. Eric Schnaible, AFFTC/PAC
- Lt. Col. Donald Simmons, SD/DEP
- Thomas Troyer, AFRPL/SEH
- Robert Wood, AFFTC/CVE

U.S. Army Corps of Engineers
- Andrew Schildt

U.S. Fish and Wildlife Service
- Jack Williams

California Air Resources Board
- Andrew Ranzieri

California Department of Fish and Game
- Paul Kelley
- Carrie Shaw

California Highway Patrol
- Sgt. Roberts

California Office of Planning and Research, State Clearinghouse
- Norma Wood

California Regional Water Quality Control Board, Lahontan Region
- Tracie Billington
- Robert Dodds
- Eric Hong

California Resources Agency
- Norman Hill

Kern County Air Pollution Control District
- Douglas McCormick
- Thomas Paxson

Kern County Environmental Health Department
- Steven McCauley

Kern County Planning Department
- Maggie Primer

San Bernardino County Air Pollution Control District
- Walter Mook

San Bernardino County Planning Department
- Robert Zuel

Aerospace Corporation
- Steven Laifman
- Frank Meyers

United Technologies Corporation-Chemical Systems Division
- Linda Ballard
- Steven Green
- Charles Keyes
- John Lamberty
- William Lawrence
- Cheryl Vinson

Wyle Laboratories
- Roy Coats
- Brian McKee
- Jack Robertson
- George Shipway
- Rudi Thigpen

6.0 LIST OF PREPARERS

This Environmental Assessment (EA) was prepared by Perry Schafer, Elaine Archibald, Gary Gruwell, and Donna Dean of Brown and Caldwell Consulting Engineers. The following individuals provided technical guidance and assisted in the preparation of the EA.

Brown and Caldwell Consulting Engineers
- Johanna Ambler
- Fred Burke
- George Chouinard
- Bruce Douglas
- Mary Jane Dunckhorst
- Pat Maroney
- Frank Morris
- Carol Murray
- Larry Phillips
- Margaret Purdy
- Janet Rogers
- Miriam Senturia
- Greg Sturges

Peter Klaveness & Associates
- Peter Klaveness
- Steve Pettyjohn

Sierra Research
- Kate Fay
- Gary Rubinstein

Roger Robinson, Consulting Archaeologist

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APPENDIX A

REPRESENTATIVE AMBIENT AIR QUALITY

APPENDIX A

REPRESENTATIVE AMBIENT AIR QUALITY

Ambient air quality monitoring data for the closest desert stations during the period 1980 through 1985 were used to estimate the ambient air quality at the Rocket Propulsion Laboratory (RPL). A summary of the seasonal peak concentrations for O_3, NO_2, TSP, and PM_{10} are shown in Table A-1.

The monitoring stations are located at Lancaster (O_3, NO_2, and TSP), Barstow (TSP and PM_{10}), and Mojave (PM_{10}). The locations of RPL and the monitoring stations are shown on Figure A-1.

Ozone

The ozone concentrations tend to decrease from 1980 through 1985. The peak hourly concentration is 0.29 parts per million (ppm) for the spring of 1980. The peak hourly concentration for 1985 was 0.19 ppm and occurred in the fall. The peak 1985 concentration of 0.19 ppm was used as the representative peak ozone concentration at RPL.

Nitrogen Dioxide

The maximum hourly concentration of 0.22 ppm occurred in the fall of 1981. This value appears to be an outlier, the next highest peak value is 0.11 ppm. The 0.11 ppm concentration was used as the representative peak NO_2 concentration.

Total Suspended Particulates

For TSP, the second highest seasonal peak concentration for each season was considered as the representative ambient air quality peak. The second highest seasonal peak concentration occurs at Boron (385 ug/m^3) for the fall of 1980. The second highest seasonal peak occurred at Lancaster (176 ug/m^3) in the fall of 1980. The 385 ug/m^3 concentration appears to be an outlier, and the 176 ug/m^3 concentration was used as the representative peak ambient air concentration for RPL.

Particulate Matter Less Than 10 Microns (PM_{10})

PM_{10} data have been monitored only since late 1984. The second highest seasonal concentration for Barstow is 54 ug/m^3. The second highest peak for Mojave is 82 ug/m^3. The monitoring of PM_{10} data is

Table A-1. Ambient Air Quality Summary

Station: Lancaster

Pollutant: Ozone, parts per million (ppm)

Seasonal concentrations	1980[a]	1981	1982	1983	1984	1985
Winter, peak hour[b]	0.11	0.14	0.12	0.08	0.10	0.13
Spring, peak hour[c]	0.29	0.20	0.15	0.16	0.18	0.18
Summer, peak hour[d]	0.25	0.21	0.16	0.18	0.17	0.19
Fall, peak hour[e]	0.14	0.14	01.4	0.08	0.14	0.13
Annual geometric mean	0.041	0.048	0.036	0.037	0.039	0.040

Pollutant: Nitrogen Dioxide, ppm

Seasonal concentrations	1980a	1981	1982	1983	1984	1985
Winter, peak hour	0.07	0.08	0.08	0.09	0.09	0.07
Spring, peak hour	0.06	0.06	0.07	0.07	0.11	0.07
Summer, peak hour	0.09	0.07	0.07	0.08	0.07	0.08
Fall, peak hour	0.08	0.22	0.08	0.09	0.11	0.08
Average geometric mean	0.012	0.012	0.012	0.015	0.018	0.015

Pollutant: Total Suspended Particulates, micrograms per cubic meter (ug/m³)

Station: Lancaster

Winter						
Peak	156	105	76	98	114	72
Second peak	138	91	62	90	109	66
Spring						
Peak	164	132	113	129	180	316
Second peak	123	125	91	120	163	131
Summer						
Peak	244	112	93	99	112	134
Second peak	148	110	81	89	91	129
Fall						
Peak	295	110	95	177	135	116
Second peak	176	99	94	78	132	100
Annual geometric mean	93.0	68.0	53.4	53.5	72.9	70.6

Station: Boron

Winter						
Peak	81	129	107	63	99	98
Second peak	77	88	51	60	92	64
Spring						
Peak	113	127	113	170	130	199
Second peak	88	80	99	132	121	125
Summer						
Peak	426	110	140	79	117	109
Second peak	289	91	93	75	69	84
Fall						
Peak	419	66	69	107	129	109
Second peak	385	57	69	94	72	85
Average geometric mean	73.2	51.8	43.0	45.3	59.3	54.5

Pollutant: Particulate Matter Less Than 10 Microns, ug/m³

Station: Barstow

Winter						
Peak	N/D[f]	N/D	N/D	N/D	N/D	N/D
Second peak	N/D	N/D	N/D	N/D	N/D	N/D
Spring						
Peak	N/D	N/D	N/D	N/D	N/D	N/D
Second peak	N/D	N/D	N/D	N/D	N/D	N/D
Summer[g]						
Peak	N/D	N/D	N/D	N/D	N/D	43
Second peak	N/D	N/D	N/D	N/D	N/D	35
Fall						
Peak	N/D	N/D	N/D	N/D	N/D	89
Second peak	N/D	N/D	N/D	N/D	N/D	54
Annual geometric mean	N/D	N/D	N/D	N/D	N/D	38[h]

Station: Mojave

Winter						
Peak	N/D	N/D	N/D	N/D	N/D	N/D
Second peak	N/D	N/D	N/D	N/D	N/D	N/D
Spring						
Peak	N/D	N/D	N/D	N/D	N/D	N/D
Second peak	N/D	N/D	N/D	N/D	N/D	N/D
Summer						
Peak	N/D	N/D	N/D	N/D	N/D	108
Second peak	N/D	N/D	N/D	N/D	N/D	82
Fall						
Peak	N/D	N/D	N/D	N/D	N/D	56
Second peak	N/D	N/D	N/D	N/D	N/D	49
Average geometric mean	N/D	N/D	N/D	N/D	N/D	59.9[h]

Source: California Air Resources Board, Air Quality Data 1980 through 1985.

[a] Reported as oxidant and ozone.
[b] January through March.
[c] April through June.
[d] July through September.
[e] October through December.
[f] No data available.
[g] Two measurements were reported for the time period.
[h] Data presented are valid, but incomplete in that an insufficient number of valid data points were collected to meet EPA and/or ARB criteria for representativeness.
[i] Not applicable.

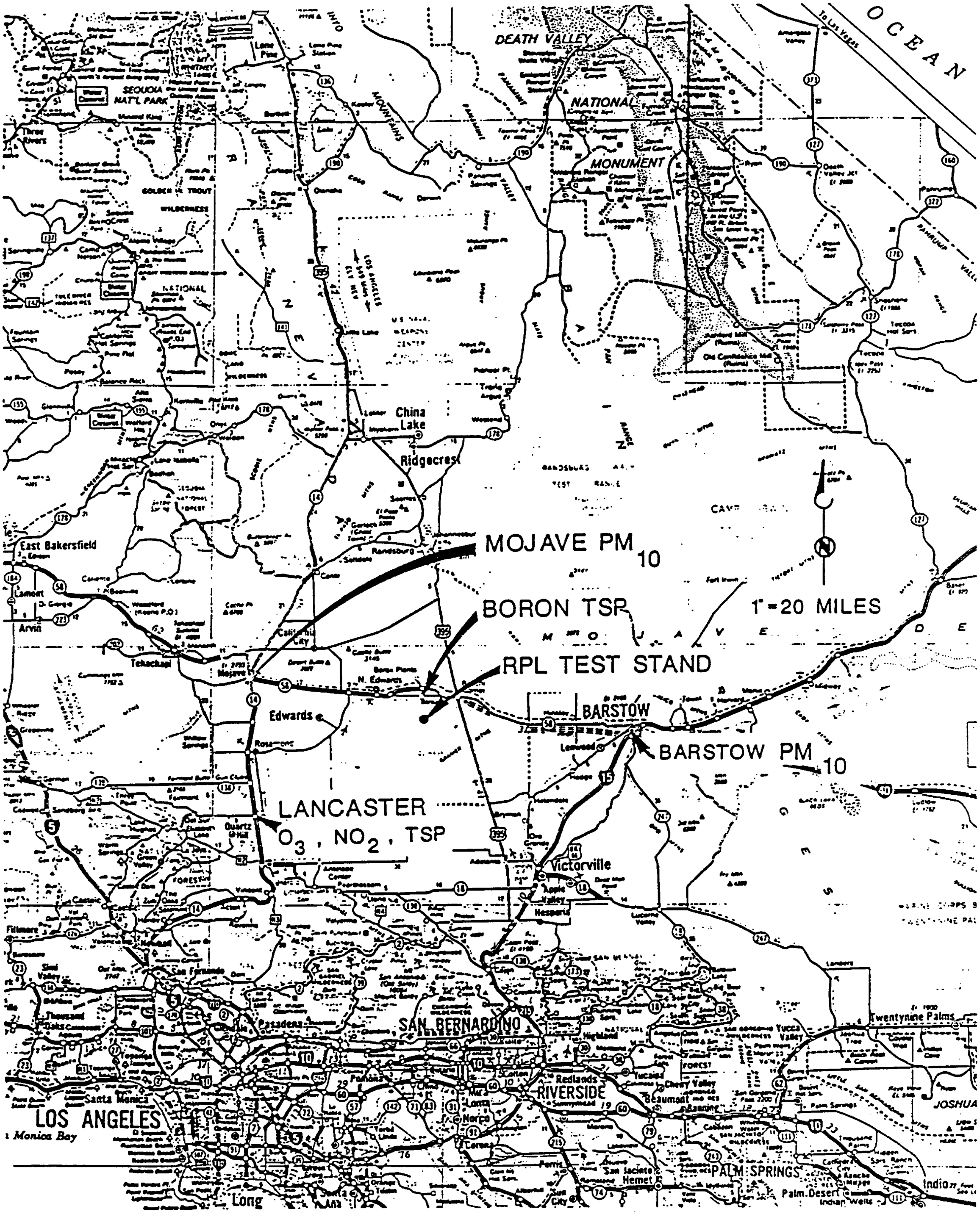

Figure A-1. Location of Ambient Air Monitoring Stations recent, and the amount of recorded data are small with a high variance. A concentration of 82 ug/m^3 was selected as a representative peak PM_{10} ambient air concentration for RPL.

Carbon Monoxide (CO)

Since the impacts due to increased concentrations of CO are negligible, the peak 1985 concentration of 12.0 ppm was used.

APPENDIX B

WAIVER OF WASTE DISCHARGE REQUIREMENTS

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD,
LAHONTAN REGION

STATE OF CALIFORNIA—THE RESOURCES AGENCY
GEORGE DEUKMEJIAN, *Governor*

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD—
LAHONTAN REGION
92 LAKE TAHOE BOULEVARD
P.O. BOX 9428
SOUTH LAKE TAHOE, CALIFORNIA 95731-2428

December 8, 1986

Robert Wood, Acting Chief
Office of Environmental Planning, Management, and Compliance
AFFTC/CVE
Edwards AFB, CA 93523

WAIVER OF WASTE DISCHARGE REQUIREMENTS FOR TITAN ROCKET MOTOR TEST, EDWARDS AFB ROCKET PROPULSION LABORATORY

Dear Mr. Wood:

On November 17, 1986, additional information was submitted to the Regional Board by Thomas Troyer, AFRPL Environmental Coordinator, as part of the report waste discharge for the planned Titan Rocket Motor tests, which will be conducted at the Edwards AFB Rocket Propulsion Laboratory (RPL). Information, regarding this project was previously submitted by your office on October 29, 1986.

The information submitted indicates that approximately 500,000 gallons of cooling water will be generated during each of the three Titan Rocket Motor tests which are proposed to be conducted in 1987. It is our understanding that cooling water for the tests will be chemically conditioned in existing concrete lined channels at the RPL. Once chemically treated to adjust the pH, the cooling water will be stored or evaporated in an above ground storage tank. We have reviewed the report of waste discharge for this project and have concluded that a waiver of waste discharge requirements would not be against the public interest because of (1) the limited nature of the tests; (2) the wastes will be chemically conditioned to adjust the pH; and (3) the expected concentrations of heavy metals appear to be below levels that would constitute a significant potential threat to water quality. Therefore, pursuant to Section 13269 of the California Water Code, we are waiving waste discharge requirements for the three proposed Titan Rocket Motor test. It should be understood that this waiver will be revoked for failure to adhere to the following condition:

> The Titan Rocket Motor tests are conducted as described in the report of waste discharge.

If you should have any questions concerning this matter, please contact Tracie Billington or Eric Hong in our Victorville office at (619) 245-6583.

Yours truly,

O. R. BUTTERFIELD
EXECUTIVE OFFICER

Robert S. Dodds
Supervising Engineer

cc: Regional Board Members
Thomas G. Troyer/AFRPL-SEH, Edwards AFB
Cheryl Vinson/United Technologies
Perry Schafer/Brown & Caldwell

APPENDIX C

KERN COUNTY AIR POLLUTION CONTROL DISTRICT RESEARCH EXEMPTION

KERN COUNTY AIR POLLUTION CONTROL DISTRICT

1601 "H" Street, Suite 250
Bakersfield, California-93301
Telephone (805) 861-3682

LEON M HEBERTSON, M.D
Director of Public Health
Air Pollution Control Officer

Date: 16 December 86

Cheryl R. Vinson
Environmental Engineer
United Technologies
& Chemical Systems
P.O. Box 50015
San Jose, CA
95150-0015

Dear ~~Mr~~ Ms. Vinson:

Thank you for your recent letter in which you requested that the project described as static testing of Titan booster rocket engine

be exempted, pursuant to Rules 202.1 and 426 of the KCAPCD Rules and Regulations, from the requirements of Regulations II and IV (except Rule 419).

A review of your exemption application has revealed that you have provided the following information:

- x Statement of the project's goal.
- x Description of measures to be taken to minimize emissions.
- x Proposed installation date, planned startup date.
- x Expected duration of project.
- x Expected air contaminants emissions testing schedule.

Because you x have ___ have not fulfilled the requirements of Rule 202.1, the District x hereby grants an exemption for this project ___ requests that you provide the remaining information.

Please be aware that if you have been granted an exemption, you must provide this office with the following to retain it:

a. Official air pollutant test results no more than 60 days after the completion of each test sequence.
b. Running record of days of operation submitted monthly beginning one month after startup.

Thank you for your cooperation. Should you have any questions please telephone the Air Quality Control Division at (805) 861-3682.

Sincerely,

LEON M HEBERTSON, M.D., A.P.C.O.

Thomas Paxson, P.E., A.S.E. III

APPENDIX B

ENVIRONMENTAL MONITORING OF A TITAN 34D 5-1/2 SEGMENT SOLID ROCKET MOTOR STATIC FIRING

AFAL-TR-88-029 AD:

Final Report
for the period
February 1987 to
July 1987

Environmental Monitoring of a Titan 34D 5½ Segment Solid Rocket Motor Static Firing

March 1988

Authors:
G. W. Rinehart, Lt, USAF
D. D. Berlinrut, Capt, USAF

prepared for the: **Air Force Astronautics Laboratory**
Air Force Space Technology Center
Space Division, Air Force Systems Command
Edwards Air Force Base,
California 93523-5000

ACKNOWLEDGEMENTS

The authors would like to thank SD/CLVT, United Technologies Chemical Systems Division, and Wyle Laboratories for putting up with the program changes we required in our "non-interference" study.

Special thanks go to Roy J. Coats for his help and cooperation; to TSgt Pat Turner, SSgt Tracy Christensen, SSgt Crystal Rigg, Sgt Willy Lapitan, and all of the other volunteers for putting in long, hard hours in the lab and in the desert, and for performing "above and beyond the call;" and of course to Mr Teddy G. Evans (who has done it all before) for venturing forth into the desert yet again with Geomet in hand.

FOREWORD

This final report documents the planning and results of the environmental monitoring of the static firing of a Titan 34D solid rocket motor at the Air Force Astronautics Laboratory (AFAL), Edwards Air Force Base, CA. AFAL Project Manager was Graham Rinehart.

This report has been reviewed and is approved for release and distribution in accordance with the distribution statement on the cover and on the DD Form 1473.

Samuel Burrell

GRAHAM W. RINEHART, 2LT, USAF
Project Manager

SAMUEL BURRELL
Chief, Safety and Health Office

FOR THE COMMANDER

William D. Carson Jr.

WILLIAM D. CARSON, JR., LT COL, USAF
Chief, Technical Services Division

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REPORT DOCUMENTATION PAGE

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19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

On 15 June 1987 a full-scale 5½ segment Titan 34D solid rocket motor was static fired at the Air Force Astronautics Laboratory, Edwards AFB, CA. An environmental monitoring program was initiated to assure protection of test personnel and compliance with environmental restrictions. A protocol for monitoring densely populated closed environments was developed and initiated in the Control Center. Realtime monitoring of gaseous hydrogen chloride and analysis of preserved collections of hydrochloric acid depositions was performed. Revolatilization chamber experiments were performed to predict and study the strength of acidic off-gassing. Results of the program indicate that the personnel and equipment involved in the test were adequately protected and no significant environmental impact occurred as a result of the motor firing.

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Graham W. Rinehart, 2LT, USAF

22b. TELEPHONE *(Include Area Code)*
(805) 275-5318

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SEH

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INTRODUCTION

On 15 June 1987, a 5 ½ segment Titan 34D solid rocket motor (SRM) was successfully test-fired at the Air Force Astronatucs Laboratory (AFAL) as part of the Titan Recovery Program. The two-minute firing was the first time a Titan 34D SRM was static-fired in a nozzle-down configuration.

The AFAL Bioenvironmental Engineering Office, along with Space Division's Bioastronautical Engineering Office, developed a strategy for the environmental monitoring of the Titan firing involving extensive test area and downrange monitoring. The effort involved monitoring the environment inside the Control Center to protect personnel and equipment, sampling for ground-level hydrogen chloride (HCl) downrange of the firing to document the amount of toxic gas at the base boundary, collection of acidic rainout from the exhaust cloud, and photographic tracking of the exhaust cloud to document its path across the East Range of Edwards AFB.

The firing provided an opportunity to test an experimental sampling device developed by The Aerospace Corporation, and another monitor built by Lawrence Livermore National Laboratory (LLNL) for the Air Force Engineering and Services Center (AFESC). Additional expertise in sampling and sampling equipment was provided by the Air Force Occupational and Environmental Health Laboratory (OEHL).

BACKGROUND AND OBJECTIVES

Following the in-flight failure of a Titan 34D launch vehicle in April 1986, Air Force Systems Command Space Division initiated the Titan Recovery Program. Part of the program was the evaluation of solid rocket motor segments; it was decided to test the segments at the AFAL. The High Thrust Space Booster Complex, Experimental Area 1-125, was chosen as the test site; it is located at the north end of Leuhman Ridge and is 900 feet above the desert floor (Figure 1).

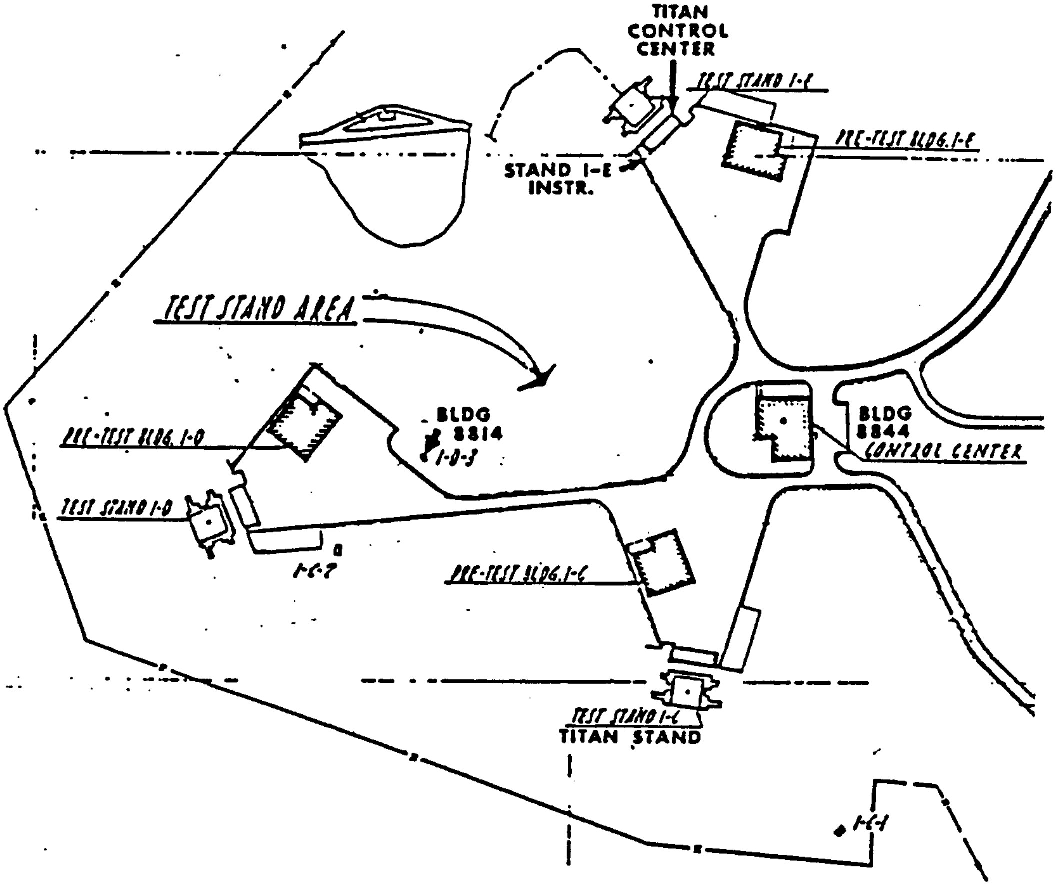

Figure 1. AFAL Experimental Area 1-125.

Area 1-125 was formerly used by Rockwell International's Rocketdyne Division during production testing of the F-1 liquid rocket engines that powered the Saturn V. The area had several large stands capable of handling the thrust of a full-scale Titan 34D SRM, and Thrust Stand 1-C was chosen to be modified for the test program. The stand, originally built for liquid engine testing using RP-1 and LOX, was modified to hold the 5-1/2 segment SRM nozzle-down (Figure 2). The water deluge system used during F-1 testing was re-serviced to provide cooling water to the exhaust deflector, or "flame bucket," during the test firing.

