ENVIRONMENTAL IMPACT ANALYSIS PROCESS

ENVIRONMENTAL ASSESSMENT

PEGASUS

AIR-LAUNCHED SPACE BOOSTER
EDWARDS AFB/WESTERN TEST RANGE, CA

SEPTEMBER 1989

DEPARTMENT OF THE AIR FORCE

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS SPACE DIVISION (AFSC)
LOS ANGELES AIR FORCE STATION, PO BOX 92960, WORLDWAY POSTAL CENTER
LOS ANGELES, CA 90009

08 OCT 1989

TO: Governmental Agencies, Public Officials and Groups, and Interested Individuals and Groups

Attached for public and governmental agency notification is the Finding of No Significant Impact (FONSI) and the Environmental Assessment (EA) for the Pegasus Air-Launched Space Booster Program. This is in compliance with the National Environmental Policy Act of 1969 and the regulations of the President's Council on Environmental Quality.

The FONSI and EA address the environmental impacts associated with the development, concept demonstration, and deployment of Pegasus. Final booster assembly and deployment of the B-52 will occur at Edwards AFB, CA. Pegasus will be air-launched from underneath the wing of the B-52 over the Western Test Range, off the California coast. The thirty (30) day notification period is not required based on the standards set in Air Force Regulation 19-2, Environmental Impact Analysis Process, para. 11 f (1-4).

Copies of the FONSI and EA may be obtained by writing to:

Department of the Air Force
Headquarters Space Division, SSD/DEV,
Attn: Captain Hector E. Malave
P.O. Box 92960, Worldway Postal Center,
Los Angeles, California 90009-2960

or by calling Capt Malave at (213)643-0935

Sincerely

WILLIAM E. LEONHARD, JR., COL, USAF
Director of Acquisition Civil Engineering
Space Systems Division

(FOR)
JOHN M. HOFFMAN, COL, USAF
Chairman, Edwards Air Force Base
Environmental Protection Committee

PEGASUS AIR-LAUNCHED SPACE BOOSTER
ENVIRONMENTAL ASSESSMENT

to

Headquarters, Space Systems Division
Los Angeles Air Force Base, P.O. Box 92960
Los Angeles, California 90009-2960

from

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P.O. Box 999
Richland, WA 99352

operated by

Battelle Memorial Institute
under Contract DE-AC06-76RLO 1830 to
U.S. Department of Energy

FINDING OF NO SIGNIFICANT IMPACT (FONSI)
PROPOSED PEGASUS AIR-LAUNCHED SPACE BOOSTER PROGRAM
EDWARDS AIR FORCE BASE, CALIFORNIA

1.0 DESCRIPTION OF THE PROPOSED ACTION

The Pegasus air-launched vehicle is part of the Advanced Space Technology Program of the Defense Advanced Research Projects Agency (DARPA). The program is designed to demonstrate high-payoff, advanced technology to improve systems' operational support to military commanders. The government launch and demonstration of the privately developed Pegasus vehicle will be used to evaluate its launch flexibility and utility for support if military objectives as well as to place small experimental payloads into orbit.

The Pegasus launch system is a three-stage solid-rocket-motor launch vehicle designed to be launched from a B-52B aircraft or similar large-lift aircraft, either government or private. It is being developed to provide a responsive, inexpensive, and highly mobile launch service to satisfy the launch needs of small mass 190 km (425-lb) and volume 1.8 m 3 (65-ft 3) payloads for the U.S. Department of Defense and other users. The DARPA has contracted for Pegasus launch services for two captive flights and two launches into polar orbit with an option for four more flights. A B-52B carrying the Pegasus will take off from Edwards Air Force Base (AFB), north of Los Angeles, California, climbing toward the town of Paso Robles. The aircraft will turn northwest about 70 km (40 mi) east of San Luis Obispo, passing to within 7 km (4 mi) of Paso Robles. The B-52B makes another turn near the Farallon Islands to head south into the Western Test Range (WTR) about 160 km (100 mi) into the Pacific Ocean. Mission control for these operations will be at the NASA Ames Research Center/Dryden Flight Research Facility, Edwards AFB, California. This environmental assessment addresses the potential environmental impacts from he six potential DARPA/NASA launches and assumes that the configuration of the Pegasus and its use of the B-52B remain as described in this document.

2.0 SUMMARY FO ENVIRONMENTAL IMPACTS

The implementation of the Pegasus air-launched rocket booster program will not significantly impact the natural or man-made environment.

2.1 NATURAL ENVIRONMENT

The only components of the natural environment that have a potential for impact from the routine operations of the Pegasus project are air quality and noise at Edwards AFB, the flight corridor, and the WTR: the terrestrial environment of Edwards AFB; and the marine environment of the WTR.