An environmental assessment was prepared and it was determined that the test would have no significant environmental impact. The assessment considered that the 5-1/2 segment SRM burns approximately 460,000 pounds of

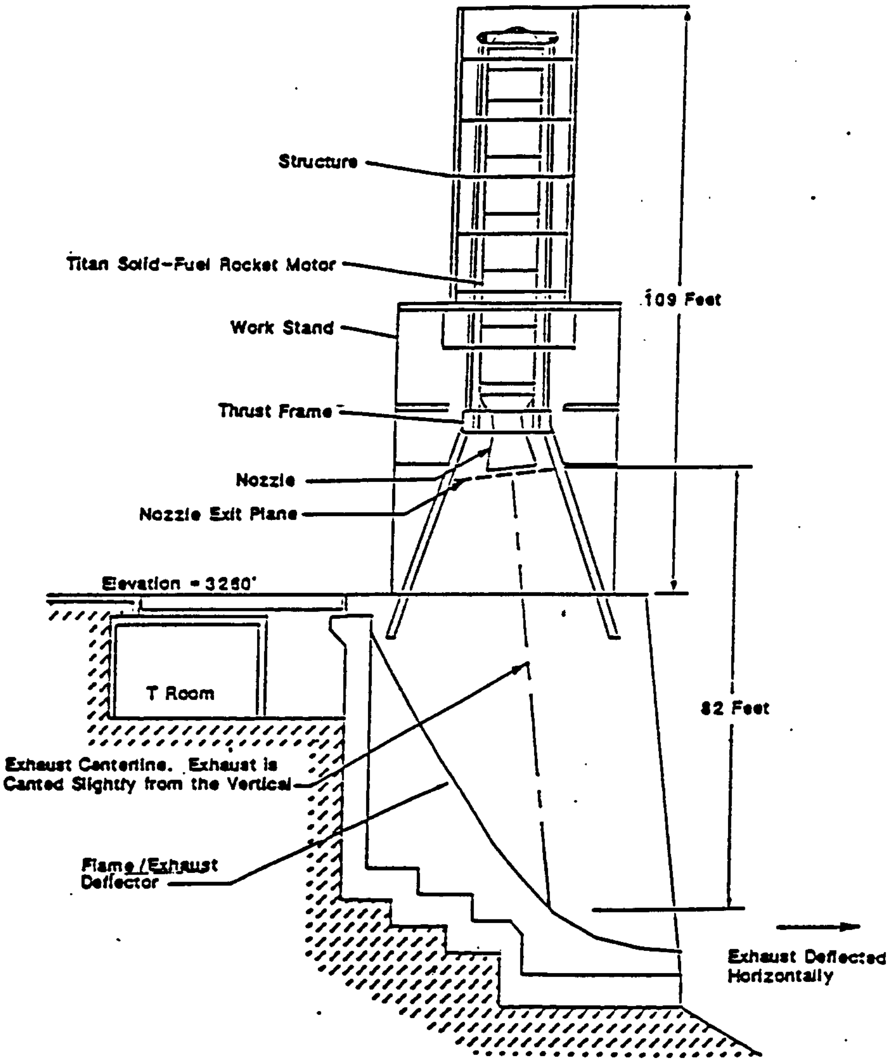

Figure 2. Thrust Stand 1-C configured for the Titan 34D firing.

propellant and produces the following exhaust constituents: HCl, aluminum oxide (Al_2O_3), carbon monoxide (CO), carbon dioxide (CO_2), water (H_2O), hydrogen (H_2), and nitrogen (N_2). Of the exhaust species, HCl is the most toxic. The assessment considered the dispersion of gaseous HCl and the mixing of the exhaust plume with buffered deluge water as well as other environmental concerns (Ref. 1).

The environmental monitoring program was developed to meet the following objectives:

1. Protection of personnel and equipment in the Control Center. The firing Control Center was located beneath Thrust Stand 1-E (shown in Figure 1) in the modified 1-E T-Room.

2. Documentation of where the exhaust cloud passed over the Edwards AFB boundary and the actual ground-level concentrations of HCl from the exhaust.

3. The study of the revolatilization process and the possibility of HCl regeneration from acidic rainout.

4. Field-testing the Aerospace and AFESC/LLNL experimental HCl monitors.

The firing was first attempted on 4 June 1987; however, it was scrubbed that day and on three successive attempts because the weather conditions did not match requirements. On 15 June the test was successfully accomplished. The motor ignited at 1802 and burned out 120 seconds later, sending approximately 96,000 pounds of HCl into the air.

CONTROL CENTER AND TEST AREA MONITORING

INFILTRATION STUDIES

Two separate infiltration studies were conducted on buildings at Area 1-125. The facilities studied were Building 8844 and the Control Center (see Figure 1 and note that the original Area 1-125 Control Center is now referred to as Building 8844). Building 8844 housed the computers used for data reduction during the firing. The Titan Control Center, located beneath Thrust Stand 1-E, housed the firing crew during the test.

Infiltration tests located sources of air infiltration (leakage) into the buildings by monitoring the concentration of a tracer gas in the building's atmosphere over a period of time. A known amount of tracer gas was injected into the building until a specific concentration was reached. The concentration was continuously monitored and the rate at which the concentration decayed indicated the rate of infiltration of "clean" outside air into the building. For the studies performed at Area 1-125, Freon-22 (chlorodifluoromethane) was the tracer gas; its concentration was measured by a Miran 1A infrared spectro-photometer.

The first infiltration test was performed on 11 February 1987. The survey identified several leak sources in the buildings (e.g., broken seals on blast doors and air intake covers, open conduit pass-throughs) which were brought to the attention of the facility contractor (Ref. 2).

A second infiltration study was performed on 23 March 1987 to verify the effectiveness of repairs. The test confirmed that the infiltration rate had dropped to one-fourth that found during the previous test, and the facility was certified for use (Ref. 3).

MONITORING PROTOCOL

The closed environment of the Control Center presented special problems, problems that were discovered during the April 1986 Titan failure at Vandenburg AFB, CA. Following the loss of the vehicle, launch personnel were forced to remain in the Launch Operations Building because of burning solid propellant and brush fires. After a prolonged period of time, the air in the building became stagnant, forcing the personnel into the hazardous environment.

To prevent this type of incident from occurring during this and future tests, a monitoring protocol was developed for use in the Control Center during the course of the firing. The protocol examines the rate of depletion of oxygen and the rate of CO_2, temperature, and HCl buildup in the building, and compares them to the rate of HCl dispersion outside the building.

It was developed in response to the need to predict at what time it would be safe to exit the Control Center after the firing, and the need to predict when conditions in the Control Center might become dangerous. The same protocol was used at an October 1987 Titan launch and is proposed for use in all launch operations buildings.

THEORETICAL DEVELOPMENT

The protocol is based on the assumption that all of the changes in parameters are governed by exponential functions, i.e., that the basic equation governing the phenomena is

$$C = C_0 e^{kt} \tag{1}$$

where C is the function value at time t, C_0 is the original function value, and k is a mathematical constant (see Figure 3).

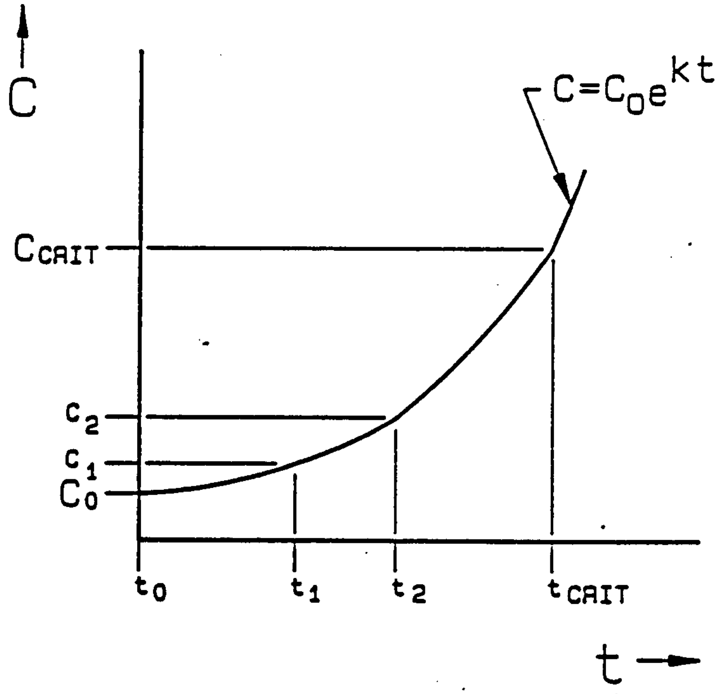

Figure 3. Simple exponential function.

Taking the natural logarithm of both sides gives

$$\ln(C) = kt*\ln(C_0) \tag{2}$$

and grouping the function values together leads to

$$kt = \ln\left(\frac{C}{C_0}\right). \tag{3}$$

The equation can now be solved for the constant k,

$$k = \left(\frac{1}{t}\right)*\ln\left(\frac{C}{C_0}\right) \tag{4}$$

or the time t,

$$t = \left(\frac{1}{k}\right)*\ln\left(\frac{C}{C_0}\right). \tag{5}$$

As seen in Figure 3, discrete points t_1 and t_2 can be found corresponding to function values c_1 and c_2, respectively. According to this protocol, function values (c_x) correspond to the measurements of parameters taken at discrete times.

For the Titan Recovery Program test firing, the parameters were

HCl(i) -- concentration of HCl in the Control Center,
HCl(e) -- concentration of HCl outside the Control Center,
CO_2 -- concentration of CO_2 in the Control Center,
O_2 -- concentration of O_2 in the Control Center,
T -- measure of heat stress in the Control Center,
and safety -- a subjective parameter controlled by the Safety representative present.

Using the discrete points of measurements taken at specific times, an empirical value of the constant k, called k_e, can be calculated by the equation

$$k_e = \left(\frac{1}{t_2-t_1}\right)*\ln\left(\frac{C_2}{C_1}\right). \tag{6}$$

Care must be taken in applying this equation. For a more accurate estimate of the rate, the longest time interval available should be used (e.g., from t_o to the time of the last measurement) in calculating the value of the constant k_e. However, in the analysis of the conditions in the Control Center, any perturbations in the rate (as might be caused by a fire in the room, a ventilation equipment breakdown, or the loss of seal integrity) must be taken into account; this was accomplished by calculating k_e over the increment of time between the two latest measurements.

Also shown in Figure 3, a critical value known as C_{crit} occurs at some future time from when the discrete readings are taken. The critical values for the parameters used in the monitoring protocol were:

$[HCl]_{crit}$ = 5 ppm (interior rising, exterior falling)
$[CO_2]_{crit}$ = 30,000 ppm (3%) (rising)
$[O_2]_{crit}$ = 18% (falling)
T_{crit} = 32.2 degrees C (WBGT) (rising).

The values for HCl, O_2, and T (thermal stress) are consistent with standard industrial hygiene practice; the value for CO_2 was established after consultation with Air Force flight surgeons.

The empirical constant k_e can be used to predict the time at which the function value will become critical:

$$t_{crit} = \left(\frac{1}{k_e}\right) * \ln\left(\frac{C_{crit}}{C_o}\right). \qquad (7)$$

If the last discrete measurement was made at time t_i, then the time until a critical value is reached would be

$$t(x) = t_{crit} - t_n \qquad (8)$$

where (x) is an identifier for whatever parameter is being studied, and t_n is the elapsed time from the original measurement (at t_o) to the last measurement, or $t_i - t_o$.

The protocol calls for such 'time-to-critical', or $t(x)$, calculations to be made for every parameter under investigation, then compared to one another to arrive at $t_{(int)}$, the time until a critical condition would be encountered in the Control Center interior, and $t_{(ext)}$, the time until the environment outside the Control Center would be free of contamination. $t_{(int)}$ is a function of all of the internal parameters as shown by

$$t_{(int)} = \text{minimum}(t_{HCl(i)}, t_{CO2}, t_{O2}, t_T, t_{safety}), \tag{9}$$

i.e., the lowest of those critical times, while $t_{(ext)}$ equals $t_{HCl(e)}$.

Finally, the values of $t_{(int)}$ and $t_{(ext)}$ are compared, and the condition determined by the following criteria:

RED:	$t_{(int)} < 30$ min
ORANGE:	$t_{(int)} < t_{(ext)}$ (RED possible)
GREEN-HOLD:	$t_{(int)} > t_{(ext)} > 0$ min
GREEN-GO:	$t_{(ext)} = 0$ min (no RED possible).

A 'RED' condition would indicate a situation in which conditions inside the Control Center would deteriorate within thirty (30) minutes, meaning an emergency egress would have to be made using Self-Contained Breathing Apparatus (SCBA); an 'ORANGE' condition would indicate that while the interior conditions did not warrant emergency status, they would deteriorate faster than conditions outside would improve and SCBAs would still have to be used in a controlled egress. The 'GREEN-HOLD' condition would indicate that the environment outside the Control Center would clear faster than the environment inside deteriorated; a controlled egress without respiratory protection would be possible when the 'GREEN-GO' condition was reached, i.e., when the environment outside the Control Center was clear.

PROTOCOL IMPLEMENTATION

Instrumentation was set up in the Control Center to measure the parameters discussed previously. To measure HCl, a Geomet HCl Detector, Model 401B, was used. As backup to the Geomet, a long-term Draeger sampling tube was in place in a polymeter pump, and direct-reading Draeger tubes were available with a hand pump. Other HCl detection devices, placed in the Control Center by OEHL, were a midget impinger and a low-flow silica gel tube.

A Foxboro-Wilkes Miran 1A infrared spectrophotometer was used to monitor the level of CO_2 in the Control Center, and was backed up by a long-term Draeger tube in a second polymeter pump. To measure O_2, a Gastechtor combination explosive gas/oxygen meter was used. For heat stress measurements, a Reuter-Stokes Heat Stress Monitor was used to calculate the Wet Bulb Globe Temperature (WBGT).

For HCl concentration measurements outside the Control Center, a Geomet Model 401B was located at Thrust Stand 1-E. The Geomet output was connected to a stripchart recorder in the Control Center. This Geomet was backed up by another 401B located at a photo bunker (Building 8814); this second Geomet, intended to provide reference data for the LLNL experimental unit, was connected via modem to computer at the AFAL Safety Operations Center. Figure 1 shows the instrument locations at the test area.

HCl Monitoring, Inside. The Geomet in the Control Center was activated at 1214 and sampled the air until 2107. The instrument did not detect any HCl in the Control Center, indicating that no infiltration took place. Applying the principles of the monitoring protocol, the variable C_0 (the original function value) was assigned the value of 0 ppm. Equation (7) relates the t_{crit} value to the natural logarithm (natural log) of the ratio of critical value to function value; for this case the ratio is 5/0.

The zero in the denominator drives the number to infinity; the natural log of the ratio also goes to infinity, making the t_{crit} (and subsequently the time-to-critical) value infinite for the interior HCl, or HCl(i). The equipment supplied by OEHL was activated at 1725, and analysis of the collection media indicated that no HCl was detected (Ref. 4). The long-term Draeger tube was not used.

<u>CO_2 Monitoring</u>. The Miran was activated at 1140 hours and operated continuously in the Control Center until shut off at 2104. The Control Center was isolated at 1755 and not opened for two days. Figure 4 shows a graph of the collected data, and Table 1 shows the t_{crit} values.

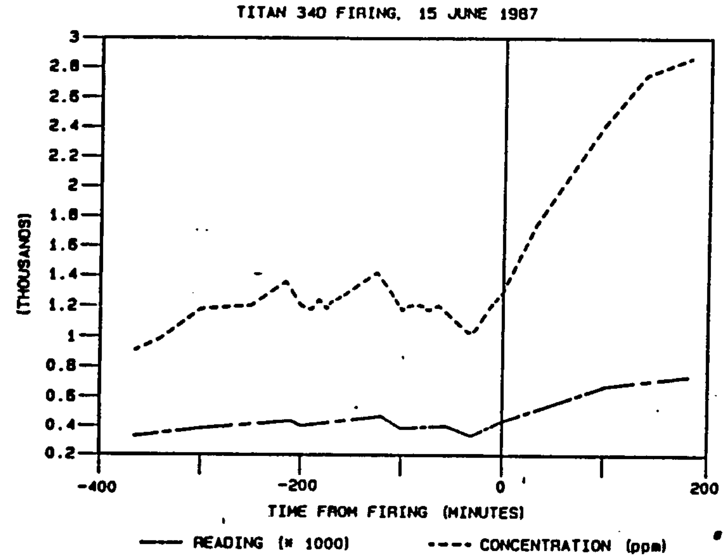

Figure 4. <u>CO_2 measurements in the Control Center.</u>

TABLE 1. CO_2 in the Control Center. Concentration and t-critical.

Date: 15 June 1987 Location: 1-E Control Center

Instrument/Measuring: Miran 1A Spectrophotometer -- CO_2

Pressure = 682.6 mm Hg
Temperature = 294.4 K
Concentration = 0.195 * lambda

C_{crit} = 3% C_o = 1014 ppm T_o = 1730 $\ln(C_{crit}/C_o) = 3.3873$

	Time (t)	Delta T	lamda/C	$\ln(C_i/C_{i-1})$	k_e	t_{crit}
1	1742	12	5400/1053	.0377	.0031	1077
2	1748	6	5800/1131	.0715	.0119	284
3	1758	10	6500/1268	.1139	.0114	297
	1802 - Firing Begins					
4	1814	16	7800/1521	.1819	.0114	297
5	1822	8	8300/1619	.0621	.0078	436
6	1830	8	8500/1658	.0235	.0029	1153

$k_e = \ln(C_i/C_{i-1})/\text{delta-t}$ $t_{crit} = \ln(C_{crit}/C_o)/k_e$

NOTES: 1) All time values are given in minutes except the local time in the first column.

2) The Miran readings were fractions of a volt which were converted to 'lambda' by use of a calibration curve. The values for lambda then had to be converted to concentration (C) in ppm by the relation given above.

As shown, the lowest critical time value was 4.7 hours (284 minutes) and occurred at 1748 (fourteen minutes before the firing); using Equation (8), the time-to-critical, or t_{CO2}, at that time was 4.4 hours (266 minutes). The lowest t_{CO2} value, however, occurred at 1814, while the t_{crit} value was 5 hours (297 minutes). The elapsed time meant the t_{CO2} value was 4.2 hours (253 minutes). This indicates that personnel could only remain in the Control Center 4.2 more hours if the CO_2 buildup continued at the rate shown (0.0114 sec^{-1}). Again the long-term Draeger tube was available but not used.

O_2 Monitoring. The Gastechtor was activated approximately 12 hours prior to the firing, and registered the amount of O_2 in the air until 2111; Table 2 shows the data collected and the t_{crit} values. Oxygen readings were completely stable up to the controlled egress at 1840; between then and the final reading the O_2 concentration fell from 20.3 to 20.1 percent. Of course, by then the Control Center was unoccupied, so the t_{crit} value of 32.8 hours (1967 minutes) and the corresponding time-to-critical (t_{O2}) value of 29.1 hours (1745 minutes) have little meaning. This indicates that the amount of oxygen in the control room should not be a limiting factor in future tests unless an anomaly, such as a fire, occurs in the room.

TABLE 2. O_2 in the Control Center. Concentration and t-critical.

Date: 15 June 1987 Location: 1-E Control Center

Instrument/Measuring: Gastechtor -- O_2

$C_{crit} = 18\%$ $C_o = 20.3\%$ $T_o = 1729$ $\ln(C_{crit}/C_o) = -.1202$

	Time (t)	Delta T	C	$\ln(C_i/C_{i-1})$	k_e	t_{crit}
1	1741	12	20.3	zero	zero	inf
2	1747	6	20.3	zero	zero	inf
3	1757	10	20.3	zero	zero	inf
	1802 - Firing Begins					
4	1814	17	20.3	zero	zero	inf
5	1822	8	20.3	zero	zero	inf
6	1829	7	20.3	zero	zero	inf
	1840 - Controlled Egress					
7	2111	162	20.1	-.0099	-.0001	1967

$k_e = \ln(C_i/C_{i-1})/\text{delta-t}$ $t_{crit} = \ln(C_{crit}/C_o)/k_e$

NOTES: 1) All time values are given in minutes except the local time in the first column.

2) Underlined values were not calculated on the day of the firing, as the Control Center was already vacant.

Heat Stress Monitoring. The Reuter-Stokes unit was activated about 12 hours before the firing and ran until 2112. Data and t_{crit} values for the indoor WBGT are shown in Table 3. As shown, the most remarkable change in the thermal stress while the room was occupied occurred between 1746 and 1756, with a corresponding t_{crit} value of 9.1 hours (545 minutes). Taking into account the elapsed time, the time-to-critical (t_T) value was 8.6 hours (514 minutes). The final reading, taken at 2112 after the Control Center had been evacuated, resulted in a t_{crit} value of 5.8 hours (345 minutes) and a t_T value of 2 hours (119 minutes). As with the O_2 buildup, this time-to-critical value is meaningful only as an indication of the trend and had no operational impact since the room was vacant.

TABLE 3. WGBT in the Control Center. Reading and t-critical.

Date: 15 June 1987 Location: 1-E Control Center

Instrument/Measuring: Reuter-Stokes Heat Stress Monitor -- WBGT(in)

C_{crit} = 305.4 K C_o = 294.3 K T_o = 1725 $\ln(C_{crit}/C_o)$ = .037

	Time (t)	Delta T	C	$\ln(C_i/C_{i-1})$	k_e	t_{crit}
1	1739	14	294.4	.0003	2.4267E-5	1525
2	1746	7	294.4	zero	zero	inf
3	1756	10	294.6	.0007	.0001	545
	1802 - Firing Begins					
4	1813	17	294.7	.0003	1.9964E-5	1853
5	1821	8	294.7	zero	zero	inf
6	1829	7	294.7	zero	zero	inf
	1840 - Controlled Egress					
7	2112	163	299.9	.0175	.0001	345

$k_e = \ln(C_i/C_{i-1})/\text{delta-t}$ $t_{crit} = \ln(C_{crit}/C_o)/k_e$

NOTES: 1) All time values are given in minutes except the local time in the first column.

2) Values for 'C', the indoor Wet Bulb Globe Temperature, are in degrees Kelvin.

3) Underlined values were not calculated on the day of the firing, as the Control Center was already vacant.

HCl Monitoring, Outside. The Geomet located at Thrust Stand 1-E was activated at 1810; however, due to an oversight data from the instrument did not start recording until 1837. For this reason, data had to be relayed by telephone from the Safety Operations Center to the Control Center; the data was generated by the Geomet and Interscan at Building 8814 and was transmitted to Operations over the LLNL modem hookup. Because the concentration outside the Control Center dropped off rapidly, t_{crit} calculations were begun but not continued; it was decided to go ahead with the egress procedure when the concentration dropped below 5 ppm. The concentration dropped below that critical value at 1839. Comparisons of the t_{crit} values (but not the time-to-critical values) calculated are shown in Table 4. The test conductor was made aware of the environmental conditions and controlled egress procedures were initiated at 1840.

TABLE 4. t-critical comparisons and condition evaluations.

Date: 15 June 1987

Location: 1-E Control Center

$[HCl_i]_{crit}$ = 5 ppm (up)
$[HCl_e]_{crit}$ = 5 ppm (down)

$[CO_2]_{crit}$ = 30 000 ppm (up)
$[O_2]_{crit}$ = 18% (down)
T_{crit} = 32.2 deg C

	Time	critical times							
		HCl_i	CO_2	O_2	T	safe	$t_{crit(i)}$	$t_{HCl(e)}$	Cond
1	1742	n/a	1077	inf	1525	inf	1077	n/a	n/a
2	1748	n/a	284	inf	inf	inf	284	n/a	n/a
3	1758	n/a	297	inf	545	inf	297	n/a	n/a
	1802 - Firing Begins								
4	1814	inf	297	inf	1853	inf	297	anomaly	G-H
5	1827	inf	436	inf	inf	inf	436	n/a	G-H
6	1833	inf	1153	inf	inf	inf	1153	n/a	G-H
	1840 - Controlled Egress								

NOTES: 1) All time values are given in minutes except the local time in the first column.
2) 'inf' means infinite.

HCl sampling was accomplished during the egress procedure using Draeger direct-reading tubes. The areas through which the egress took place had not been continuously monitored, and the first people to egress wore SCBAs because of the unknown concentration of HCl. Seven negative samples were taken during the egress maneuver, so the test conductor decided to go ahead with the general egress of Control Center personnel.

TEST AREA MONITORING

As mentioned previously, Geomet HCl Detectors were placed at Thrust Stand 1-E and Building 8814 (refer to Figure 1). HCl detection equipment placed at Thrust Stand 1-E by OEHL consisted of a large impinger and high-and low-flow silica gel tubes. OEHL placed the same type of equipment plus a midget impinger at Building 8814. The Aerospace Corporation located their experimental HCl monitor at Thrust Stand 1-E, and LLNL placed their experimental unit and an Interscan Compact Portable Analyzer at Building 8814.

Thrust Stand 1-E. As mentioned, the Geomet at this location was activated at 1810 but its data collection did not begin until 1837. Because the Geomet produces time-resolved data, the data regarding the HCl concentrations found immediately after the test was lost. A plot of the data is shown in Figure 5. The plot shows that for as long as three hours after the test firing, an HCl concentration of 0.1 ppm was present; this HCl concentration is attributed to revolatilization (off-gassing) of HCl from the deposition of acidic rainout. Analysis of their sampling media indicated that OEHL's impinger and low-flow silica gel tube detected no HCl, while their high-flow tube detected 7.9 ppm (2-minute average) (Ref. 4). The Aerospace unit failed, apparently due to a power surge.

Building 8814. The Geomet at this location was activated at 1725 and pegged immediately after the 1802 firing. Set on the 0-10 ppm scale, any concentration of HCl over that would cause the Geomet to read 10 ppm until the concentration dropped below that level. The Interscan placed at Building 8814 by LLNL read a peak value of 62.4 ppm; a plot of the Geomet and Interscan readings is given in Figure 6. (It is interesting to note that prior to the

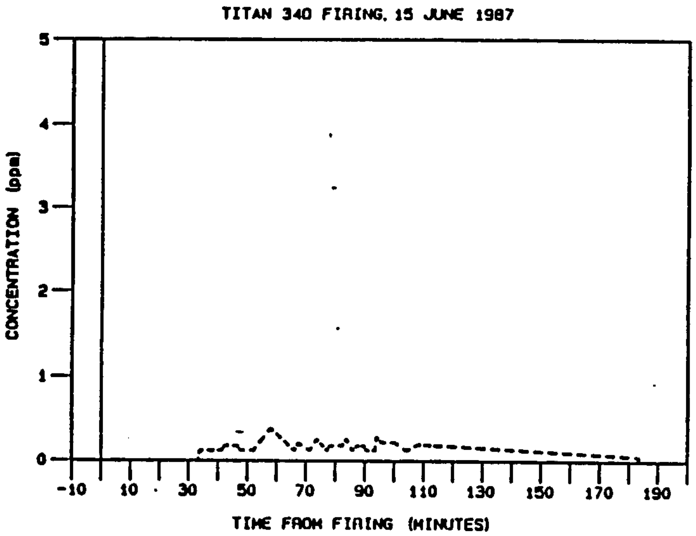

Figure 5. HCl measurements at Thrust Stand 1-E.

firing the Geomet registered 0.0 ppm of HCl while the Interscan was reading an average of 0.61 ppm.) OEHL's analysis of their sampling media indicated that their equipment detected the following levels of HCl (2-minute averages):

Large Impinger	204 ppm
Midget Impinger	744 ppm
High-Flow Silica Gel Tube	137 ppm
Low-Flow Silica Gel Tube	234 ppm (Ref. 4).

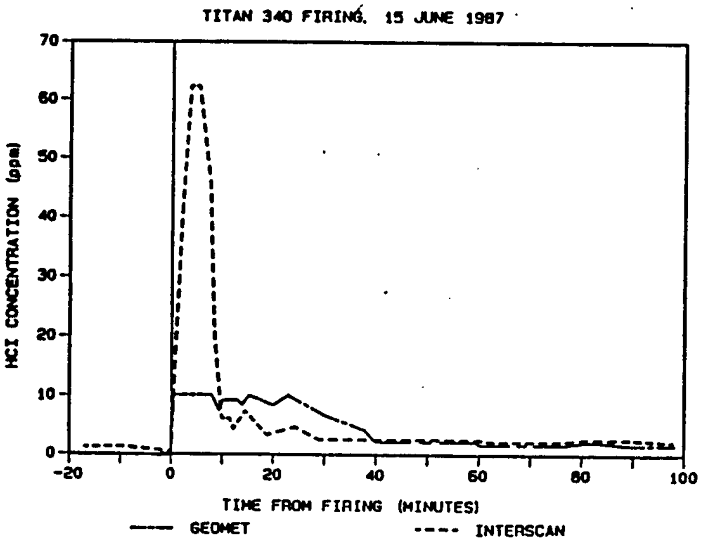

Figure 6. HCl measurements at Building 8814.

The LLNL experimental unit failed to operate properly because depositions from the exhaust cloud impacted its mirrors, blocking the infrared beam.

DOWNRANGE MONITORING

METEOROLOGICAL DATA COLLECTION

Because of the amount of propellant being burned in the Titan 34D firing, special meteorological constraints were required, especially with regard to wind direction. The environmental assessment specified a wind corridor of 260 - 310 degrees azimuth, which is shown in Figure 7. (Ref. 1)

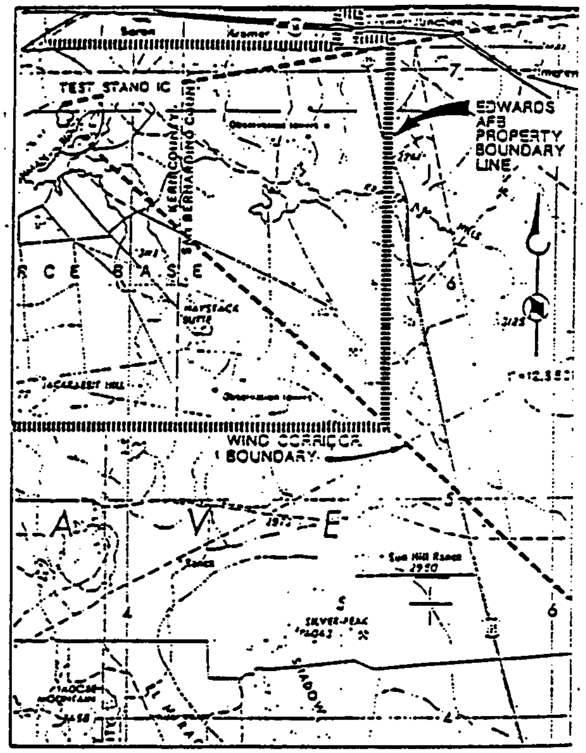

Figure 7. Wind corridor for the Titan 34D firing.

Air Weather Service Detachment 21 provides meteorological support for the Air Force Flight Test Center and the AFAL. In supporting the AFAL they rely mainly on the AFAL Automaetic Weather System (AWS), shown in Figure 8. The AWS is a network of instrumented towers spread across the AFAL. These towers record wind velocity, delta-T (the difference in temperature between points 6 and 54 feet above the ground), humidity, and barometric pressure and relay the information to the AFAL Safety Operations Center. There the data is displayed on a terminal and is used to support rocket motor tests and other hazardous operations.

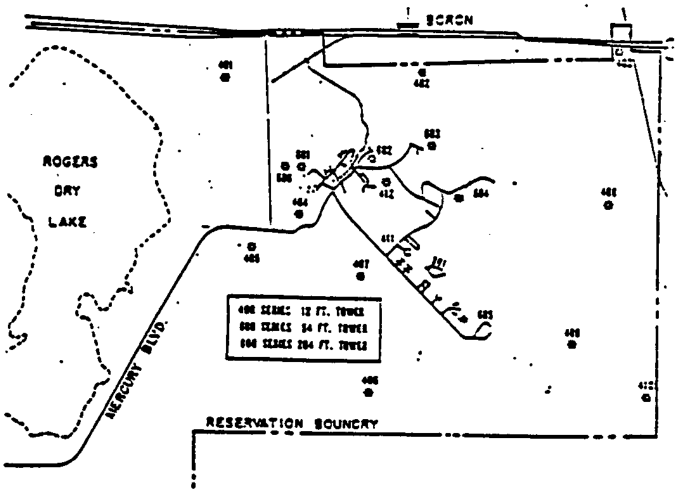

Figure 8. AFAL automatic weather system.

The meteorological support for the Titan test, however, was more extensive. Winds aloft were considered in establishing go/no-go criteria, making the use of weather balloons necessary. Air Weather Service Det 21 launches rawinsonde balloons daily in its regular support operations, and the data from these balloons was relayed to Operations. On the first day the Titan test was attempted, Det 21 also sent up pilot balloons on a regular basis, relaying the data to the AFAL Safety Operations Center.

When the first firing attempt was scrubbed, it was surmised that the meteorological information might not be accurately reflecting the conditions at the AFAL. All balloon launches had been taking place at the rawinsonde site at Edwards main base, over twelve miles across Rogers Dry Lake from AFAL Area 1-125. It was decided to launch the pilot balloons from AFAL Area 1-36 for all other firing attempts, in order to obtain wind data more representative of AFAL winds. Figure 9 illustrates balloon launch points, and Table 5 gives the wind data collected on the day of the firing.

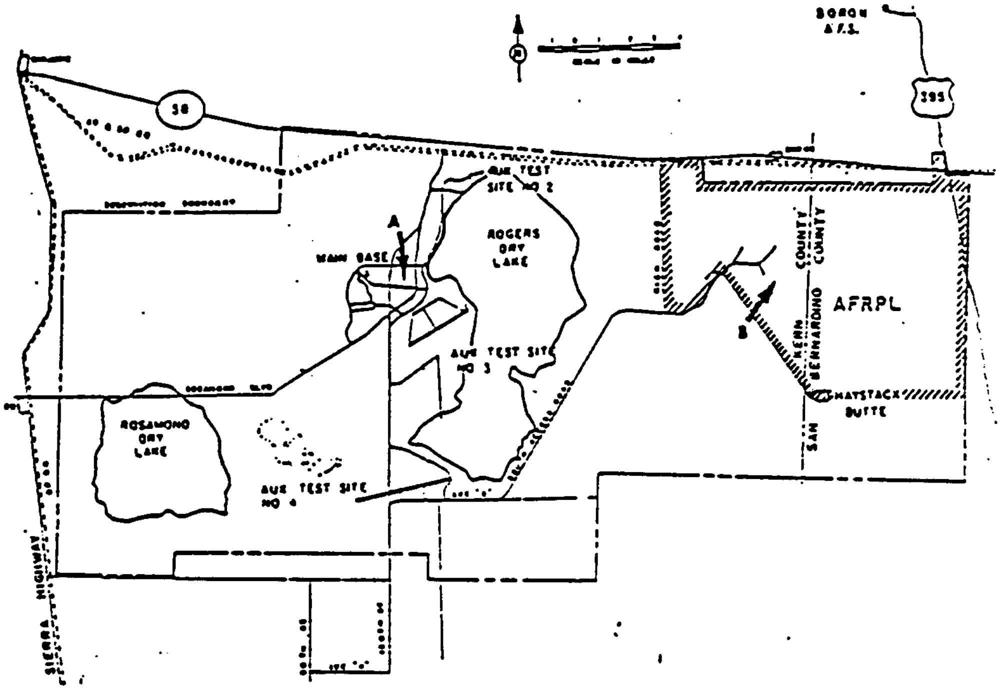

Figure 9. Weather balloon launch sites.
A - Edwards AFB rawinsonde site.
B - AFAL Area 1-36.

TABLE 5. Wind data, 15 June 1987.

Wind directions (degrees azimuth) and speeds (knots) with respect to time and height above the ground.

	Height above ground level (feet)												
Time	12	1K	2K	3K	4K	5K	6K	7K	8K	9K	10K	Mean	
1234L	280	260	250	240	250	250	260	270	260	260	250	257	deg
	22	16	18	26	28	28	29	31	31	33	41	27	kts
1305L	250	260	260	250	250	240	250	250	260	250	250	252	deg
	15	40	33	19	36	29	30	25	28	33	37	29	kts
1335L	240	250	260	260	250	240	250	250	250	250	250	250	deg
	14	15	12	15	19	24	28	32	33	35	36	24	kts
1408L	250	240	250	260	260	250	250	250	250	260	260	254	deg
	13	17	20	24	26	26	33	36	41	42	46	29	kts
1445L	280	260	260	250	250	250	240	250	250	260	260	256	deg
	20	33	32	20	21	22	19	33	45	54	53	32	kts

TABLE 5. Wind data, 15 June 1987 (concluded).

Wind directions (degrees azimuth) and speeds (knots)
with respect to time and height above the ground.

	Height above ground level (feet)												
Time	12	1K	2K	3K	4K	5K	6K	7K	8K	9K	10K	Mean	
1518L	250	250	260	260	260	250	250	260	250	250	250	253	deg
	15	20	20	19	21	20	29	33	38	41	45	27	kts
1548L	250	260	260	270	270	270	260	240	250	260	250	258	deg
	25	20	24	28	36	31	25	24	37	43	43	30	kts
1618L	260	260	270	270	280	260	250	260	260	250	250	260	deg
	15	23	25	23	26	26	23	38	38	36	35	28	kts
1649L	250	250	250	270	270	260	260	260	260	250	250	257	deg
	16	25	29	24	24	21	27	34	27	40	39	28	kts
1721L	260	260	270	270	270	280	260	260	260	260	250	263	deg
	14	33	28	24	23	26	22	34	40	39	35	29	kts

SAMPLING STRATEGY

Atmospheric and dispersion modeling experts from NASA's Marshall Space Flight Center and from The Aerospace Corporation attempted to predict the dispersion of HCl from the static firing. Their predictions had a high degree of uncertainty, however, due to the complex chemical reactions between the exhaust plume and the buffered deluge water and the complex windflow patterns around Leuhman Ridge.

Because accurate HCl dispersion predictions were not available, downrange sampling was designed to take advantage of the specified wind corridor, and provided for both near-field and far-field sampling of ground-level HCl concentrations. The sampling scheme called for three near-field sampling sites (AFAL Experimental Areas 1-90, 1-100, and the Receiving, Inspection and Storage (RIS) Building), three far-field sites (Askania camera sites 1-A, 2-A, and 3-A), and a number of sites along the base boundary and near local communities. These sites are shown in Figure 10, and their instrumentation and sampling results are presented in Table 6.

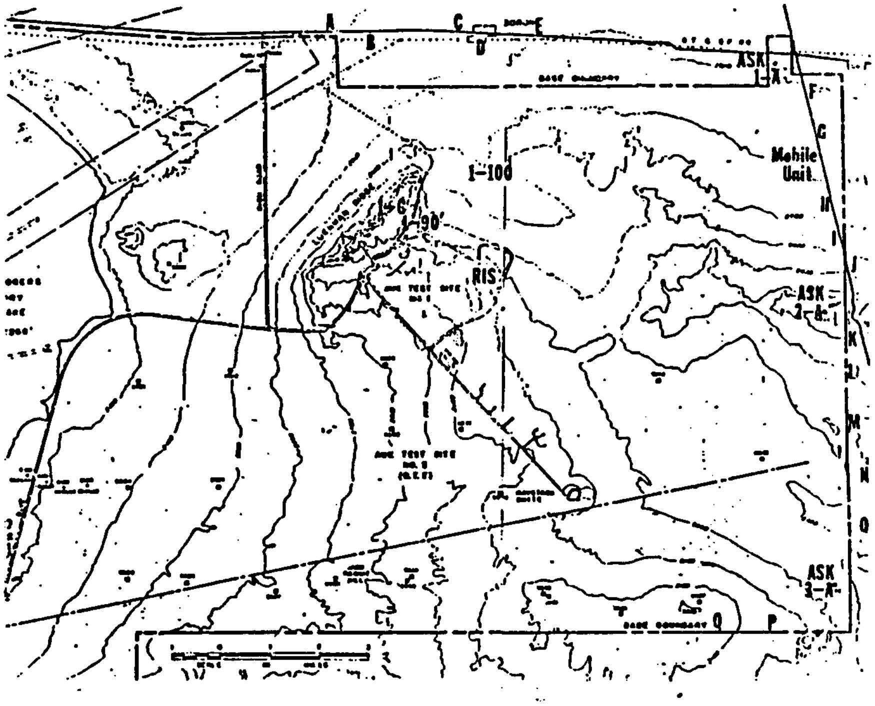

Figure 10. Downrange sampling locations.

TABLE 6. Downrange sampling results.

Designation/ Location	Equipment	Responsible Agency	Results
Area 1-90	Geomet	AFAL/SD	Equip Fail
	Interscan	OEHL	0.4 ppm (peak)
	Large Impinger	OEHL	ND
	High Flow Tube	OEHL	ND
Area 1-100	Geomet	AFAL/SD	ND
	Interscan	OEHL	0.02 ppm (peak)
	Large Impinger	OEHL	ND
	High Flow Tube	OEHL	ND
RIS Bldg	Geomet	AFAL/SD	0.3 ppm (5 min)
	Interscan	OEHL	0.69 ppm (peak)
	Large Impinger	OEHL	ND
	High Flow Tube	OEHL	ND
Askania 1-A	Geomet	AFAL/SD	0.1 ppm (1 min)
	Interscan	OEHL	Equip Fail
	Midget Impinger	OEHL	3.2 ppm
	High Flow Tube	OEHL	ND

TABLE 6. Downrange sampling results (concluded).

Designation/ Location	Equipment	Responsible Agency	Results
Askania 2-A	Geomet	AFAL/SD	ND
	Interscan	OEHL	Anomaly
	Large Impinger	OEHL	ND
	Midget Impinger	OEHL	ND
	High Flow Tube	OEHL	ND
Askania 3-A	Geomet	AFAL/SD	ND
	Interscan	OEHL	ND
	Large Impinger	OEHL	ND
	Midget Impinger	OEHL	ND
	High Flow Tube	OEHL	ND
Mobile Unit	Interscan	OEHL	0.12 ppm (peak)
	Large Impinger	OEHL	ND
	Midget Impinger	OEHL	2.8 ppm
	High Flow Tube	OEHL	ND
Boundary Samplers			
A	High Flow Tube	OEHL	ND
B	High Flow Tube	OEHL	ND
C	High Flow Tube	OEHL	ND
D	High Flow Tube	OEHL	ND
E	High Flow Tube	OEHL	ND
F	High Flow Tube	OEHL	ND
G	High Flow Tube	OEHL	ND
H	High Flow Tube	OEHL	ND
I	High Flow Tube	OEHL	ND
J	High Flow Tube	OEHL	ND
K	High Flow Tube	OEHL	ND
L	High Flow Tube	OEHL	ND
M	High Flow Tube	OEHL	ND
N	High Flow Tube	OEHL	ND
O	High Flow Tube	OEHL	ND
P	High Flow Tube	OEHL	ND
Q	High Flow Tube	OEHL	ND

Notes: 1. ND means 'none detected.' It does not indicate that no HCl was present, it merely notes that none was detected: HCl may have been present below the limit of the particular equipment. For instance, 'ND' on a Geomet would indicate that HCl may have been present, but the concentration would have to be below 0.01 ppm.

2. Values for the midget impingers are 10-minute time-weighted-averages as determined by the appropriate NIOSH analytical method.

The accuracy of the Askania 1-A and mobile unit readings are questionable. According to the analysis of the sampling media in the OEHL impingers, the HCl concentration at these sites was 3.2 and 2.8 ppm, respectively (10-minute average) (Ref. 4). The Geomet at Askania 1-A only registered 0.1 ppm for approximately one minute, and the mobile Interscan detected a similarly low value. In addition, the lack of physical evidence casts doubt on these results. The odor threshold of gaseous HCl is listed as 1-5 ppm (Ref. 5), but physical responses have been documented at concentrations as low as 0.067 ppm (Ref. 6). Experience has shown that the presence of HCl can be detected below 1 ppm because of its irritating effects; therefore, it is logical to assume that the personnel located at Askania 1-A and in the mobile unit would be able to sense the HCl at the levels indicated at these sites. However, the personnel at Askania 1-A neither smelled anything resembling HCl nor felt any discomfort, and the personnel who were in the mobile unit disagree on what they sensed: one claims that he sensed nothing, the other that he caught "a faint wiff" of the gas (Ref. 7).

PHOTOGRAPHIC COVERAGE

The environmental monitoring effort of the Titan firing was supported by two types of photographic coverage. Photographic tracking of the exhaust cloud as it passed over the test area was provided by the Air Force, and The Aerospace Corporation provided computer-enhanced visible and infrared imagery of the exhaust plume. Locations of the photographic equipment used are shown in Figure 11.

EXHAUST CLOUD TRACKING

Contravi tracking mounts at four surveyed locations tracked the exhaust cloud as it moved away from the stand. The cameras photographed the cloud at a rate of five frames per second and were trained on the cloud's highest point. Disagreement between the camera operators as to where the highest point was (the cloud being very tenuous as it dissipated) made it difficult to plot the cloud's ground track. A plot was ultimately produced, but it only tracked the cloud 400 feet downwind.

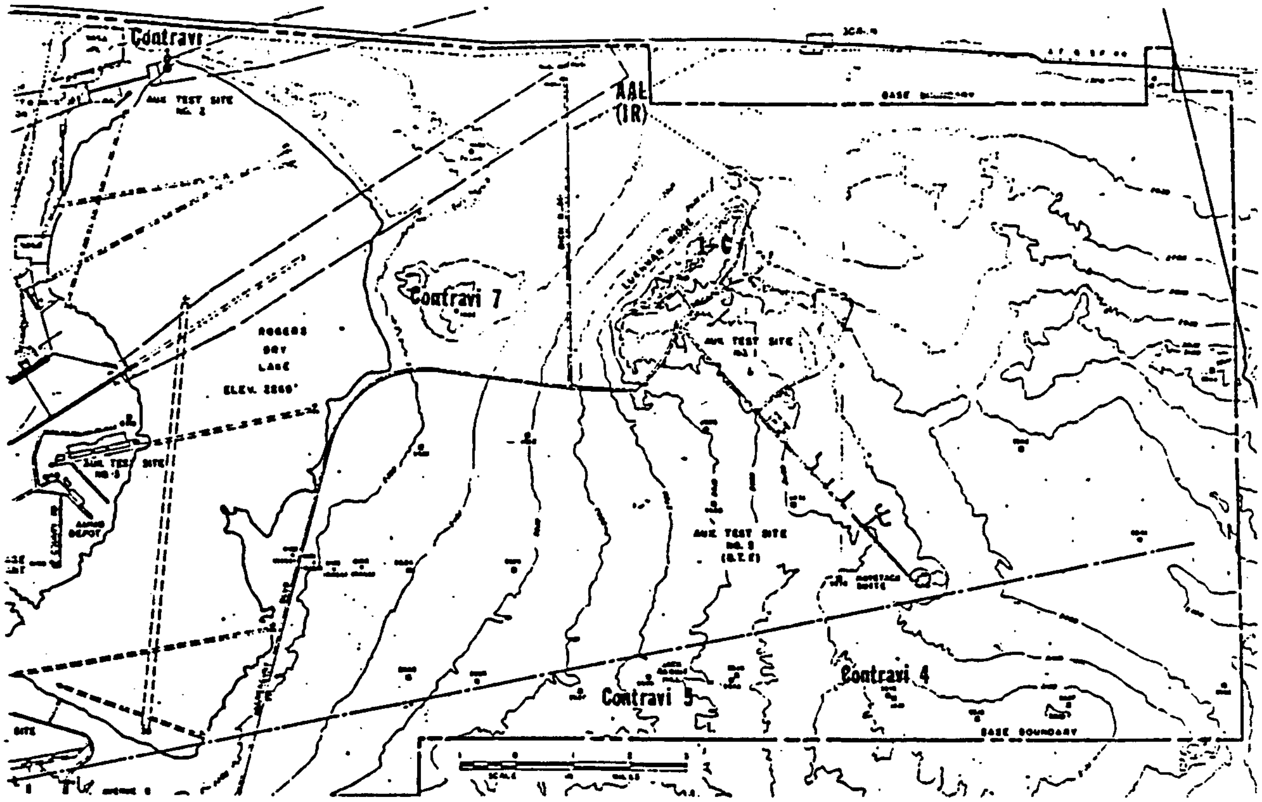

Figure 11. Photographic coverage locations.