2.1.1 Air Quality

Impacts to air quality were examined from routine chemical emissions from the Vehicle Assembly Building (VAB), and B-52B engine combustion products. The primary constituent of the atmospheric releases from assembly is likely to be isopropyl alcohol. Because the routine air concentration within the VAB is estimated to be at least 100 times lower than occupational exposure limits and the atmospheric dispersion potential of any releases from the VAB would decrease the concentration an additional 4 orders of magnitude before reaching the nearest point of human exposure after release (OSC office trailer), no significant environmental impacts are expected from the routine assembly of the Pegasus. A chemical spill within the VAB would require short-term mitigative actions and is not expected to create a health hazard.

Noise and jet engine combustion products from the four B-52B takeoffs is not expected to be significant addition to the flight testing activities currently under way at Edwards AFB. Upon leaving Edwards AFB, the B-52B will climb to an altitude of about 6,100m (20,000 ft) before crossing the Edwards AFB boundary proceeding to an altitude of about 12,200 m (40,000 ft) for its flight through the land corridor on its way to the WTR. During this flight from Edwards AFB, the noise and jet engine combustion products will be released at such and altitude as to be of no consequence to humans or the natural environment.

2.1.2 Ecology

Ecological impacts are not expected to occur from the routine chemical emissions from the Pegasus assembly or from the noise and jet engine combustion products produced by the B-52B as it taxies and takes off from Edwards AFB, travels through the land corridor and launches Pegasus in the WTR.

2.2 MANMADE ENVIRONMENT

Pegasus is also not likely to cause socioeconomic impacts. Because of the transient nature of Edwards AFB personnel as a result of project initiation and termination, the addition of eight fulltime workers and 12 temporary workers is not expected to have an observable impact on the manmade environment (housing and community services, such as hospitals, schools, traffic congestion, etc.).

3.0 FINDINGS

Based upon the preceding discussion, a finding of no significant impact is made. An Environmental Assessment of the proposed action dated July 1989, is on file at:

Department of the Air Force
HQ Space Systems Division/DEV
Attn: Captain Hector E. Malave
P.O. Box 92960, World Way Postal Center
Los Angeles, CA 90009-2960

CONTENTS

FIGURES

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ABBREVIATIONS AND ACRONYMS

ACGIH	American Council of Governmental Industrial Hygienists
AFB	Air Force Base
AFFTC	Air Force Flight Test Center
AIT	Assembly Integration Trailer
C	Centigrade
CFR	Code of Federal Regulations
CMP	Coastal Management Plan
DARPA	Defense Advanced Research Projects Agency
dB	decibel
DFG	Department of Fish and Game (California)
DFRF	Dryden Flight Research Facility
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EA	environmental assessment
EEGL	Emergency exposure guidance levels
EPA	U.S. Environmental Protection Agency
F	Fahrenheit
ft	feet
ft^2	square feet
ft^3	cubic feet
FTS	Flight Termination System
g	gram(s)
gal	gallon(s)
HCL	hydrochloric acid (hydrogen chloride)
hr	hour(s)
HVAC	heating, ventilating, and air conditioning
in.	inch(es)
kg	kilogram
km	kilometer
KOH	potassium hydroxide
lb	pound(s)
L	liter
LDN	Level Day/Night

m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
mb	millibar(s)
mi	mile(s)
mg	milligram
min	minute
mph	Miles per hour
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
n.d.	no date
NOAA	National Oceanic and Atmospheric Administration
NPL	Noise Pollution Level
NRC	National Research Council
OSC	Orbital Science Corporation
OSHA	Occupational Safety and Health Administration
PEL	public emergency limit
PNL	Pacific Northwest Laboratory
ppm	parts per million
qt	quart(s)
TOS	Transfer Orbital Stage
TSP	Total suspended particulate matter
sec	second(s)
SPEGL	short-term public emergency limit
STEL	short-term emergency limit
USAF	United States Air Force
USC	U.S. Code
USFWS	U.S. Fish and Wildlife Service
V	volt(s)
VAB	Vehicle Assembly Building
VAC	ventilation and air conditioning
st	weight
WTR	Western Test Range
yd	yard(s)

<	less than
/	per
%	percent
°	degrees
ìg	microgram(s)
ìm	micrometer(s)