Two things precluded being able to track the exhaust cloud as it traveled further downrange. The first was the rate at which the Contravi cameras photographed the cloud: five frames per second was too fast for tracking the slow-moving cloud (the Contravi mounts are typically used for tracking aircraft missions). The second was the rate at which the cloud dissipated. Within minutes of the firing it was difficult to pick out the cloud against the sky. Thus the only way to mark at what point the cloud passed over the base boundary was from the position of the mobile sampling unit.

The cloud stabilized at approximately 2000 feet above ground level (AGL), dissipating as it moved eastward. Mobile unit personnel estimated the position of the cloud and placed themselves under it. Their position on Highway 395 was approximately one mile south of Kramer Junction; extrapolating their position back to Area 1-125, it was found that the cloud remained in the wind corridor specified in the Environmental Assessment.

Photographic coverage by The Aerospace Corporation produced the pictures of the development of the ground cloud shown in Figures 12a-c. The photographic sequence shows how quickly the cloud formed and how completely it inundated the valley below Thrust Stand 1-C.

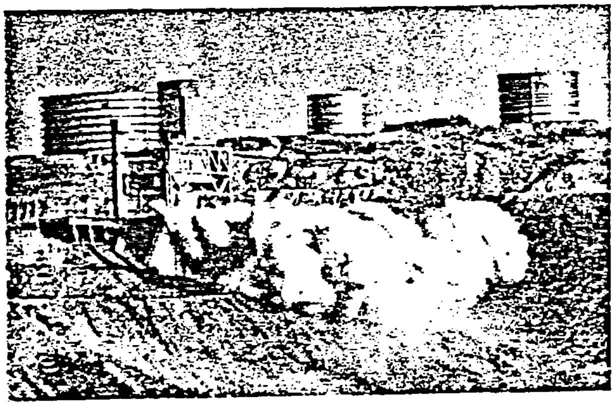

Figure 12a. Ground cloud formation. (T + 1 second)
(Photo courtesy The Aerospace Corporation)

Figure 12b. Ground cloud formation. (T + 4 seconds)
(Photo courtesy The Aerospace Corporation)

Figure 12c. Ground cloud formation. (T + 15 seconds)
(Photo courtesy The Aerospace Corporation)

COMPUTER IMAGERY

Located north of Area 1-125 near an old clay mine, The Aerospace Corporation set up visible and infrared imagery cameras, along with computer equipment for data reduction and storage. The infrared camera was equipped with a special filter tuned to the absorption wavelength of HCl, which made it feasible to register the HCl apart from the other constituents of the exhaust plume. Both the visible imagery of the exhaust plume and the infrared imagery of the HCl in the plume were recorded on video discs.

The effectiveness of the enhancement technology is shown in Figures 13 through 15. Figures 13a-e are a regular photographic sequence of the exhaust plume, again showing the massive ground cloud completely obscuring the test area and the rapid dissipation of the cloud.

Figure 13a. Titan 34D exhaust plume. (T + 10 seconds)
(Photo courtesy The Aerospace Corporation)

Figure 13b. Titan 34D exhaust plume. (T + 1 minute)
(Photo courtesy The Aerospace Corporation)

Figure 13c. Titan 34D exhaust plume. (T + 2 minutes)
(Photo courtesy The Aerospace Corporation)

Figure 13d. Titan 34D exhaust plume. (T + 2 minutes, 30 seconds)
(Photo courtesy The Aerospace Corporation)

Figure 13e. Titan 34D exhaust plume. (T + 3 minutes)
(Photo courtesy The Aerospace Corporation)

Figure 14 consists of a sequence of computer-generated pictures of the firing. Figures 14a-c are "unsubtracted" images, i.e., the background can still be clearly seen. Figures 14d-f are images in which the computer has subtracted the background. The final result is shown in Figure 14f, in which the entire background has been subtracted; the dark area in the image is the area affected by rainout from the exhaust cloud.

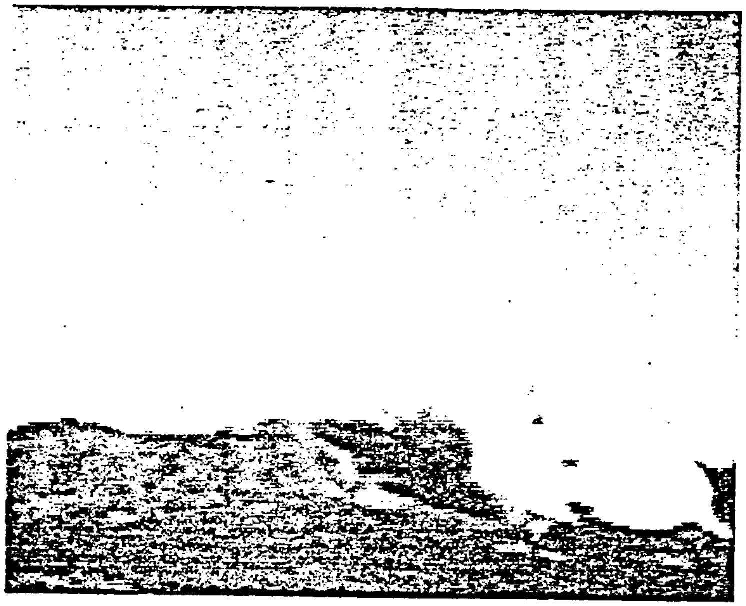

Figure 14a. Visible imagery of the Titan 34D exhaust plume.
(Visible unsubtracted, T + 1 minute)
(Photo courtesy The Aerospace Corporation)

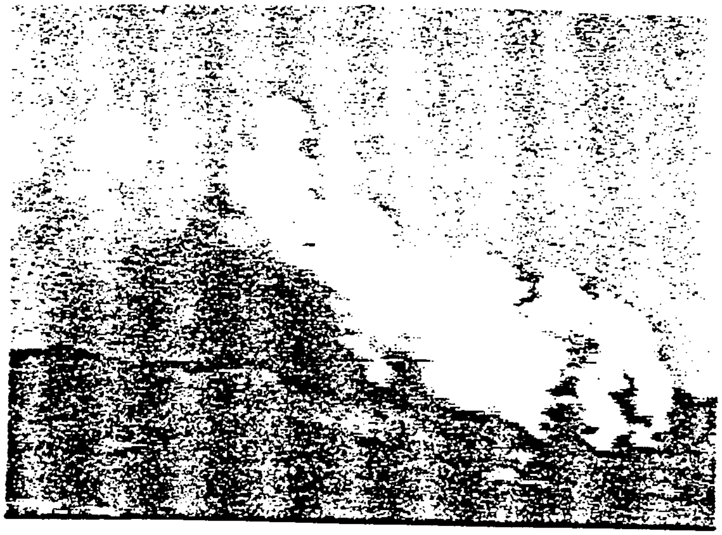

Figure 14b. Visible imagery of the Titan 34D exhaust plume.
(Visible unsubtracted, T + 2 minutes)
(Photo courtesy The Aerospace Corporation)

Figure 14c. Visible imagery of the Titan 34D exhaust plume. (Visible unsubtracted, T + 3 minutes)
(Photo courtesy The Aerospace Corporation)

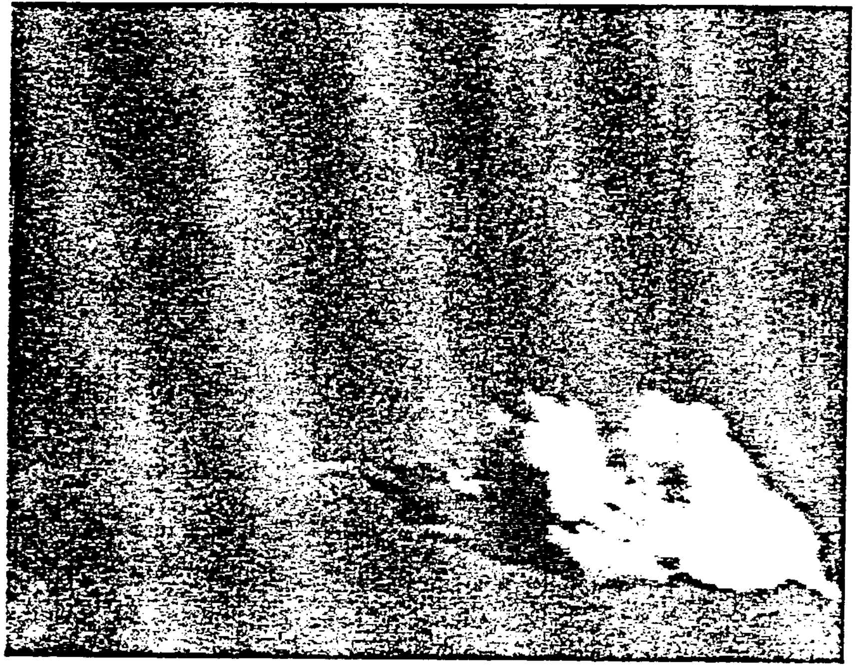

Figure 14d. Visible imagery of the Titan 34D exhaust plume. (Visible subtracted, T + 1 minute)
(Photo courtesy The Aerospace Corporation)

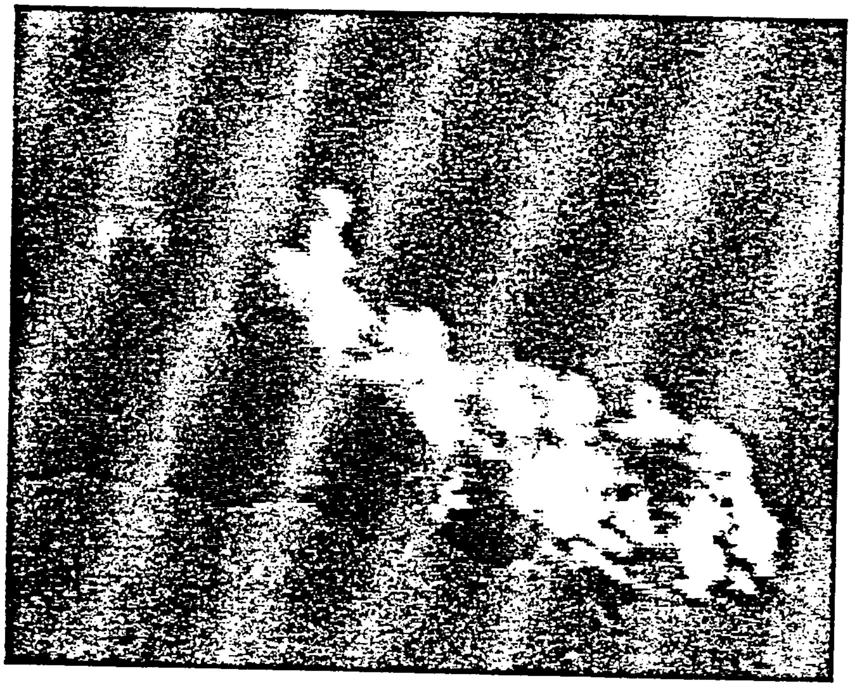

Figure 14e. Visible imagery of the Titan 34D exhaust plume.
(Visible subtracted, T + 2 minutes)
(Photo courtesy The Aerospace Corporation)

Figure 14f. Visible imagery of the Titan 34D exhaust plume.
(Visible subtracted, T + 14 minutes)
(Photo courtesy The Aerospace Corporation)

Figure 15 displays the infrared imagery of the HCl and water aerosol in the plume with the background subtracted. In Figure 15a the lightest areas are probably hot HCl gas emission; the faint outline of the exhaust cloud can be seen, while the densest concentration of HCl appears to be directly over the test area. In Figure 15b the HCl cloud has moved downrange and the exhaust cloud boundary has become less distinct as the cloud dissipated. In Figure 15c the background has greyed for better contrast and the image is similar to Figure 14f; the dark splotch is the part of the hill on which the cloud rained out and the white spot is the area of heaviest HCl deposition below the stand, which remains extremely hot due to HCl reaction with the soil. Figure 15d, taken closer to the time of Figure 14f, shows the dynamics of the HCl reaction. Comparing Figures 15d and 15c, it is seen that both the large dark area and the bright spot below the test area have grown smaller and less distinct, indicating that some of the HCl in the rainout has reacted or revolatilized. Comparing Figures 15d and 14f, it is clear that the rainout is still present although the acid has off-gassed.

Figure 15a. Infrared imagery of the Titan 34D exhaust plume.
(IR subtracted, T + 2 minutes, 30 seconds)
(Photo courtesy The Aerospace Corporation)

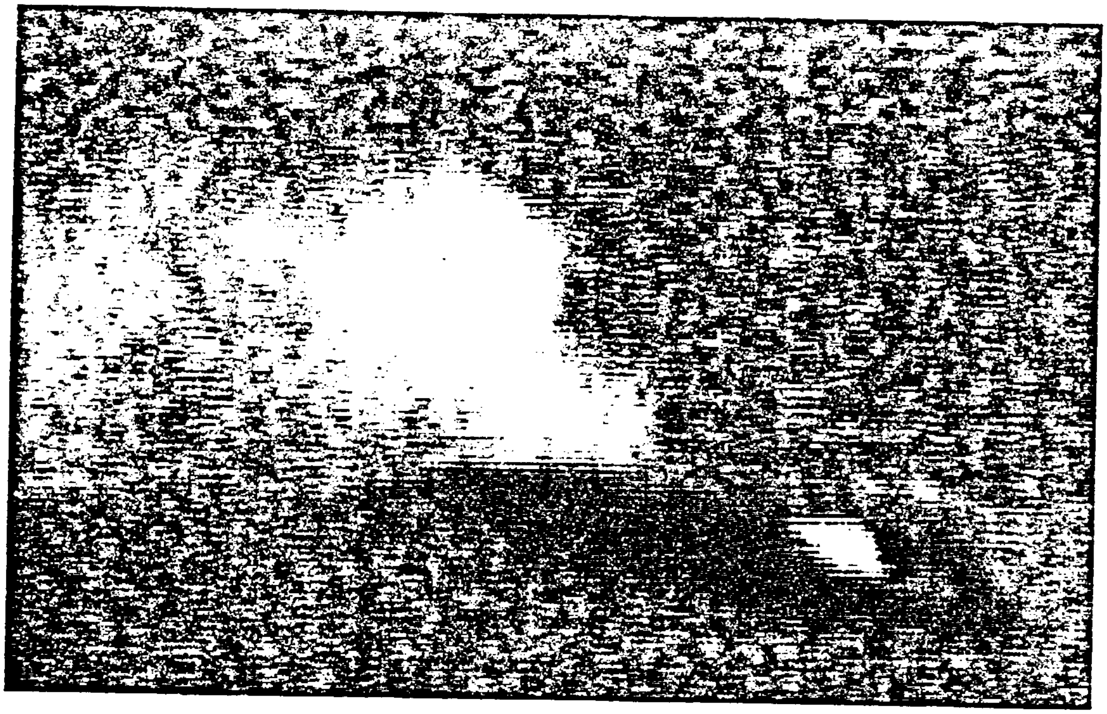

Figure 15b. Infrared imagery of the Titan 34D exhaust plume. (IR subtracted, T + 3 minutes)
(Photo courtesy The Aerospace Corporation)

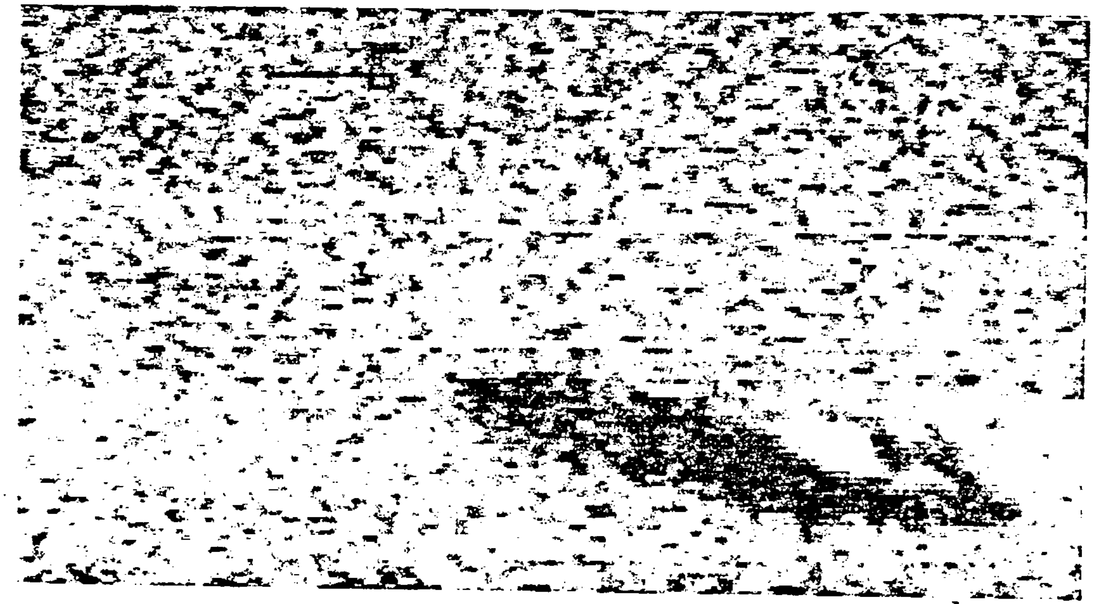

Figure 15c. Infrared imagery of the Titan 34D exhaust plume. (IR subtracted, T + 4 minutes)
(Photo courtesy The Aerospace Corporation)

Figure 15d. Infrared imagery of the Titan 34D exhaust plume.
(IR subtracted, T + 12 minutes, 30 seconds)
(Photo courtesy The Aerospace Corporation)

REVOLATILIZATION

ROCKET EMISSIONS ANALYSIS FACILITY

In a cooperative effort between SD and the AFAL, the Rocket Emissions Analysis Facility (REAF) was established at the AFAL in the Spring of 1987. The facility contains space for the calibration of instrumentation used in monitoring static firings and launches. The focal point of the facility is the revolatilization chamber, a small wind tunnel used to study the revolatilization (off-gassing) of materials from surfaces representative of those at operational sites under controlled conditions of wind speed, humidity, temperature, and solar flux. A layout of the REAF is shown in Figure 16.

HCl REGENERATION

Local soil was collected from Area 1-125 for revolatilization studies. The purpose of the study was to examine the reaction between HCl solution and local soil, and to predict the strength of revolatilization from soil representative of the test area. The soil used in the study was gathered from near Building 8814.

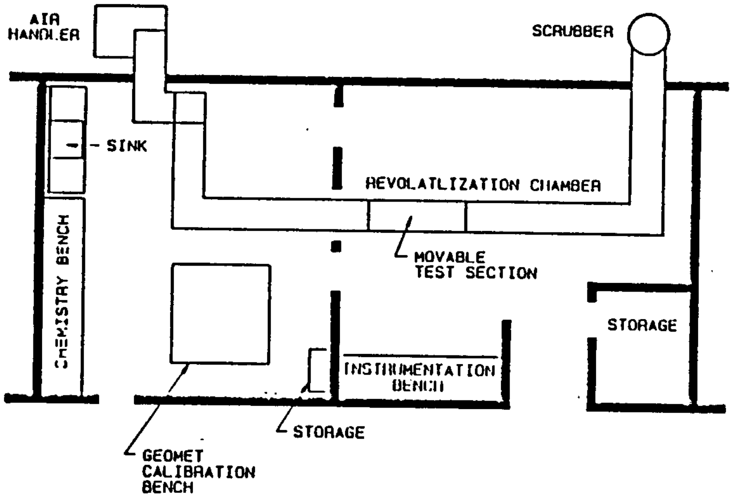

Figure 16. Rocket Emissions Analysis Facility layout.

The soil was packed into the test section of the revolatilization chamber and was deluged with a 5.0 molal solution of HCl. The reaction between the acid and the alkaline soil was immediate, the soil changing from its usual tan color to a dull yellow; the soil displayed a high degree of buffering capability. The density of the soil changed in the reaction, from 1.49 g/cc to 1.41 g/cc.

The strength of HCl revolatilization is measured using two Geomet HCl Detectors, one upstream and one downstream of the chamber's test section, as shown in Figure 17. During the 2 June 1987 pre-firing revolatilization run, the upstream Geomet registered a constant 0.0 ppm, indicating that no HCl was circulating back into the system; a plot of the downstream Geomet results is given in Figure 18. The strength of revolatilization was found to be 0.074 g HCl per minute per square meter of surface area. Based on that figure, the expected HCl concentration in the breathing zone over the deposition area due to revolatilization was 1.7 ppm.

DEPOSITION COLLECTION

Eight specially-designed collection pans, each 9 ft^2, were fabricated from stainless steel for this project and coated to resist the effects of the acid. The pans, shown in Figure 19, were placed strategically around the test

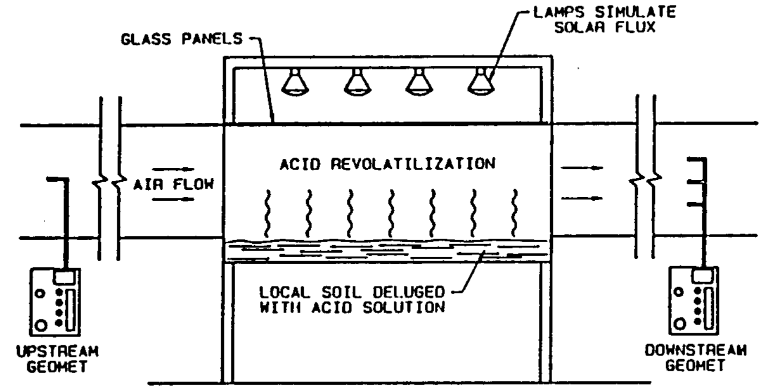

Figure 17. Revolatilization chamber test schematic.

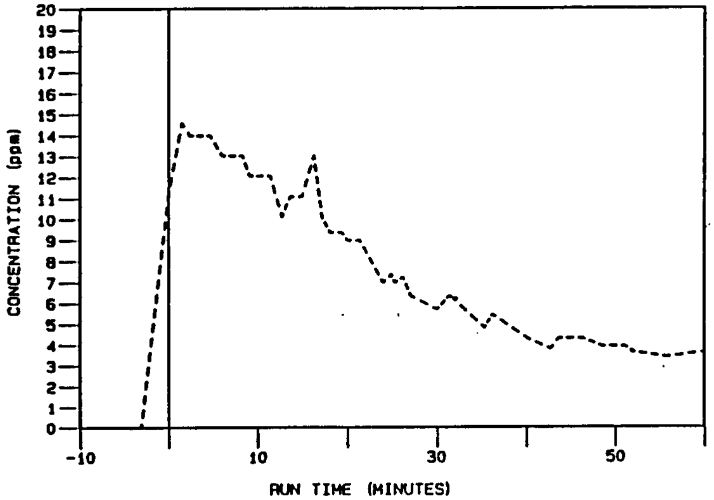

Figure 18. Revolitilization strength measurements.
Downstream concentration of HCl during the 2 June 1987 revolitilization run.

area as shown in Figure 20, with two pans placed at each location. The pans were filled approximately one inch deep with light paraffin oil (mineral oil), which acted as an evaporation inhibitor by allowing depositions to fall to the bottom of the pan while the oil floated on top.

Large amounts of deposition were collected in the pans at Thrust Stand 1-E, Building 8814, and the containment trench, but the pans downhill of the test article (Site A of Figure 20) were flooded with mud. The Site A pans had not been affected during combined systems tests when the deluge water system was run, but the added momentum of the exhaust plume drove the deluge water

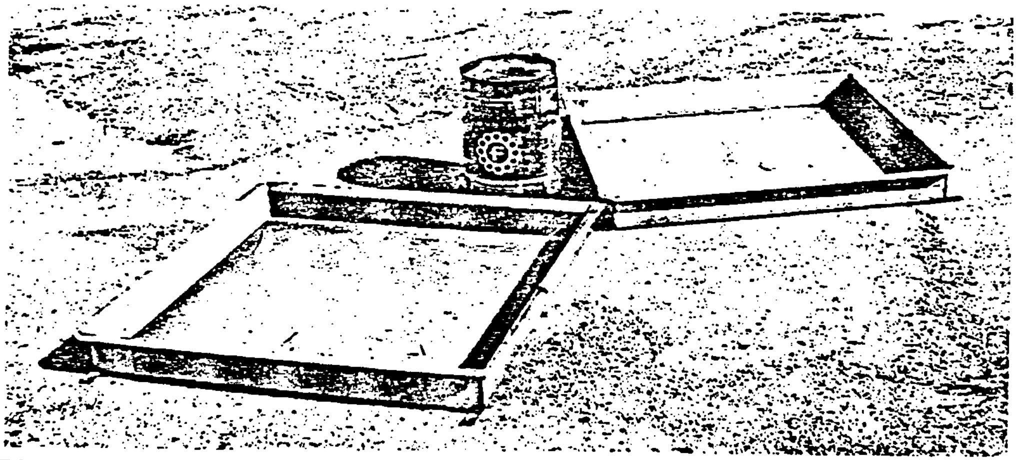

Figure 19. Deposition collection pans with a can of mineral oil.

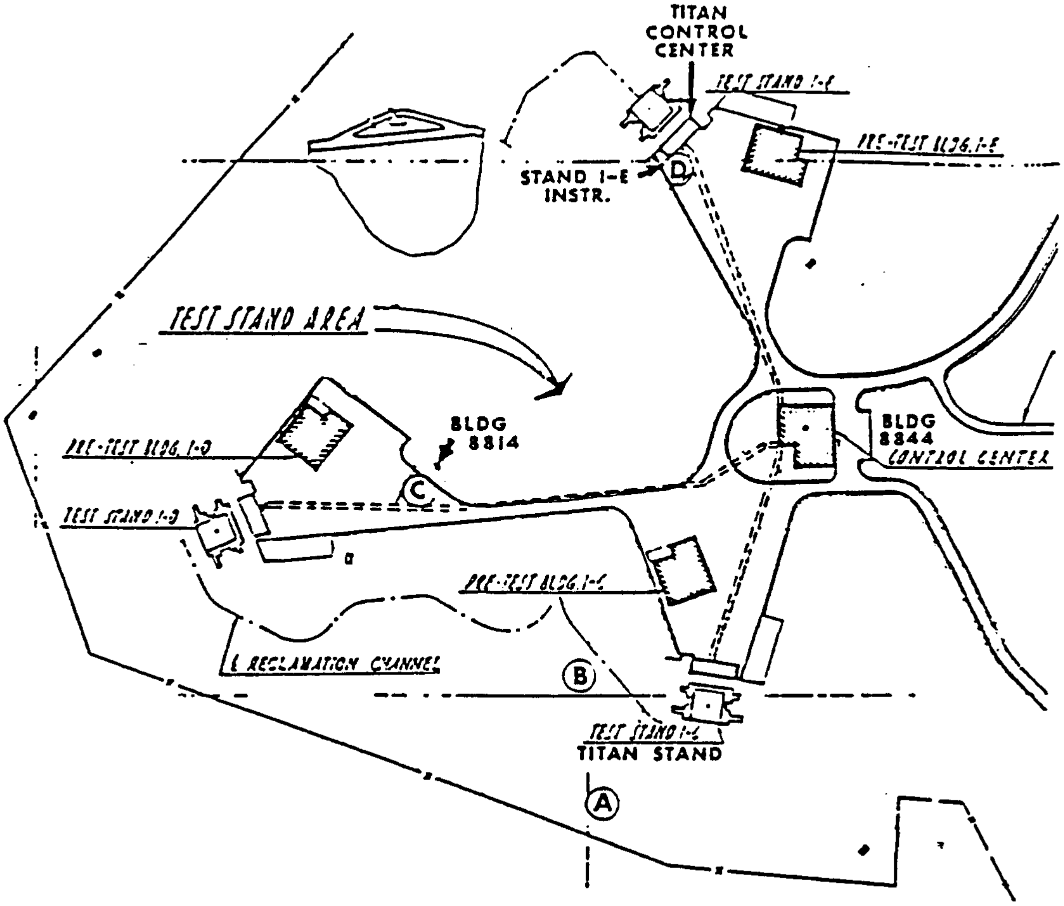

Figure 20. Placement of the collection pans.
A - Downhill from the test article.
B - Containment trench.
C - Building 8814.
D - Thrust Stand 1-E.

further out from the stand than anticipated, flooding the pans with acidic mud washed down from the hill below the stand. The other sets of pans collected nearly an order of magnitude more deposition than that caught at Cape Canaveral from Shuttle launches. The amount of rainout collected and the pH of the deposition at each site was:

Site	Mass Loading (l/m^2)	pH
Containment Trench	7.87	1.10
Building 8814	8.38	1.91
Thrust Stand 1-E	9.91	3.31.

A graph of the above data is shown in Figure 21. Note that as the pans got further away from the test article, more deposition was caught and the deposition became less acidic.

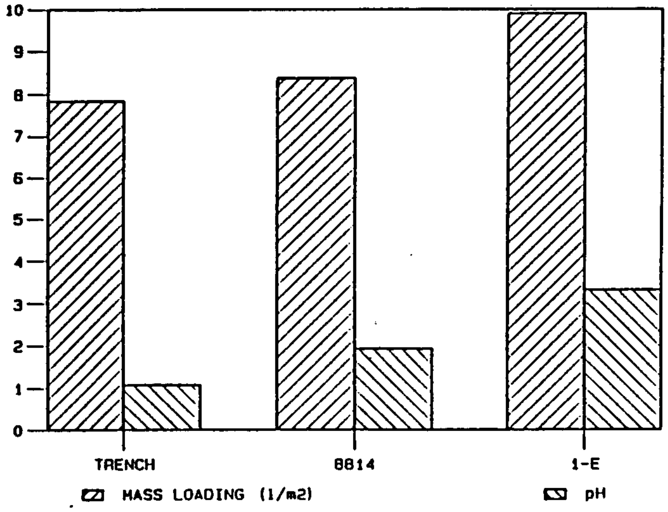

Figure 21. Deposition mass loading and pH.

As shown, the pH of the depositions was fairly high, indicating weakly acidic solutions. It is postulated that the pans caught large amounts of the buffered deluge water that was blasted away from the stand and rained-out in the area without contacting the majority of the HCl plume. This water significantly diluted the samples; a revolatilization study was performed with some of the depositions collected after the firing, but no revolatilization was observed due to the weak acidity of the samples.

The valley in front of Thrust Stand 1-C was inundated with acidic rainout and deluge water. In addition to flooding the collection pans placed below the stand, the viscous green rainout reacted with the valley soil, turning it a bright yellow. A week later the deposition coloration had faded to a dull yellow, much different from the soil color prior to the firing. The second color change is thought to have been caused by gradual chemical reaction of the deposition with the soil.

Supporting this theory, in addition to the infrared imagery provided by The Aerospace Corporation, are HCl measurements taken after the firing. At Building 8844 the concentration of HCl the day after the firing was 0.1 ppm at midday; by late afternoon the concentration had dropped to 0.02 ppm. At Building 8814, located in the path of visible deposition, a 0.5 ppm concentration of HCl was detected the day after the firing. Two days after the firing the concentration of HCl at Building 8844 varied between 0.01 and 0.02 ppm. Acid vapors could still be smelled two days after the firing and the smell of HCl persisted for a week due to revolatilization of available unreacted HCl.

INSTRUMENTATION

GEOMET HCL DETECTOR

The Geomet HCl monitor works on the chemiluminescence principle. An air sample is drawn into the instrument through an alumina tube coated with a mixture of sodium bromate and sodium bromide; HCl in the incoming gas stream reacts with the mixture to form hypochlorite and hypobromite and is drawn into contact with an alkaline solution of 5-amino-2, 3-dihydro-1, 4-phthalazinedione (luminol). The hypochlorite and hypobromite initiate oxidation of the luminol, producing visible light. The light intensity is directly proportional to the concentration of HCl in the air sample and is converted via a photomultiplier tube into an output voltage which can be recorded on a stripchart (Ref. 8). Geomet samplers are illustrated in Figure 22; an operational schematic is shown in Figure 23.

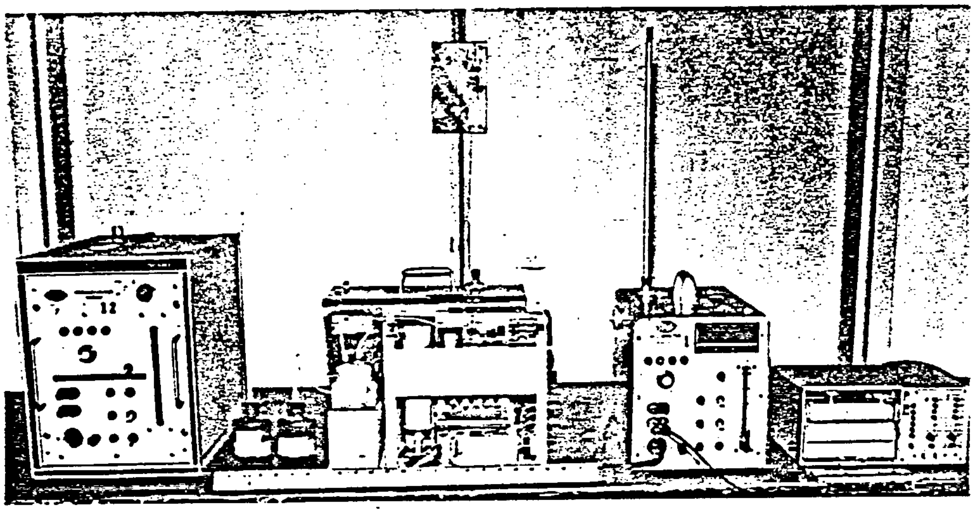

Figure 22. Geomet HCl detectors.
Left to right: Model 401S, Model 401B with cover removed (side view), Model 401B with stripchart recorder.

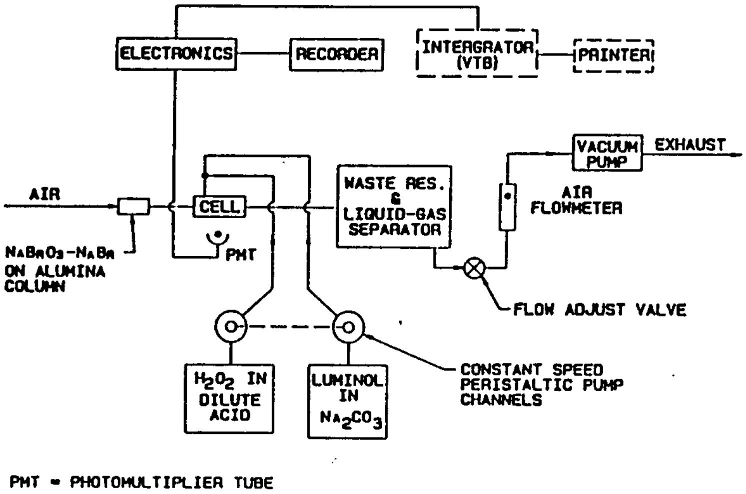

Figure 23. Geomet operational schematic.

The Geomets used in this project were Model 401Bs, as well as older Model 401Ss. They were calibrated using a G-Cal ovenless calibrator, with which a known concentration of gas is pumped into the Geomet and the instrument is adjusted until its readout corresponds to the known concentration. Problems encountered in calibrating with HCl gas in previous studies (Ref. 9) led to the use of the G-Cal unit using chlorine gas. Chlorine may be substituted for HCl in the calibration process because the responses are identical.

INTERSCAN COMPACT PORTABLE ANALYZER

The Interscan is an electrochemical detector in which the air sample passes through a diffusion medium after which the gaseous molecules are adsorbed on the sensing element. The element is an electrode on which the molecules are electrochemically reacted; the reaction produces an electric current which is directly proportional to the concentration of HCl in the sample (Ref. 10). An Interscan is shown in Figure 24.

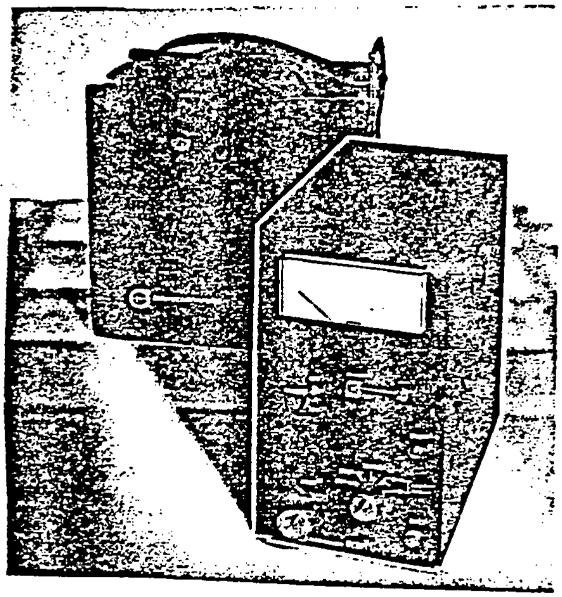

Figure 24. Interscan compact portable analyzer.

OEHL and LLNL used Interscans during the monitoring project, but the LLNL unit was actually on loan to them from OEHL. The OEHL Interscans were calibrated with HCl using a MAST permeation system set up in the REAF.

IMPINGERS

Impingers are absorption samplers consisting of glass bottles in which contaminated air is bubbled through a liquid reagent. Figure 25 shows impingers like those used by OEHL to sample for HCl.

The midget impinger is a gas washing bottle in which air is simply bubbled through the liquid; no additional mixing of the gas and the reagent is accomplished. Such impingers are typically used to sample for gases that react readily with the reagent (Ref. 11).

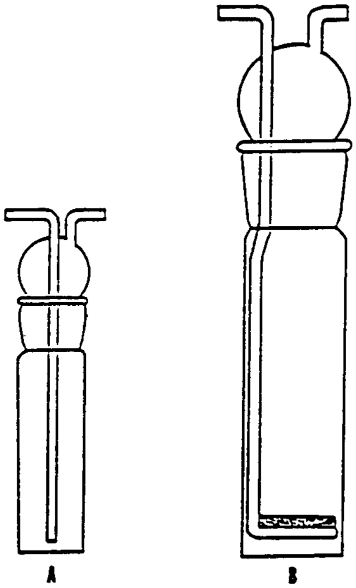

Figure 25. Impingers. A - Midget impinger. B - Large impinger.

The large impinger is a fritted bubbler, characterized by the passage of the air through a frit, a porous glass plate. The frit causes the gas to form small bubbles in the liquid, increasing the mixing of the gas and the reagent. Because of the mixing action, the large impinger is typically more efficient than the simple bubbler. Large impingers are also used for gases that react well with the sampling media (Ref. 11).

OEHL used distilled water as the sampling media in all of its impingers and used DuPont sampling pumps to pull their samples. The pumps were calibrated and the samplers prepared in the REAF (Ref. 4).

SILICA GEL TUBES

Contrasted with the impinger (an absorption device), the silica gel tube is an adsorption sampler. Adsorption samplers are typically glass tubes (either straight or U-shaped) filled with an adsorbent, usually activated charcoal or silica gel (Ref. 11).

The sampling effectiveness of silica gel tubes is dependent on the mesh size of the gel, ambient humidity and temperature, and the rate of airflow (Ref. 11). OEHL used DuPont sampling pumps to draw air through their tubes and used two tubes operating at different flow rates in critical areas (Ref. 4).

DRAEGER TUBES

Draeger detector tubes are a proven method for making on-the-spot measurements of the concentrations of atmospheric contaminants. They consist of a glass tube through which an air sample is drawn with a pump; the tubes are filled with a reagent which reacts with the suspect contaminant. The amount of the contaminant in the air is indicated by a color change in the reagent; the length of the color change is directly related to the concentration. Draeger tubes are calibrated and indicate the concentration given a specific amount of air that must be sampled (Ref. 12). Figure 26 shows Draeger detector tubes and their associated pumps.

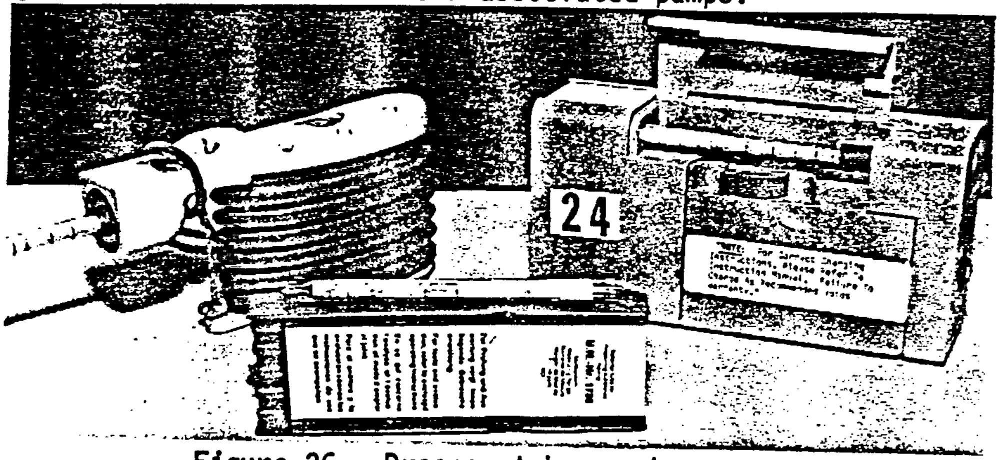

Figure 26. Draeger tubes and pumps.
Foreground: HCl tube with box of tubes.
Background: (left to right) hand pump, polymeter pump.

The tubes used in this study were HCl short-term tubes and HCl and CO_2 long-term tubes. Short-term tubes are typically used with a hand pump that pulls 100 mL of air through the tube per stroke, while long-term tubes are used with automatic pumps that count the number of revolutions of the pump. While short-term tubes are read directly to obtain the concentration, long-term tubes require that a series of calculations be performed to obtain the results, and while short-term tubes indicate the instantaneous concentration, long-term tubes indicate the average concentration over the sampling period (Ref. 12).

THE AEROSPACE CORPORATION HCl MONITOR

The experimental unit placed at Thrust Stand 1-E consisted of an infrared detection system housed in a nitrogen-purged enclosure. The detector scanned with an infrared laser diode tuned to a single rotational line of HCl, measuring the concentration of HCl by how much of the IR beam was absorbed. The system used PVC pipe attached to a ladder to pull in air from approximately thirty feet above the detector; a port in the PVC took the air into the detector. A schematic of the system is shown in Figure 27.

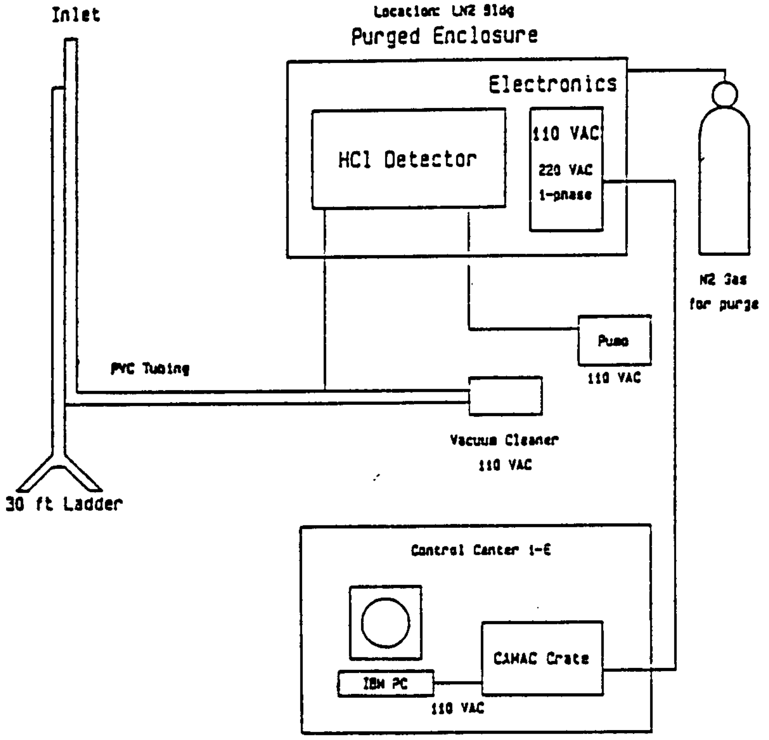

Figure 27. Aerospace HCl monitor schematic.

The CAMAC crate shown in the figure provided data translation so the data could be recorded on the computer. The video display would show that HCl was present, but it could not display quantitative data.

Apparently a power surge occurred around the time of the firing, causing the laser diode power supply to automatically shut down. Consequently, the Aerospace unit was unable to measure the amount of HCl present at Thrust Stand 1-E.

LAWRENCE LIVERMORE NATIONAL LABORATORY HCl MONITOR

The unit placed at Building 8814 by LLNL was a prototype of an HCl detector proposed for measuring HCl at Vandenberg AFB launch sites. The unit operated on the principle of dispersive IR absorption, in which the infrared radiation is separated into a reference band and a sample band, as shown in Figure 28a. The sample band corresponded to the absorption wavelength of HCl; the reference band was chosen so the presence of HCl would not affect it and is used to take into account any electronic, mechanical, or thermal effects that may affect the sample signal (Ref. 13).

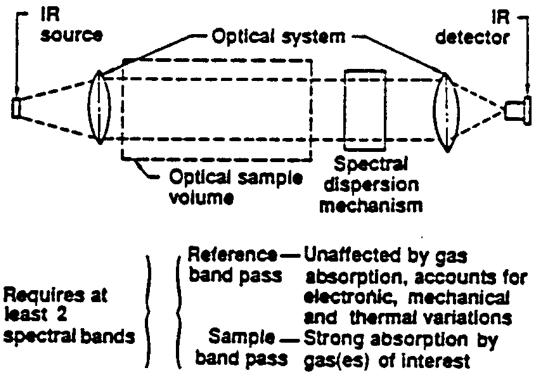

Figure 28a. Lawrence Livermore HCl monitor dispersive IR absorption operating principle.

The data acquisition system (DAS) for the LLNL detector is shown in Figure 28b. The sensor head was hung about two meters off the ground outside Building 8814, while the sensor electronic unit and the remote DAS station were inside the building. The remote DAS station was connected to the central station through the use of modems and a standard telephone line; the central station was located at the Safety Operations Center.

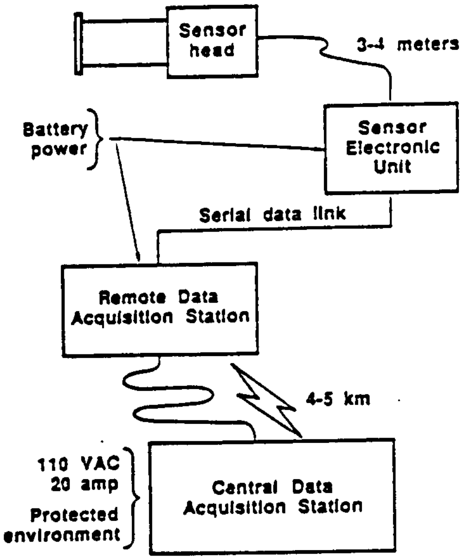

Figure 28b. Lawrence Livermore HCl monitor data acquisition system schematic.

The detector was operated during every firing attempt, as well as on the day of the test. The equipment operated properly every day and tests of the data transmission system indicated that the modem hookup is a practical and effective method of connecting the remote unit to the central DAS station. The unit's operation during the firing was spoiled by deposition which impacted the optical mirrors, preventing the signal from completing the optical path; thus the unit could not register the amount of HCl at Building 8814.

MIRAN 1A INFRARED SPECTROPHOTOMETER

The Miran 1A portable gas analyzer is a single beam spectrophotometer that scans the infrared range of 2.5 to 14.5 microns. It has a 5.6 liter Teflon-coated gas cell with a variable beam path length from 0.75 to 20.25 meters. The unit is illustrated in Figure 29. The Miran, like the Aerospace and LLNL detectors, operates on the principle that specific compounds absorb infrared radiation at specific wavelengths (Ref. 14).

Calibration of the Miran is accomplished with a bellows pump plumbed into the detector cell. Measured amounts of gas are injected into the system through a septum, and the deflection of the instrument noted. The concentration of the gas in the detector cell is calculated knowing the capacity of the cell and the amount of gas injected, and is corrected for temperature and pressure. A calibration curve is developed from which the ambient concentration can be obtained given the deflection of the instrument (Ref. 15).