1.0 SUMMARY

This environmental assessment (EA) addresses the potential environmental impacts of assembling and launching the Pegasus air-launched vehicle. The Pegasus is a three-stage solid-rocket-motor launch vehicle designed to be launched from a B-52B aircraft or similar large-lift aircraft. It is being developed to satisfy the launch needs of small mass [190 kg (425 lb)] and volume [1.8 m^3 (65 ft^3)] payloads for the U.S. Department of Defense and other users. The Defense Advanced Research Projects Agency (DARPA) has contracted the Orbital Sciences Corporation to provide the vehicles for two captive flights and two launches into polar orbit with an option for four additional launches. A B-52B carrying the Pegasus will take off from Edwards Air Force Base (AFB) north of Los Angeles, California, fly a northwest-trending route to cross the California coast at a point some 130 km (81 mi) north of San Luis Obispo, and position the Pegasus for a southward launch approximately 160 km (100 mi) out into the Western Test Range (WTR) over the Pacific Ocean (Figure 1.1). The WTR is a military test range controlled by the Western space and Missile Center at Vandenberg AFB, California. Mission control of these operations will be at the NASA Ames Research Center/Dryden Flight Research Facility (NASA DFRF), Edwards AFB, California. The captive flights will be accomplished using an inert Pegasus. During the captive flights, the Pegasus will remain attached to the B-52B for stability and air-worthiness testing. All launches, other than the captive ones, will use fully functional and operational boosters.

This EA addresses the potential environmental impacts for the six potential DARPA/NASA launches and assumes that the configuration of the Pegasus and its use of the B-52B remain as described in this document. The environmental impacts of the payloads are addressed separately. Both routine impacts from Pegasus assembly and launch and impacts from potential accidents were assessed.

Components of the environment that have a potential for impact form the routine operations of the Pegasus project are air quality and noise levels at Edwards AFB, the flight corridor, and the WTR; the terrestrial environmental of Edwards AFB; the marine environment of the WTR; and the manmade environment at Edwards AFB.

Impacts to air quality were examined from routine chemical emissions form Pegasus assembly and B-52B engine combustion products. The primary constituent of the atmospheric releases from assembly is likely to be isopropyl alcohol. No significant environmental impacts are expected for the routine assembly of the Pegasus. A chemical spill within the assembly building would require short-term mitigative actions and is not expected to create a health hazard.

Noise and jet engine combustion products form the six B-52B takeoffs is not expected to be a significant addition to the flight testing activities currently under way at Edwards AFB. During the flight from Edwards AFB, the noise and jet engine combustion products will be released at such an altitude as to be of no consequence to humans or the natural environment.

Ecological Impacts are not expected to occur from the routine chemical emissions form Pegasus assembly or from the noise and jet engine combustion products produced by the B-52B as it taxies and takes off from Edwards AFB, travels through the land corridor, and launches Pegasus in the WTR.

Neither is Pegasus likely to cause socioeconomic impacts. Because of the transient nature of Edwards AFB personnel as a result of project initiation and termination, the addition of eight fulltime workers and 12 temporary workers is not expected to have an observable impact on the

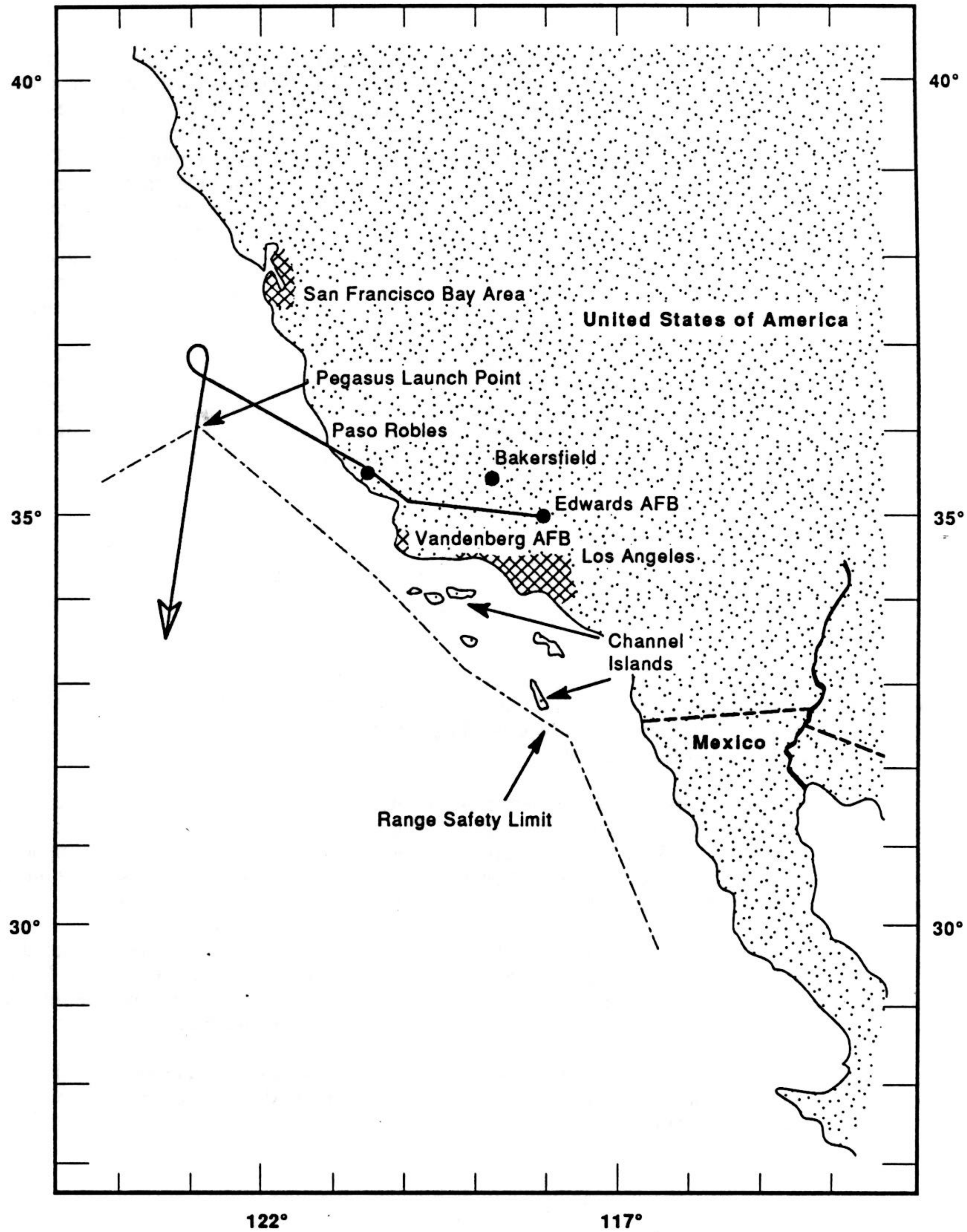


FIGURE 1.1. Pegasus Flight Path

manmade environment (housing and community services, such as hospitals, schools, traffic congestion, etc.).

This EA presents the need for the Pegasus air-launched booster in Chapter 2.0, followed by a detailed description of Pegasus assembly, transport, and mating to the B-52B; its flight to the WTR; and its launching in Chapter 3.0. Releases to the environment (source terms) are also presented in Chapter 3.0. The current environmental setting into which the proposed action is placed is described in Chapter 4.0. The potential environmental impacts of the proposed action (Chapter 3.0) on the environment (Chapter 4.0) are discussed in Chapter 5.0. Chapter 6.0 presents the permits and regulations under which the proposed action will be pursued.

2.0 PURPOSE AND NEED FOR ACTION

The Pegasus air-launched vehicle is part of the Advanced Space Technology Program of the Defense Advanced Research Projects Agency (DARPA). The program is designed to demonstrate high-payoff, advanced technology to improve space systems' operational support to military commanders. The government launch and demonstration of the privately developed Pegasus vehicle will be used to evaluate its launch flexibility and utility for support of military objectives as well as to place small experimental pay loads into orbit.

2.1 BACKGROUND

Over The past 25 years, the United States has maintained a national policy to promote the commercial development of space. From the Kennedy Administration's encouragement of private-sector ownership and operation of communications satellites to the Bush Administration's support of a commercial launch vehicle industry, each Administration and Congress has broadened the Government's support for private-sector space ventures. Since 1984, commercial firms have been able to request licenses from the U.S. Department of Transportation (DOT), in accordance with the Commercial Space Launch Act of 1984 (Public Law 98-575), for the right to launch commercial expendable launch vehicles from government facilities on a noninterference basis to place commercial satellites into orbit.

Orbital Sciences Corporation (OSC) was formed in 1982 to develop and operate commercial space transportation systems. OSC has developed the Transfer Orbit Stage (TOS) space transfer vehicle. TOS is currently in production to launch two high-priority National Aeronautics and Space Administration (NASA) satellite missions. Pegasus is being developed as a joint venture between OSC and Hercules Aerospace Company, which has also made significant commitments to the commercial space transportation business. The company constructed its Bacchus West complex, a new highly automated facility for the manufacturing of solid rocket motors. Hercules was recently awarded government contracts for the production of solid rockets for the Titan IV and Delta II launch vehicles, positioning it for commercial sales as well.