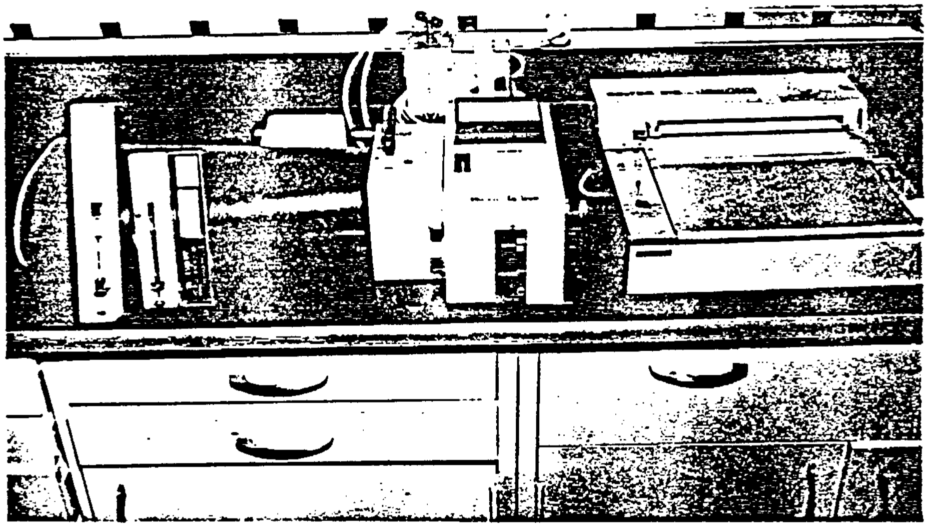

Figure 29. Miran 1-A and calibration equipment.
Front to back, left to right: calibrated syringes,
Miran 1-A stripchart recorder, bellows pump.

For use in the Control Center, the Miran had to be calibrated for CO_2. The ambient concentration of CO_2 (0.033% or 330 ppm) caused some problems during the calibration, so the instrument was purged with nitrogen and calibrated with a purged gas cell. After calibration the Miran was purged again and the cell closed; the cell was not opened until sampling was to start.

GASTECHTOR

A Model 1214MP Gastechtor Gas Alarm was used in the Control Center to monitor the level of oxygen in the room. Its oxygen sensor is an electrochemical cell consisting of gold and lead electrodes in an alkaline electrolyte; the sensor is covered by a permeable membrane. Oxygen diffuses through the membrane and is electrochemically reacted to form lead oxide. The rate of the reaction (and the current generated by the reaction) is directly proportional to the partial pressure of oxygen (Ref. 16). A Gastechtor is pictured in Figure 30.

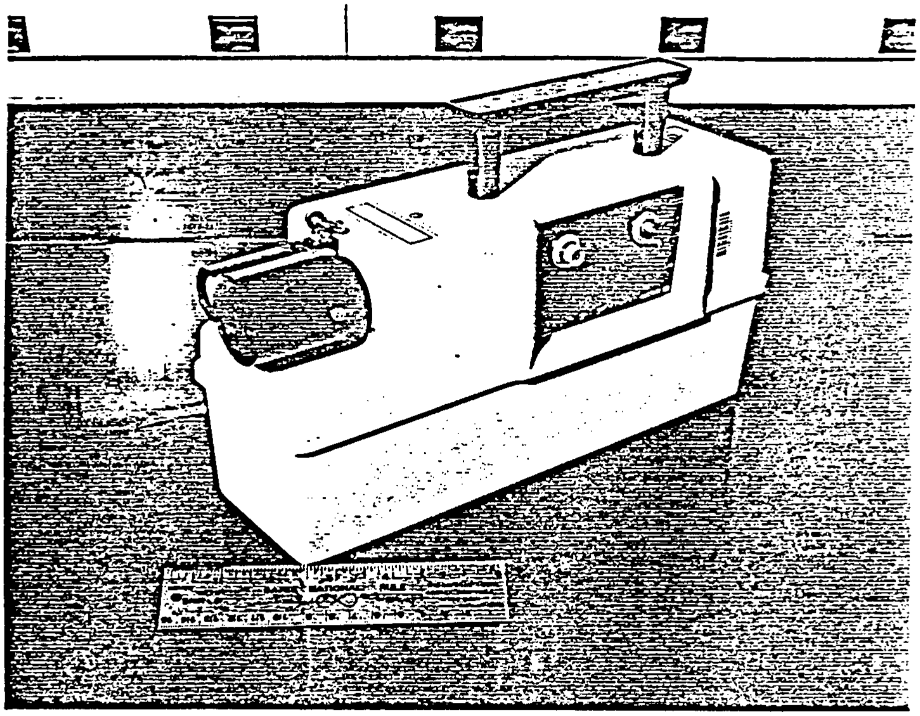

Figure 30. Gastechtor oxygen and combustible gas meter.

REUTER-STOKES HEAT STRESS MONITOR

The Wet Bulb Globe Temperature index (WBGT) is used to evaluate the heat stress conditions present in the working environment and is determined by using a dry bulb thermometer, a natural (static) wet bulb thermometer and a globe thermometer. The dry bulb must be shielded from the sun and the wet bulb wick kept wet with distilled water. The globe thermometer consists of a hollow copper sphere painted matte black on the outside with a temperature sensor fixed at the center of the sphere. The WBGT is calculated from the temperature readings; for WBGT inside a building (or outside with no solar loading) the equation is:

$$\mathrm{WBGT} = 0.7\ \mathrm{WB} + 0.3\ \mathrm{GT} \qquad (10)$$

where WB is the wet bulb temperature and GT is the globe temperature. The dry bulb temperature is only used for calculating the outdoor WBGT (Ref. 17).

The Reuter-Stokes Model RSS-217 Heat Stress Monitor and Logger was used in the Control Center during the firing. The unit takes temperature measurements and calculates the WBGT automatically, displaying either the indoor or outdoor WBGT at the operator's discretion. Figure 31 shows the Reuter-Stokes 'Wibget' unit.

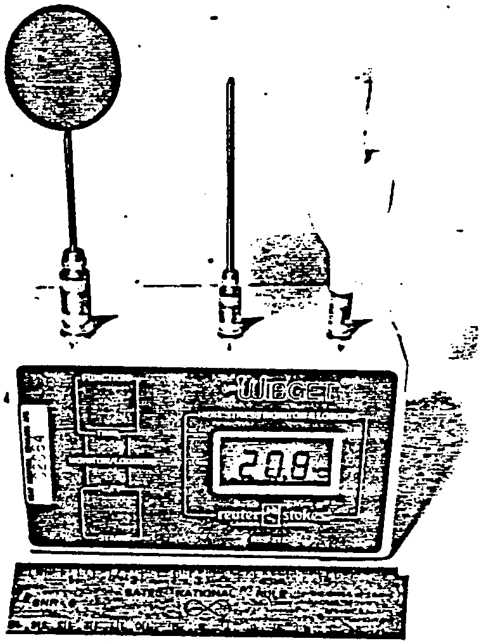

Figure 31. Reuter-Stokes Heat Stress Monitor.

CONCLUSIONS AND RECOMMENDATIONS

Operational and physical precautions taken at Area 1-125 included strict procedures for shutting down ventilation and sealing the buildings prior to and personnel egress after the firing, infiltration studies, and repairs to area facilities to reduce the chance of HCl contamination. The precautions proved effective in protecting personnel and equipment in the Control Center and Building 8844 from the high HCl concentrations generated by the test. The same precautions should be taken during future tests of this magnitude.

The gaseous HCl that passed over the base boundary was concentrated in the exhaust cloud, the ground-level concentrations encountered posed no threat to public health. Although it must be noted that other meteorological conditions might have caused very different dispersion of the HCl, there is no evidence that future tests of this magnitude should be hindered in any way for environmental reasons as long as similarly prudent constraints are considered. Future tests should, of course, be accompanied by similar monitoring efforts.

The decision that all winds up to 10,000 feet AGL had to be within the corridor proved to be too strict. Future test wind criteria should be limited to 5000 feet AGL, as this test proved that the exhaust cloud remains stable and relatively low-level.

The overall wind corridor was effective in keeping the exhaust cloud from passing over nearby population centers; however, time-resolved (real time) meteorological data was not available. It is quite possible that windows of opportunity were missed while waiting for balloons to be launched and their data reduced at discrete intervals; thus data-gathering for future tests should be carefully considered. The use of acoustic sounders, Doppler Lidar, and wind tracers might prove cost-effective if operational windows can be better identified and utilized.

The disparities in results among different sampling devices makes it difficult to evaluate their applicability to monitoring this and similar tests. Programs to compare the performance of HCl monitors have typically concentrated on laboratory evaluations; comparative studies in monitoring actual field operations have been rare. A program should be initiated to further study HCl sampling devices to determine which performs best in field applications.

The wind flow over the complex terrain of the AFAL should be studied and modeled in an effort to better understand the transport of gaseous contaminants, and to relax the wind restrictions imposed on this type of test. A study of this type may produce information applicable to conditions at the Western Space and Missile Center at Vandenberg AFB or the Eastern Space and Missile Center at Cape Canaveral.

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REVOLATILIZATION CALCULATIONS

Revolatilization test calculations are made by considering the test section as a control volume as shown in Figure A-1. The mass flow into and out of the control volume is written as

$$m_1 + m_2 = m_3 \tag{A-1}$$

where m_1 represents the mass of HCl flowing into the control volume from the upstream side,

m_2 represents the mass of HCl flowing into the control volume from the control surface, and

m_3 represents the mass of HCl flowing out of the control volume. Thus if m_1 and m_3 are known, m_2 can be calculated and is the strength of revolatilization.

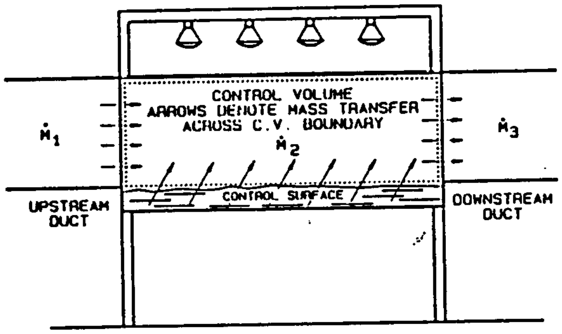

Figure A-1. Revolatilization test control volume.

In revolatilization studies performed in the REAF, m_1 and m_3 are calculated from the concentration of HCl measured upstream and downstream of the test section, respectively. The measurements are made with Geomet HCl detectors.

As a function of concentration, the mass flow is written as

$$m = \frac{C\ V}{t} \tag{A-2}$$

where C is the concentration,
V is the volume, and
t is an increment of time.

The volume V is obtained by the relation

$$V = ASt \tag{A-3}$$

where A is the cross sectional area of the chamber duct,
S is the speed of airflow through the chamber duct, and
t is an increment of time.

Substituting equation (A-3) into equation (A-2) and assuming the increments of time are the same leads to

$$m = CAS \tag{A-4}$$

which leads to

$$C_1A_1S_1 + m_2 = C_3A_3S_3. \tag{A-5}$$

In the revolatilization run performed on 2 June 1987, the Geomet upstream of the test section (measuring C_1) registered a constant value of 0.0 ppm. This allows the simplification of equation (A-5) to

$$m_2 = C_3A_3S_3. \tag{A-6}$$

The data gathered by the downstream Geomet (measuring C_3) during the 2 June 1987 run was shown in Figure 19. The average value of C_3 was calculated to be 4 ppm over the one hour run; the air speed was 2 miles per hour.

The cross-sectional area of the chamber duct is 4 ft^2. Using the values of C_3 = 4 ppm HCl and S_3 = 2 mph, m_2 is calculated by

$$m_2 = \left(\frac{4 \text{ moles HCl}}{10^6 \text{ moles air}}\right)\left(\frac{36.5 \text{ g HCl}}{1 \text{ mole HCl}}\right)\left(\frac{1 \text{ mole air}}{22.4 \text{ l air}}\right)$$

$$* (4\ \text{ft}^2)\left(\frac{2\ \text{mi}}{1\ \text{hour}}\right)\left(\frac{5280\ \text{ft}}{1\ \text{mi}}\right)\left(\frac{1\ \text{hr}}{60\ \text{min}}\right)$$

$$* \left(\frac{30.48\ \text{cm}}{1\ \text{ft}}\right)^3\left(\frac{1\ \text{ml}}{1\ \text{cm}^3}\right)\left(\frac{1\ \text{l}}{1000\ \text{ml}}\right) \tag{A-7}$$

or

$$m_2 = 0.13\ \frac{\text{g HCl}}{\text{min}}. \tag{A-8}$$

The value of m_2 is converted to a mass flux by the relation

$$o_m = \frac{m_2}{A_2} \tag{A-9}$$

and for the pre-firing run was found to be

$$o_m = \left(\frac{0.13\ \frac{\text{g HCl}}{\text{min}}}{(2\ \text{ft})(9.5\ \text{ft})}\right)\left(\frac{10.76\ \text{ft}^2}{1\ \text{m}^2}\right) \tag{A-10}$$

or

$$o_m = 0.074\ \frac{\text{g HCl}}{(\text{min})(\text{m}^2)} \tag{A-11}$$

APPENDIX C

BIOLOGICAL RESOURCE EVALUATION FOR TWO TITAN IV TEST PROJECT AREAS

BIOLOGICAL RESOURCE EVALUATION FOR TWO TITAN IV TEST PROJECT AREAS

March 31, 1988

Prepared for:

U.S. Air Force Space Division SD/DEV
P.O. Box 92960
Worldway Postal Center
Los Angeles, California 90009

Prepared by:

Mark Hagan, Environmental Protection Specialist
Michael V. Phillips, Chief Environmental Planning & Analysis
U.S. Air Force Systems Command
Air Force Flight Test Center
Office of Environmental Planning, Management and Compliance
Edwards AFB, CA 93523-5000

Biological Resource Evaluation For Two Titan IV Test Project Areas

Mark Hagan, Environmental Protection Specialist. U.S. Air Force,
Edwards AFB, CA 93523-5000

Michael V. Phillips, Chief, Environmental Planning and Analysis,
U.S. Air Force, Edwards AFB, CA 93523-5000

Abstract

Five Titan IV solid rocket motors will be tested at the Air Force Astronautics Laboratory with each test lasting almost 2.25 minutes. Two project areas were evaluated for ecological parameters which will be impacted. Twenty-six species of plants and eleven species of animals were observed during the railroad spur survey. Thirty-two species of plants and ten species of animals were observed during the rocket test stand survey. Both survey areas have experienced past disturbances. Further study is recommended for the railroad spur study area to determine the amount of impact to Mojave ground squirrels (*Spermophilus mojavensis*). Further study is recommended for the rocket test stand area to determine the impacts to desert tortoises (*Gopherus agassizi*) and desert cymopterus (*Cymopterus deserticola*).

New requirements for larger, more sophisticated satellites and a growing need for increases in payload injection capability have generated a need for new, more powerful, space booster systems to support U.S. space programs. The solid rocket motor upgrade (SRMU) program proposed for testing at the Air Force Astronautics Laboratory (AFAL) will improve U.S. payload capabilities more than 35 percent.

An existing railroad spur will be modified in support of the Titan IV testing program. A flat concrete pad approximately 30.3 meters by 15.2 meters will be constructed. Construction will also include earth excavation and backfilling, an asphalt parking area and rail spur refurbishment. Minor modifications will be made to an existing rocket motor test stand to accommodate the test firings. An area below the test stand will be subject to impacts from test firings.

This study was conducted to identify the ecological parameters of two areas which will be impacted by this project. Also included are suggested mitigations for environmental impacts resulting from this project.

Study Area

The Air Force Flight Test Center (AFFTC), Edwards AFB, is located in the western Mojave desert of southern California and covers approximately 121,408 hectares (Figure 1). The railroad spur upgrade project area is located on the southeastern end of Leuhman Ridge, SE1/4 of NE1/4 of Section 24, T10N, R8W, S.B.B.M. (Figure 2). The rocket motor test stand (Test Stand 1C) is located along the northern slope of Leuhman Ridge, SE1/4 of NE1/4 of Section 23, T10N, R8W, S.B.B.M. (Figure 3). Both project areas lie entirely within Kern County.

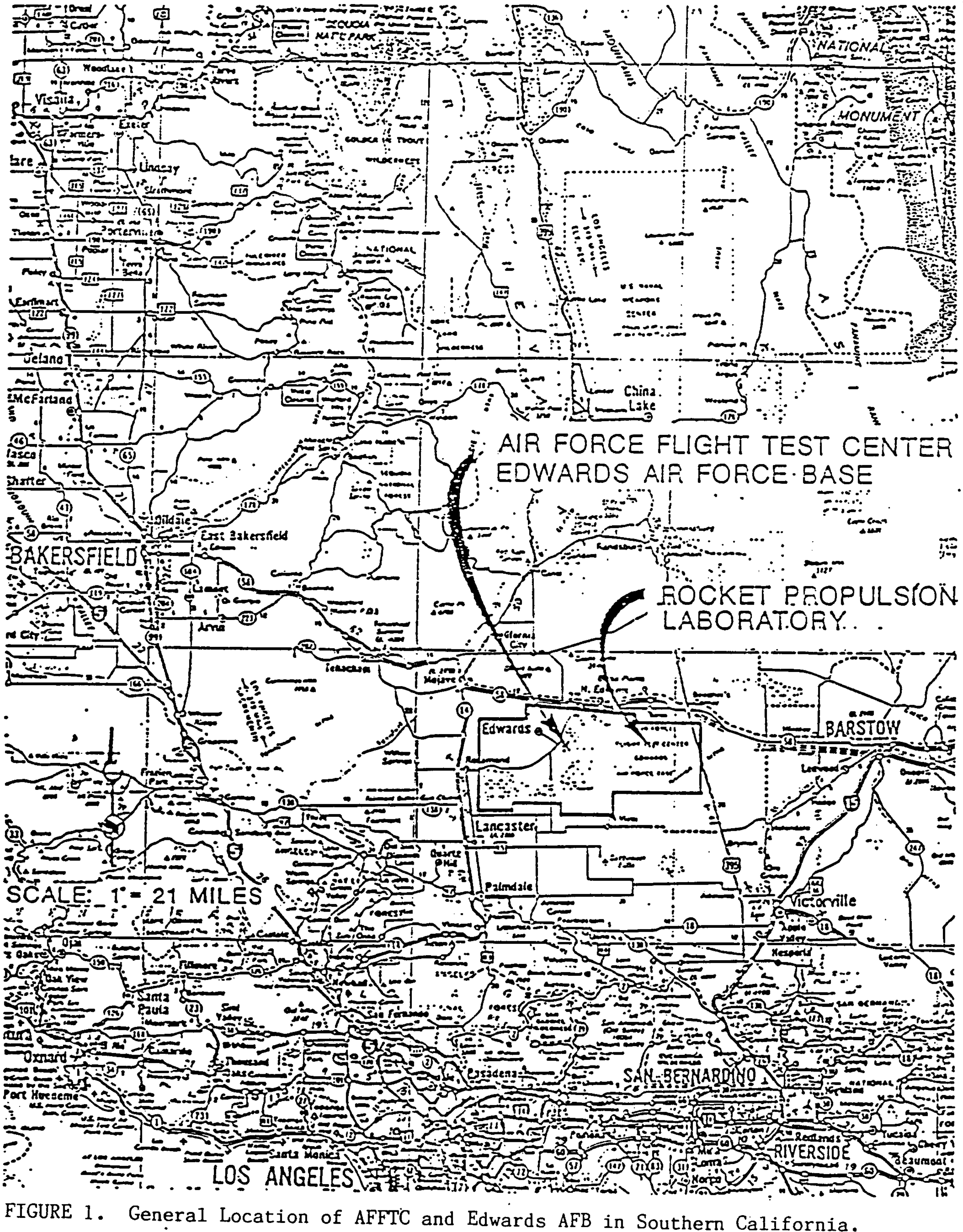

FIGURE 1. General Location of AFFTC and Edwards AFB in Southern California.

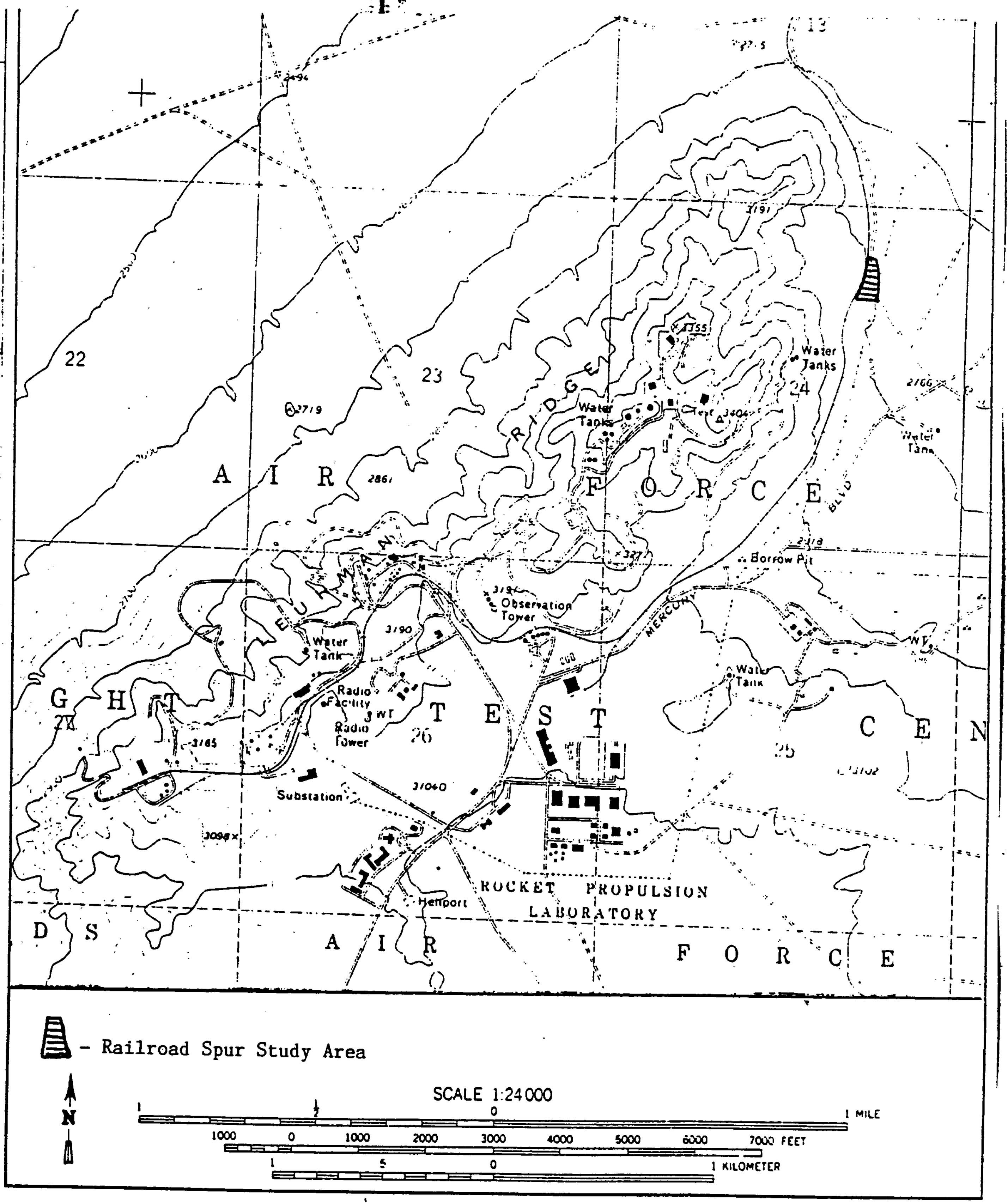

FIGURE 2. Location of railroad spur study area on U.S.G.S. topographic map, Leuhman Ridge, CA quadrangle.

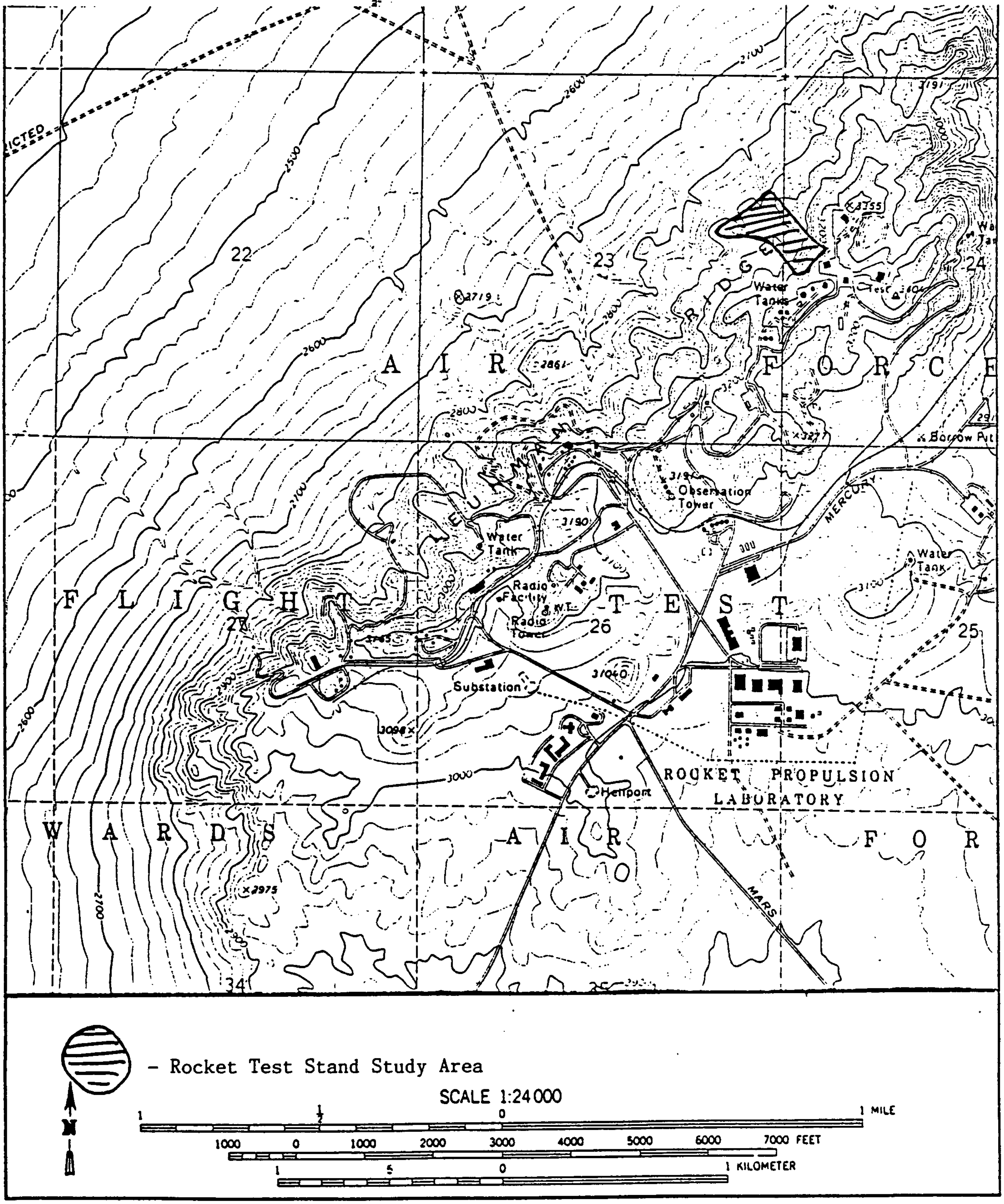

FIGURE 3. Location of rocket test stand study area on U, S, G, S, topographic map, Leuhman Ridge, CA quadrangle.

Methods

The railroad spur area was surveyed by walking transects twenty meters apart. The test stand area was surveyed by walking random transects as rugged terrain prevented utilization of transects a standardized distance apart.

Floral parameters were measured by conducting general visual observations and floral collections. Collected plants were keyed to species in the laboratory. Faunal parameters were measured by conducting general visual observations aided by 7 X 50 binoculars. Examinations of animal tracks and scat were used in determining the presence of animal species. Further floral and faunal parameters were identified through literature research.

Results

A field survey of the railroad spur area was conducted from 1330 hours to 1600 hours on 28 Mar 88, which covered 0.81 hectares. Weather conditions consisted of temperatures between 21.1 degrees Celsius and 23 degrees Celsius with clear skies and a light breeze. The study area has a southeasterly aspect, a slope of 0-10 percent, and an elevation of 848.5 meters to 851.5 meters.

The railroad spur study area has experienced previous disturbances and the natural surface soil is almost entirely gone. The original soil surface was probably a coarse grain, granitic, sandy loam soil type. Much of the area is now covered with railroad bedding material (crushed rock).

The study area is characteristic of creosote (*Larrea tridentata*) scrub community type with burroweed (*Ambrosia dumosa*) a codominant shrub based on general observations of abundance and density. The dominant grasses and herbaceous plants were filaree (*Erodium cicutarium*), fiddleneck (*Amsinckia tessellata*), and schismus (*Schismus sp.*). Twenty-six species of plants were observed during the railroad spur survey and were identified to genus or species (Table 1). Eleven species of birds, mammals, and reptiles were identified within the survey area (Table 2). An abundance of insect life was also noted, however, species identification was not conducted (Table 2).

A field survey covering 4.1 hectares was conducted from 1000 hours to 1400 hours on 29 Mar 88 for the rocket test stand study area. Weather conditions consisted of temperatures between 18.3 degrees Celsius and 23.9 degrees Celsius, with clear skies and no breeze. The study area has a northern aspect, a slope of 45-90 percent, and an elevation of 878.8 meters to 909.1 meters.

The study area has a sandy loam soil type with quartz monzonite rocks. One area was noted as a sandy soil type due to the ongoing formation of sand dunes. Also, large quartz monzonite boulders resulting from blasting operations, cover a portion of the study area. An area approximately 1.2 hectares in size was observed to be nearly devoid of vegetation and the small amount of vegetation present appeared to be dying. Soil, rocks, and vegetation were discolored to a dark brownish color.

The study area was once probably characteristic of a creosote scrub

TABLE 1. LIST OF PLANT SPECIES OBSERVED AT RAILROAD SPUR PROJECT AREAS

COMMON NAME	SCIENTIFIC NAME
Creosote Bush	*Larrea tridentata*
Saltbush	*Atriplex* sp.
Burroweed (White Bursage)	*Ambrosia dumosa*
Mormon Tea	*Ephedra nevadensis*
Desert Trumpet	*Eriogonum inflatum*
Phacelia	*Phacelia* sp.
Indian Rice Grass	*Oryzopsis hymenoides*
Schismus	*Schismus* sp.
Red Brome	*Bromus rubens*
Fiddleneck	*Amsinckia tessellata*
Storksbill (Filaree)	*Erodium cicutarium*
Broom Snakeweed	*Gutierizzia sarothrae*
Desert Larkspur	*Delphinium parishii*
Pincushion	*Chaenactis* sp.
Silver Cholla	*Opuntia echinocarpa*
Joshua Tree	*Yucca brevifolia*
Cheesebush	*Hymenoclea salsola*
Desert Parsley	*Lomatium mojavense*
Dwarf Cedar (Pygmy Cedar)	*Peucephyllum schottii*
Desert Aster (Mojave Aster)	*Aster abatus*
Coreopsis	*Coreopsis* sp.
Goldfield	*Baeria platycarpha*
Brodea (Desert Hyacinth)	*Brodiaea capitata pauciflora*
Beavertail Cactus	*Opuntia basilaris*
Golden Yarrow	*Eriophyllum wallacei*
Small-flowered Forget-me-not	*Cryptantha micrantha*

TABLE 2. LIST OF ANIMAL SPECIES OR THEIR SIGN OBSERVED AT RAILROAD SPUR PROJECT AREA

COMMON NAME	SCIENTIFIC NAME
Common Raven	*Corvus corax*
White-Crowned Sparrow	*Zonotrichia leucophrys*
Red-Tailed Hawk	*Buteo jamaicensis*
Southern Pocket Gopher	*Thomomys umbrinus*
Woodrat	*Neotoma lepida*
Antelope Ground Squirrel*	*Ammospermophilus nelsoni*
Mojave Ground Squirrel*	*Spermophilus mojavensis*
Kangaroo Rat	*Dipodomys* sp.
Rodent(s) sp(p).	Order: Rodentia
Coyote	*Canis latrans*
Long-Tailed Brush Lizard	*Urosaurus graciosus*
Insects	Order
Black fire ants	Hymenoptera
Orange Butterfly with Black Spots	Lepidoptera
Beetles	Coleoptera
Flies/Midges	Diptera
Bees	Hymenoptera

* Unable to identify species of squirrel from single observation.

community type. However, burroweed and mormon tea (Ephedra nevadensis) were the dominant shrub species based on general observations of abundance and density. The dominant grasses and herbaceous plants were red brome (Bromus rubens), schismus, and fiddleneck. Thirty two species of plants were observed during the rocket test stand survey and were identified to genus or species (Table 3). Ten species of birds, mammals, and reptiles were identified within the survey area (Table 4). Also a black-throated sparrow (Amphispiza bilineata) nest with 3-4 young nestlings was found in a silver cholla (Opuntia echinocarpa).

Discussion

No significant floral resources are likely to be present within the proposed railroad spur project area. However, the potential exists for Mojave ground squirrels (Spermophilus mojavensis) to inhabit the proposed project area. The type of survey conducted is insufficient to provide qualitative and quantative data related to this species. A live trapping study would be better suited to obtain the necessary data. Although not observed during this study, other animal species are likely to occur in this area (Table 5).

No significant floral resources are likely to be present within the rocket test stand study area. However, desert cymopterus (Cymopterus deserticola) is known to occur two miles NNE of test stand 1C. Desert cymopterus is also known to occur two miles west of test stand 1C. In addition, the desert floor north of Leuhman Ridge is likely habitat for desert cymopterus. This plant is a species of special concern due to the rarity of known populations. Further surveys for this plant species may be warranted as no data is presently available to predict potential impacts, such as acidic deposition, resulting from rocket motor test firings. Monitoring of plants within the primary impact area of the rocket test stand might be a possible mitigation measure.

During the spring of 1987, verified sightings of a prairie falcon (Falco mexicanus) were made within one quarter mile of test stand 1C. There are several areas along Leuhman Ridge which represent potential prairie falcon nesting sites.

The occurrence of desert tortoises (Gopherus agassizi) within the study area should be addressed. One adult tortoise was observed within the area of discoloration and plant die offs. This would indicate that an unknown number of tortoises could be at risk from rocket motor test firings. Further study of tortoises which may occur downslope of the primary impact area is warranted. This would provide more qualitative and quantative data to address impacts to tortoises outside the primary impact area. Impacts such as noise and acid rain outside the primary impact area have never been comprehensively studied for past rocket motor test firings at AFAL. Further study would also allow predictive modelling to determine the likeihood of tortoises immigrating into the primary impact area between test firing dates. These surveys do not guarantee all plant and animal species were observed, nor guarantee all species have been identified through the literature research.

Gully erosion downslope of test stand 1C probably deserves attention. Consideration should be given to remedial measures such as gully check dams to slow the rates of erosion. And of special note is the formation of sand dunes downslope of test stand 1C. In the event of project modification

TABLE 3. LIST OF PLANT SPECIES OBSERVED AT ROCKET TEST STAND PROJECT AREA

COMMON NAME	SCIENTIFIC NAME
Silver Cholla	Opuntia echinocarpa
Beavertail Cactus	Opuntia basilaris
Joshua Tree	Yucca brevifolia
Schismus	Schismus sp.
Indian Rice Grass	Oryzopsis hymenoides
Red Brome	Bromus rubens
Storksbill (Filaree)	Erodium cicutarium
Rumex (Wild Rhubarb)	Rumex hymenosepalus
Pincushion	Chaenactis sp.
Desert Aster (Mojave Aster)	Aster abatus
Broom Snakeweed	Gutierizzia sarothrae
Burroweed (White Bursage)	Ambrosia dumosa
Creosote Bush	Larrea tridentata
Mormon Tea	Ephedra nevadensis
Desert Trumpet	Eriogonum inflatum
Dwarf Cedar (Pygmy Cedar)	Peucephyllum schottii
Cheesebush	Hymenoclea salsola
Winter Fat	Eurotia lanata
Desert Thorn	Lycium brevipes
Cotton Thorn	Tetradymia spinosa
Evening Primrose	Oenethera micrantha
Fiddleneck	Amsinckia tessellata
Goldfield	Baeria platycarpha
Plantago	Plantago sp.
Large-Flowered Gilia	Gilia latiflora
Desert Alyssum	Lepidium fremontia
Penstemon	Penstemon sp.
Hairy-Leaved Caulanthus	Caulanthus lasiophyllus
Slender-Stemmed Buckwheat	Eriogonum gracillium
Scalebroom	Lepidospartum squamatum
Desert Dandelion	Malacothrix glabrata
Desert Parsley	Lomatium mojavense
Small-flowered Forget-me-not	Cryptantha micrantha

TABLE 4. LIST OF ANIMAL SPECIES OR THEIR SIGN OBSERVED AT ROCKET TEST STAND PROJECT AREA

COMMON NAME	SCIENTIFIC NAME
Common Raven	*Corvus corax*
Oregon Junco	*Junco oreganus*
Black-Throated Sparrow	*Amphispiza bilineata*
Purple Finch	*Carpodacus purpureus*
Rabbit	Order: Lagamorpha
Rodents	Order: Rodentia
Southern Pocket Gopher	*Thomomys umbrinus*
Coyote	*Canis latrans*
Long-tailed Brush Lizard	*Urosaurus graciosus*
Desert Tortoise	*Gopherus agassizi*
Insects	Order
Orange Butterfly with Black Spots	Lepidoptera
Beetles	Coleptera
Flies	Diptera
Bees	hymenoptera
Aphids	Homoptera

TABLE 5. ANIMAL SPECIES KNOWN TO OCCUR IN GENERAL AREA OF PROJECT BUT NOT OBSERVED DURING SURVEY

COMMON NAME	SCIENTIFIC NAME
Prairie Falcon	Falco mexicanus
Horned Lark	Eremophila alpestris
Western Meadowlark	Sturnella neglecta
Black-Chinned Sparrow	Spizella atrogularis
Crissal Thrasher	Toxostoma dorsale
Cottontail Rabbit	Sylvilagus audubonii
Black-Tailed Hare	Lepus californicus
Desert Kit Fox	Vulpes macrotis
Badger	Taxidea taxus
Bobcat	Lynx rufus

subsequent to 30 Mar 88, further research will be required.

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APPENDIX D

CULTURAL RESOURCE SURVEY FOR THE TITAN IV SOLID ROCKET MOTOR UPGRADE

Cultural Resource Survey for the Titan IV Solid Rocket Motor Upgrade

In accordance with the National Historic Preservation Act of 1966 and AFR 126-7, a cultural resource survey was performed for an undertaking at Edwards AFB CA. The proposed project entails the test firing of five Titan IV booster rocket motors at the 1C test stand at the Astronautics Laboratory on Leuhman Ridge. The reactivation and use of test stand 1C for testing was addressed in an earlier report (Robinson 1986, see SHPO project # USAF 870112A). No adverse impacts to cultural resources were predicted as a result of that investigation. This survey amends the earlier report to include new construction associated with the present project, and its potential for impacting cultural resources.

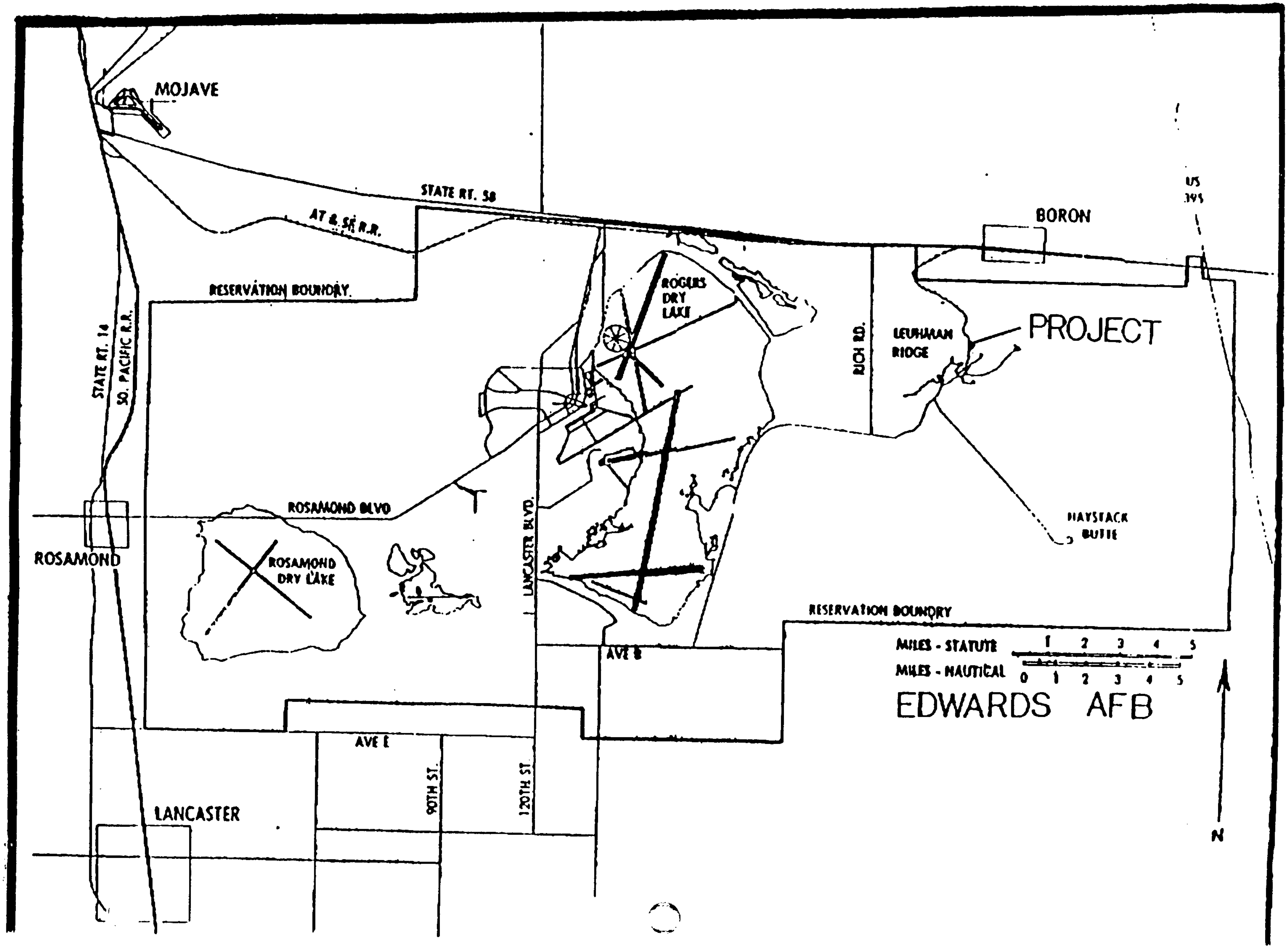
The area under consideration here lies on the east side of Leuhman Ridge adjacent to the Railroad line and spur (See attached map). A new pad will be built here to facilitate unloading and transportation of the rocket motors to the test stand. The pad construction will occur next to the railroad on land that has been disturbed earlier during the original construction of the railroad.

The survey was performed on March 28 and 29, 1988, by Richard H. Norwood (Base Historic Preservation Officer) and Mark Hagan (Environmental Protection Specialist). The pad area and adjoining five acres were examined with negative results. Since no cultural resources were identified as a result of this survey and earlier work no adverse impacts the cultural record are anticipated as a result of this project.

In the event alteration of the proposed project occurs after 29 March 1988, additional cultural resource survey and/or evaluation will be necessary. If cultural resources are encountered during the construction, work shall be stopped and the base archaeologist or his representative will be contacted immediately (805-277-8092).

Richard H Norwood

RICHARD H. NORWOOD, Base Historic Preservation Officer
AFFTC/DEV, Edwards AFB CA, March 30, 1988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AT & SF R.R.
BORON
US 395
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ROGERS DRY LAKE
RICH RD.
LEUHMAN RIDGE
PROJECT
STATE RT. 14
SO. PACIFIC R.R.
ROSAMOND BLVD
ROSAMOND
ROSAMOND DRY LAKE
LANCASTER BLVD.
HAYSTACK BUTTE
RESERVATION BOUNDRY
MILES - STATUTE 1 2 3 4 5
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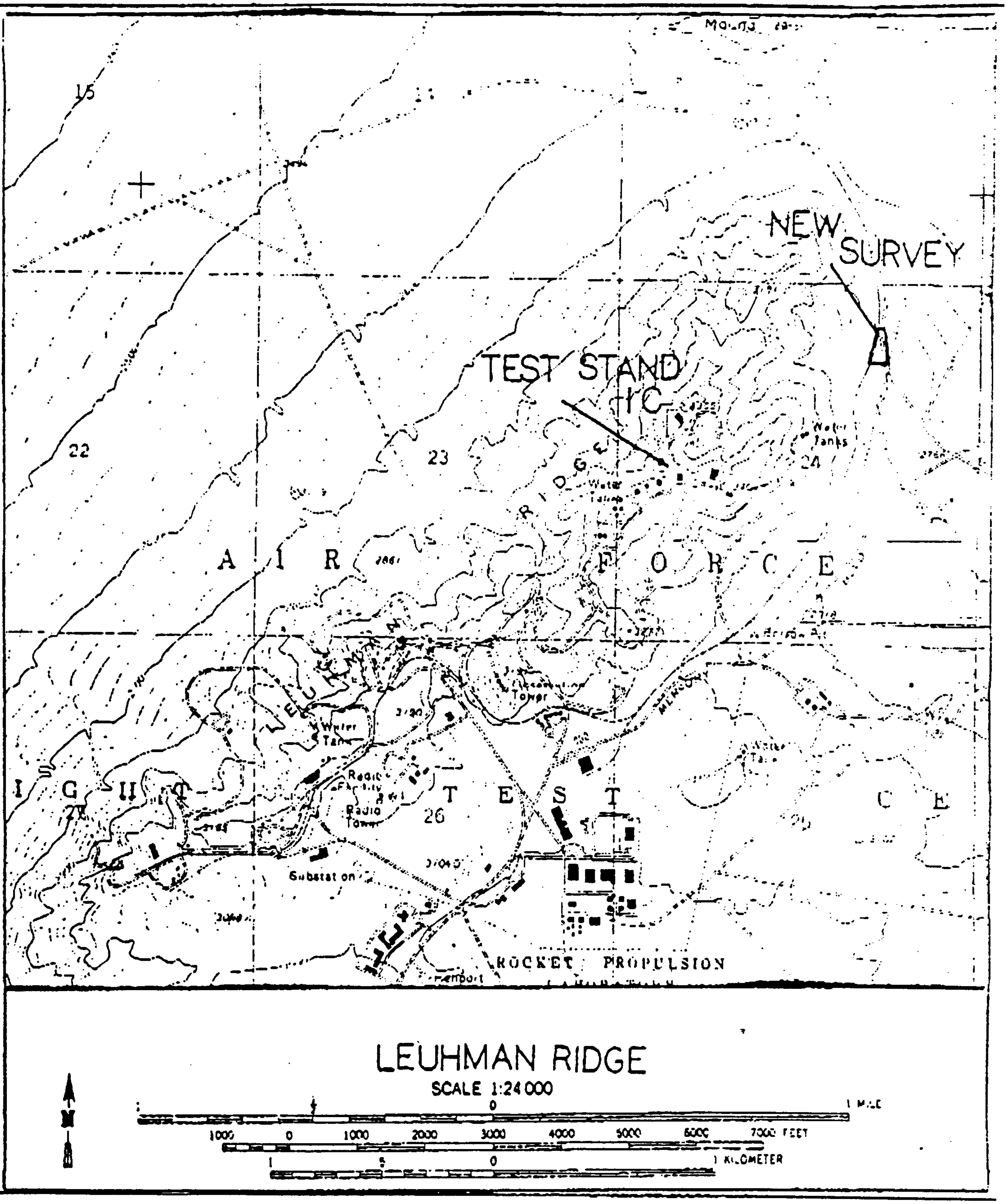

LEUHMAN RIDGE

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CULTURAL
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APPENDIX E

ROCKET TEST PLUME RISE CALCULATIONS

APPENDIX E

ROCKET TEST PLUME RISE CALCULATIONS

According to Briggs (1971), plume rise under nonstable conditions is a function of the buoyancy parameter $F(m^4s^{-3})$, and the windspeed, where

$$F = \frac{g\ V_s\ d^2\ \Delta T}{4\ T_s}$$

T_s is the stack plume exit temperature (°K), ΔT is the difference between ambient and stack plume temperature (°K), d is the stack inner diameter, V_s is the stack plume exit velocity, and g is the acceleration of gravity.

For F over 55 m^4s^{-3}, the plume height (H) in meters is determined by

$$H = h' + \frac{21.425\ F^{3/5}}{u(h)} ,$$

where h′ is the stack height and u(h) is the windspeed, which is usually determined at stack height. The windspeed height is not of concern for the simulation of emissions from the Titan IV, since a constant windspeed is assumed throughout the layer of plume rise and plume transport. Briggs gives a slightly different formula for F less than 55 m^4s^{-3}:

$$H = h' + \frac{38.71\ F^{3/5}}{u(h)}$$

Whether F is greater than or less than 55 m^4s^{-3}, the amount of plume rise is inversely proportioned to the windspeed. Thus, an observation of plume rise under one windspeed can be used to make estimates of plume rise at other windspeeds.

According to visual estimates the plume height above the desert terrain east of Leuhman Ridge was 2000-2500 ft for the June 15, 1987, Titan 34D 5-1/2 segment rocket motor test. To be conservative, a height of 2000 ft will be assumed here. At the time of the test, winds in the 0-2000 ft layer averaged approximately 25 knots (13 m/sec). Rocket Test Stand 1-C is located on Leuhman Ridge, which juts sharply above the desert floor. Test Stand 1-C, where the Titan 34D was tested and where the Titan IV will be tested, was estimated from a USGS topographic map to be approximately 650 ft above the terrain east of the ridge. Using the ridge as a "stack," the above equation can be used to estimate the plume rise (h).

$$\begin{aligned} &H = h' + h \\ \text{or}\quad &h = H - h' = 2000\ \text{ft} - 650\ \text{ft} \\ & = 1350\ \text{ft} \end{aligned}$$

Since plume rise is inversely proportional to windspeed, the plume rise and total plume height for the other modeled wind conditions are calculated as follows:

For 13-knot winds:

$$h = \frac{25\text{ kts}}{13\text{ kts}}(1350\text{ ft}) = 2596\text{ ft}$$

For 8-knot winds:

$$h = \frac{25\text{ kts}}{8\text{ kts}}(1350\text{ ft}) = 4219\text{ ft}$$

For 5-knot winds:

$$h = \frac{25\text{ kts}}{5\text{ kts}}(1350\text{ ft}) = 6750\text{ ft}$$

Adding back in the "stack" height (h′) of 650 ft, we obtain total plume heights above the desert floor of 3246 ft (990 m), 4869 ft (1484 m), and 7400 ft (2256 m) for the windspeeds of 13 knots, 8 knots, and 5 knots, respectively.

APPENDIX F

ESTIMATION OF NO_x AND CO CONCENTRATIONS IN TITAN IV EXHAUST GASSES

APPENDIX F

ESTIMATION OF NO_x AND CO AMOUNTS IN TITAN IV EXHAUST GASES

Information from Hercules, Inc. (Appendix G) provided the basis for estimating the amount of NO_x and CO generated during the proposed tests of the Titan IV rocket motor. The Hercules information gave propellant weight as 680,694 lb and expended inert material as 4,127 lb. It is assumed that "expended inert" is a ceramic material not radically different from Al_2O_3 in thermal properties but not participating in the chemical equilibrium which produces the composition of rocket effluent. On this basis, Table G-1 is analogous to Table 3.1 of Appendix A. In this table, H and OH free radicals were assigned to H_2O, atomic chlorine plus equivalent molecular hydrogen were assigned to HCl, and a residual 0.0318 wt % for all else was assigned to Al_2O_3.

Table 3.3, "Rocket Exhaust Products Following Afterburning" of Appendix A appears not to constitute a material balance for all species. Hydrogen listed in Table 3.3 is unaccounted for as water in Table 3.2. Oxygen, presumably from air admixture during the afterburning process appears in the "NO_x" entry (only 2.8×10^{-5} moles NO and 3.9×10^{-11} moles per 100 grams NO_2 in the exhaust gas at the nozzle plume) and in additional CO_2. Further, there must be free oxygen present in the exhaust gas that is not accounted for in Table 3.3 because "NO_x" cannot be generated from N_2 in the absence of free oxygen or of a chemical species which donates the equivalent of free oxygen.

The only plausible source of free oxygen with which to make NO_x and to convert most of the CO present at the nozzle exit plume to CO_2 is air entrained into the rocket exhaust gases. That oxygen is associated with nitrogen to the extent of 3.76 wt of N_2 per unit weight O_2. Table G-2 shows the composition of the rocket exhaust gases when enough air had been admixed to supply the oxygen needed for all the carbon to be present as CO_2 (if all the free oxygen were combined with the CO). This exact amount of air needed in theory to convert all carbon species to CO_2 is called "stoichiometric air." It is typical of ordinary fuel gas combustion processes for the maximum flame temperature to occur at or near fuel admixture with stoichiometric air (i.e., with little, if any, "excess air"). Air needed to supply oxygen for converting to water the hydrogen initially present is also provided.

The compositions in Table G-2 are equilibrium compositions under the following assumptions:

1. The amount of air mixed into the exhaust gases is such that the free oxygen and the unreacted CO are in correct stoichiometric ratio to produce CO_2.

2. The rocket exhaust containing the admixed air is at thermodynamic equilibrium with respect to the reactions:
   $CO + 1/2\ O_2 = CO_2$ and
   $1/2\ O_2 + 1/2\ N_2 = NO$.

3. The temperature of the rocket exhaust containing the admixed air is 2500°K.

4. The pressure of the rocket exhaust is approximately 1 atm.

The 2500°K maximum temperature for afterburning is taken from the figure labelled "Predicted Titan Plume Temperature" (personal communication, John Edwards, USAF SD/DEV, and C. R. Boston, ORNL, March 23, 1988). The assumed temperature increase due to the afterburning process is about 255°K, above the nozzle exit plume temperature of 2245°K.

Data for estimating the equilibrium NO and CO concentrations were taken from the JANAF tables (JANAF 1981), and the relevant equilibrium constants are

$$(K_{eq})_{NO} = P_{NO}/P_{N_2}{}^{1/2}\ P_{O_2}{}^{1/2} = 0.0593 \text{ at } 2500°K \text{ and}$$

$$(K_{eq})_{CO} = P_{CO_2}/P_{CO}\ P_{O_2}{}^{1/2} = 27.5 \text{ at } 2500°K,$$

where P_i is partial pressure (atm) of the ith component participating in the reaction.

It is conservative to assume that cooling of the exhaust gases following "afterburning" by radiation or by admixture of more (excess) air or by injection of water, occurs so rapidly as to "quench" the foregoing NO and CO reactions at their high-temperature equilibrium conditions. As the reaction temperature decreases below 2500°K, the value of the foregoing equilibrium constants change such that the quantities of NO and CO present at equilibrium at lower temperature would be less than what is at the higher temperature.

If cooling is achieved by mixing excess air into the exhaust gases (following afterburning), the favorable effect of decreased equilibrium constant for the NO formation reaction is partially offset by increasing concentration of the reagents (N_2 and O_2) which drive the NO-forming reaction forward. However, the effect of increasing reagent concentration does not overbalance the effect of decreasing temperature; cooling by air admixture is still favorable but not quite as favorable as if the only effect were the effect of temperature on equilibrium constant. The effect of excess air admixture is wholly favorable with respect to the CO-CO_2 equilibirum; both lowered temperature and increased free oxygen concentration in the exhaust gases decrease the amount of CO present at equilibrium.

The effect of "slow cooling" (slow with respect to the chemical kinetics of the relevant chemical reactions) is not minor. Table G-3 shows the extent to which the NO production reaction would reverse and the CO depletion reaction would proceed further if cooling of the exhaust gases occurred slowly enough for equilibrium to be attained at 1000°K.

The assumed temperature of 1000°K for (727°C) Table G-3 is a "cold flame" temperature, and is approximately the lowest temperature at which the kinetics governing the CO-O_2-CO_2 equilibrum could proceed in an uncatalyzed system at a rate sufficient to sustain very slow "combustion." The NO-O_2-N_2 equilibrium probably freezes-in at about 1500 to 1600°K.

To the extent that water-quenching the exhaust gas affects the NO and CO content of the gas the effect probably will be unfavorable because the slower the gas cools the more time is available for the governing reactions to proceed in favorable directions during the cooldown. If, however, the deluge water lowers the maximum temperature during the afterburning process, the amounts of NO_x and CO present would be less than the values shown in Table G-2.

The build-in of NO_2 pollutant into the combustion gases can be estimated by the thermodynamic equilibrium for the reaction

$$1/2\ O_2 + NO = NO_2.$$

At 1000°K, $K_{eq} = P_{NO_2}/P_{O_2}{}^{1/2}\ P_{NO} = 0.12$, which gives about 7 wt % of NO_x being NO_2 instead of NO. At 900°K (627°C) the equilibrium constant for the foregoing reaction is 0.29, which gives about 15 wt % of NO_x being NO_2. On the basis of just the O_2-NO-NO_2 chemical equilibrium, (neglecting kinetics and the effect of competing reactions such as the effect of ozone) the assumption in Appendix A that 10% of NO_x is NO_2 corresponds to an exhaust gas-admixed air temperature of about 960°K (690°C).

REFERENCE FOR APPENDIX F

JANAF Thermochemical Tables, Second Edition; D. R. Stull and H. Prophet, Project Directors, Publication NSRDS-NBS37, U.S. National Bureau of Standards, Washington, D.C. (USGPO), June 1971.

Table F-1. Exhaust composition at nozzle plane (neglecting "expended inert")

Exhaust product	wt %	pounds	kg-moles
$Al_2O_3(C)$	35.9120	244,451	1,087
CO	21.9274	149,259	2,417
HCl	21.3960	145,641	1,812
N_2	8.3410	56,777	919
H_2O	7.7070	52,461	1,321
CO_2	2.4942	16,978	175
H_2	2.2224	15,127	3,404
TOTAL	100.0000	680,694	11,111

Table F-2. Composition of rocket exhaust containing stoichiometric air (neglecting "expended inert")

Exhaust product	wt %	pounds	kg-moles
$Al_2O_3(C)$	15.0	244,463	1,087
CO	2.3	37,346	605
HCl	8.9	145,641	1,812
N_2	47.8	729,321	11,815
H_2O	11.5	186,716	4,701
CO_2	11.9	192,840	1,988
O_2	1.3	21,305	309
NO[a]	0.5	7,405	112
Air	0.8	13,074	148
TOTAL	100.0	1,565,037	24,235

[a] Calculated as NO_2 the weight would be 11,704 lbs, but at the assumed temperature of formation (2500°K) only NO will be present.

Table F-3. Equilibrium composition of rocket exhaust gases at 1000°K, cooled by excess air admixture (neglecting "expended inert")

Exhaust product	wt %	pounds	kg-moles
$Al_2O_3(C)$	3.6	244,451	1,087
CO	neg.	neg.	neg.
HCl	2.1	145,641	1,812
N_2	70.3	4,838,463	68,137
H_2O	2.7	186,658	4,701
CO_2	3.6	251,492	2,593
NO_x[a]	0.003	207	3
O_2	17.1	1,177,415	16,690
Air	0.6	39,149	990
TOTAL	100.000	6,884,446	106,233

[a] About 93% NO and 7 NO_2 at 1000°K, if at equilibrium.

APPENDIX G

THERMOCHEMICAL DATA FOR EXHAUST EMISSIONS

SYSTEM STUDIES
Hercules - Bacchus Works
System Design Optimization

October 29, 1987
Log #S-54 ①

Titan IV Exhaust Plume Thermal Properties

These comparative data are for the Hercules 126 inch SRMU and the CSD seven segment SRM, using best available data for the latter.

Pressure *vs* time at 60°F

SRMU		
	0 sec	1090 psia
	15	1100
	25	1000
	35	1000
	100	580
	133	470

Web action time 133

CSD SRM
Maximum pressure = 835 psia
Web action time = 112.4 sec
Action time = 123.8 sec

Thermal properties at the nozzle exit plane were calculated using the Solid Propellant Performance (SPP) code. These calculations were run at action time average pressure for consistency with the specific impulse performance calculations, but pressure is not expected to have a major effect on calculated temperature at the nozzle exit plane.

The SPP code considers axisymmetric two dimensional two phase flow assuming fixed exhaust composition. The oxide particle size distribution is based on an empirical correlation.

Configuration		
Propellant	QDI	UTP-3001
Action time, sec	139.6	123.8
Action time average P, psia	891	663
Initial throat diameter, in.	32.5	39.8
Nozzle exit diameter, in.	128.6	126.1
Conditions at nozzle exit plane		
Average oxide particle T, °R	4189	4189
Gas temperature °R	3781	3630
Average particle concentration, W_p/W_g	0.5013	0.4077
Thermal emissivity	0.29	0.33
Radiation thermal flux, BTU/ft^2-sec	43	48

The oxide particle temperature, 4189°, is the melting point of aluminum oxide. The SPP calculation actually considers three particle size classes, and the smaller particles are somewhat cooler than the average temperature given above. Also the oxide particle concentration and size distribution varies between the nozzle centerline and the exit ID.

The plume emissivity and radiation thermal flux were estimated using the procedure defined in F. C. Price *et al*, *Internal Environment of Solid Rocket Nozzles*, Air Force Rocket Propulsion Laboratory, Edwards AFB, RPL-TDR-64-140, 30 July, 1964. This procedure requires consideration of the variation in particle concentration and size distribution across the exit plane. These depend on nozzle expansion ratio and contour as well as thermochemical properties.

ATTACHMENT 4.4.1-4

②

Thermochemical data were calculated for one dimensional isentropic flow using the KENVIL code, which uses the same free energy minimization algorithm as the NASA-Lewis code. JANNAF thermochemical data for the combustion products were used. The effective gamma calculated by this code is the value for the isentropic exponent required to give the same thrust coefficient by the classical equation assuming fixed composition as is calculated by the code assuming equilibrium flow.

The weight basis for these data is 100 grams. In particular, note that the fixed composition heat capacity for the gas is given in cal/100 gm of total products.

SRMU	Chamber	Throat	Exit
Pressure, psia	891	515.4	8.16
Temperature, °K	3452.3	3353.7	2245.0
Weight % oxide particles	33.39	34.16	35.88
Enthalpy, cal/100 gm	-43642	-56334	-130496
Moles gas/100 gm	3.3989	3.3713	3.2678
Isentropic exponent, γ	1.1299	1.1298	1.1645
Fixed composition γ	1.166	1.164	1.185
Effective γ	-	-	1.1290
Fixed composition C_p, cal/100 gm			
Total products	47.50	47.46	41.57
Gas only	32.44	32.05	29.93
Equilibrium C_p, cal/100 gm	93.35	87.63	49.99

CSD SRM	Chamber	Throat	Exit
Pressure, psia	663	381.5	9.76
Temperature, °K	3293.2	3094.1	2007.5
Weight % oxide particles	28.96	29.57	30.45
Enthalpy, cal/100 gm	-44465	-57168	-122591
Moles gas/100 gm	3.6351	3.6104	3.5450
Isentropic exponent, γ	1.1419	1.1445	1.1951
Fixed composition γ	1.180	1.179	1.204
Effective γ	-	-	1.1405
Fixed composition C_p, cal/100 gm			
Total products	47.44	47.31	41.53
Gas only	34.37	33.97	31.77
Equilibrium C_p, cal/100 gm	80.43	73.95	44.05

Calculated exhaust compositions are shown on the following pages.

Lowell Smith	Thermochemical calculations	251-6185
Dennis Davis	SPP Flow calculations	251-6323
Monty Cunningham	Thermal	251-6765

(3)

Hercules SRMU

Conditions at Nozzle Exit Plane
One Dimensional Ideal Equilibrium Flow

Chamber pressure = 891 psia	Expansion ratio = 15.67
Exit pressure = 8.16 psia	Exit temperature = 2245.0 K
Enthaply = −130496 cal/100 gm	3.26783 moles gas/100 gm

PRODUCT	MW	MOLES	WT. PCT.	MOLE PCT.	VOLUME PCT.
AL	26.98150	1.40433D-07	0.0000	0.0000	0.0000
AL CL	62.43450	1.58940D-04	0.0099	0.0044	0.0049
AL CL2	97.88750	6.48512D-05	0.0063	0.0018	0.0020
AL CL3	133.34050	3.31608D-05	0.0044	0.0009	0.0010
AL H	27.98947	1.06040D-08	0.0000	0.0000	0.0000
AL N	40.98820	2.54349D-13	0.0000	0.0000	0.0000
AL O	42.98090	2.10684D-07	0.0000	0.0000	0.0000
AL O CL	78.43390	7.51254D-05	0.0059	0.0021	0.0023
AL O H	43.98887	6.28506D-06	0.0003	0.0002	0.0002
AL O2	58.98030	2.66884D-08	0.0000	0.0000	0.0000
AL O2H	59.98827	1.03047D-05	0.0006	0.0003	0.0003
AL2O	69.96240	3.48439D-09	0.0000	0.0000	0.0000
AL2O2	85.96180	1.31840D-09	0.0000	0.0000	0.0000
BI	208.98000	5.48945D-06	0.0011	0.0002	0.0002
BI CL	244.43300	9.11918D-08	0.0000	0.0000	0.0000
BI H	209.98797	7.08115D-08	0.0000	0.0000	0.0000
BI O	224.97940	2.64870D-08	0.0000	0.0000	0.0000
BI2	417.96000	5.45086D-13	0.0000	0.0000	0.0000
C H2O	30.02649	8.99233D-08	0.0000	0.0000	0.0000
C H4	16.04303	7.40753D-10	0.0000	0.0000	0.0000
C N	26.01785	2.87308D-10	0.0000	0.0000	0.0000
C O	28.01055	7.82825D-01	21.9274	21.6265	23.9555
C O CL	63.46355	2.77777D-07	0.0000	0.0000	0.0000
C O2	44.00995	5.66745D-02	2.4942	1.5657	1.7343
CL	35.45300	6.96615D-03	0.2470	0.1924	0.2132
CL O	51.45240	5.22812D-08	0.0000	0.0000	0.0000
CL2	70.90600	2.89582D-06	0.0002	0.0001	0.0001
H	1.00797	1.82753D-02	0.0184	0.5049	0.5592
H AL O	43.98887	1.20414D-10	0.0000	0.0000	0.0000
H C N	27.02582	3.37962D-07	0.0000	0.0000	0.0000
H C O	29.01852	5.17969D-07	0.0000	0.0000	0.0000
H CL	36.46097	5.79852D-01	21.1420	16.0191	17.7442
H N O	31.01407	5.10845D-09	0.0000	0.0000	0.0000
H O CL	52.46037	1.64958D-07	0.0000	0.0000	0.0000
H2	2.01594	1.09729D+00	2.2121	30.3139	33.5785
H2O	18.01534	4.26717D-01	7.6875	11.7886	13.0581
N	14.00670	2.77164D-08	0.0000	0.0000	0.0000
N H	15.01467	1.09691D-08	0.0000	0.0000	0.0000
N H2	16.02264	8.08630D-08	0.0000	0.0000	0.0000
N H3	17.03061	1.55475D-08	0.0000	0.0000	0.0000
N O	30.00610	2.79330D-05	0.0008	0.0008	0.0009
N O2	46.00550	3.93126D-11	0.0000	0.0000	0.0000
N2	28.01340	2.97750D-01	8.3410	8.2257	9.1115
O	15.99940	1.21910D-05	0.0002	0.0003	0.0004
O H	17.00737	1.08222D-03	0.0184	0.0299	0.0331
O2	31.99880	1.99638D-06	0.0001	0.0001	0.0001
AL2O3(C)	101.96120	3.51919D-01	35.8820	9.7222	

CSD 7 Segment SRM

Conditions at Nozzle Exit Plane
One Dimensional Ideal Equilibrium Flow

Chamber pressure = 663 psia Expansion ratio = 10.04
Exit pressure = 9.76 psia Exit temperature = 2007.3 K
Enthaply = −122591 cal/100 gm 3.54499 moles gas/100 gm

PRODUCT	MW	MOLES	WT. PCT.	MOLE PCT.	VOLUME PCT.
AL	26.98150	1.39247D-09	0.0000	0.0000	0.0000
AL CL	62.43450	9.55978D-06	0.0006	0.0002	0.0003
AL CL2	97.88750	8.70921D-06	0.0009	0.0002	0.0002
AL CL3	133.34050	1.52203D-05	0.0020	0.0004	0.0004
AL H	27.98947	1.85522D-10	0.0000	0.0000	0.0000
AL N	40.98820	1.38701D-15	0.0000	0.0000	0.0000
AL O	42.98090	1.77865D-09	0.0000	0.0000	0.0000
AL O CL	78.43390	4.58374D-06	0.0004	0.0001	0.0001
AL O H	43.98887	3.00656D-07	0.0000	0.0000	0.0000
AL O2	58.98030	1.80968D-10	0.0000	0.0000	0.0000
AL O2H	59.98827	4.56142D-07	0.0000	0.0000	0.0000
AL2O	69.96240	9.15284D-12	0.0000	0.0000	0.0000
AL2O2	85.96180	3.83526D-12	0.0000	0.0000	0.0000
C H2O	30.02649	1.47683D-07	0.0000	0.0000	0.0000
C H4	16.04303	7.27436D-09	0.0000	0.0000	0.0000
C N	26.01785	7.21457D-11	0.0000	0.0000	0.0000
C O	28.01055	9.81649D-01	27.4965	25.5394	27.6912
C O CL	63.46355	1.33592D-07	0.0000	0.0000	0.0000
C O2	44.00995	6.75709D-02	2.9738	1.7580	1.9061
CL	35.45300	1.49086D-03	0.0529	0.0388	0.0421
CL O	51.45240	2.15279D-09	0.0000	0.0000	0.0000
CL2	70.90600	7.34710D-07	0.0001	0.0000	0.0000
FE	55.84700	1.94522D-05	0.0011	0.0005	0.0005
FE CL	91.30000	1.53772D-06	0.0001	0.0000	0.0000
FE CL2	126.75300	3.07525D-03	0.3898	0.0800	0.0867
FE CL3	162.20600	4.15144D-07	0.0001	0.0000	0.0000
FE O	71.84640	1.24813D-07	0.0000	0.0000	0.0000
FE O2H2	89.86174	9.66944D-07	0.0001	0.0000	0.0000
H	1.00797	4.36047D-03	0.0044	0.1134	0.1230
H AL O	43.98887	1.41038D-12	0.0000	0.0000	0.0000
H C N	27.02582	6.21580D-07	0.0000	0.0000	0.0000
H C O	29.01852	2.74528D-07	0.0000	0.0000	0.0000
H CL	36.46097	5.66889D-01	20.6693	14.7486	15.9913
H N O	31.01407	4.84590D-10	0.0000	0.0000	0.0000
H O CL	52.46037	2.39044D-08	0.0000	0.0000	0.0000
H2	2.01594	1.22934D+00	2.4783	31.9835	34.6783
H2O	18.01534	3.86844D-01	6.9691	10.0644	10.9124
N	14.00670	1.26892D-09	0.0000	0.0000	0.0000
N H	15.01467	1.07745D-09	0.0000	0.0000	0.0000
N H2	16.02264	2.99476D-08	0.0000	0.0000	0.0000
N H3	17.03061	2.89850D-06	0.0000	0.0001	0.0001
N O	30.00610	2.48290D-06	0.0001	0.0001	0.0001
N O2	46.00550	8.24089D-13	0.0000	0.0000	0.0000
N2	28.01340	3.03553D-01	8.5036	7.8975	8.5629
O	15.99940	3.58965D-07	0.0000	0.0000	0.0000
O H	17.00737	1.41950D-04	0.0024	0.0037	0.0040
O2	31.99880	4.87085D-08	0.0000	0.0000	0.0000
AL2O3(C)	101.96120	2.98687D-01	30.4544	7.7709	