The Pegasus launch system is a three-stage solid-rocket-motor launch vehicle designed to be launched from a B-52B aircraft or similar large-lift aircraft, either government of private. DARPA has contracted for Pegasus launch services for two captive flights and two launches into polar orbit. Captive flights will be accomplished using an inert Pegasus, filled with concrete or selected fuel components to approximate the true weight of the Pegasus, as part of the ongoing research and development program. During captive flights, Pegasus will remain attached to the B-52B for stability and air-worthiness testing. The two launches will use fully functional and operational boosters. Options exist for an additional four launches. This environmental assessment addresses the potential environmental impacts from the six DARPA/NASA launches and assumes that the configuration of the Pegasus and its use of the B-52B remain as described in this report. The environmental impacts of the payloads are addressed separately.

2.2 PURPOSE

Pegasus provides the capability for economically launching small payloads from any accessible airborne location and the flexibility to place a small payload into any orbit over any geographic region. It also provides for launch vehicle survivability via mobility.

2.3 NEED

Small satellites provide the research and development capacity to test concepts in space before they are incorporated into larger and more expensive operational satellites. They or other small payloads also provide a relatively inexpensive means to conduct basic research related to the earth and to space. In the past, these small payloads would typically ride piggyback with the operational satellites. When riding piggyback, the small satellite had to accept the launch position (orbit) selected for the operational satellites, thereby potentially reducing its effectiveness. In the past, small satellites that had a dedicated launch would use the land-launched Scout booster. All the existing Scout boosters have been reserved for missions, and there are no plans to reopen production. With the Shuttle and other failures of expendable launch vehicles, small satellites have not been launched. (These alternatives are discussed further in Section 3.2.).

3.0 PROPOSED ACTION AND ALTERNATIVES

3.1 PROPOSED ACTION

The proposed action for this environmental assessment (EA) consists of the transportation of rocket motors from Magna, Utah, to Edwards AFB; operation of the Ground Support Facilities including assembly of the components into a fully functional Pegasus booster; transport and mating of the Pegasus to the B-52B; takeoff and flight of the B-52B (with Pegasus) west across the California coastline and into the WTR; launch of the Pegasus space booster within the WTR; and landing of the B-52B at Edwards AFB (Figure 3.1). This EA addresses the potential environmental impacts of the six proposed Pegasus launches, two launches confirmed with four others depending on availability of small payloads to be launched.

3.1.1 Transportation of Pegasus Rocket Motors to Edwards Air Force Base

Pegasus rocket motors will be delivered in a truck transportation trailer called the TARVAN, approved by the DOT in accordance with 49 CFR 171 to 179 and 49 CFR 350 to 399. The TARVAN is a specially designed covered trailer measuring about 18 m (60 ft) long and 3 m (9 ft) wide.

Each Pegasus vehicle will require two shipments form Hercules Aerospace Company, Magna, Utah, to Edwards AFB in the TARVAN by a commercial trucking firm. The second- and third-stage motors will be transported together; the first-stage motor will be shipped separately because of its size. The primary route of Pegasus transport will most likely be from Magna, Utah on U.S. Highway 15, through Las Vegas, Nevada, into California. The TARVAN will proceed to Barstow where it will most likely turn west on California State Highway 58 to the North Gate of Edwards AFB. The total distance is about 1,120 lm (700 mi). About 12 rocket motor shipments are planned for the six potential rocket assemblies.

When rocket components arrive at Edwards AFB, they will be transported through the base to the Pegasus Ground Support Facilities located within the NASA DFRF adjacent tot the western edge of Rogers Dry Lake (Figure 3.2).

3.1.2 Operation of the Ground Support Facilities

The Ground Support Facilities consist of a double-wide office trailer and a Butler®-type steel building called the Vehicle Assembly Building (VAB). The final assembly of all components will take place on the Assembly Integration Trailer (AIT) within the VAB. At no time will the Pegasus be lifted by crane.

The VAB measures about 24 by 18 by 5 m (80 by 60 by 16 ft) high. The construction of these facilities was addressed in a United States Air Force (USAF) Categorical Exclusion and support documents. The layout of the VAB is shown in Figure 3.3. Included within the VAB will be a 8-by-9-m (25-by-30-ft) test equipment room (maintained at positive pressure to ensure clean room conditions during equipment testing and some phases of payload integration) and a class 10,000 clean room (used for payload mating). Chemical and hazardous waste storage will be outside the building within a cyclone-fenced area on concrete. Utilities including electrical service, and ordnance grounding system, and fire and potable water are supplied from existing Edwards AFB systems. The building will have temperature and humidity

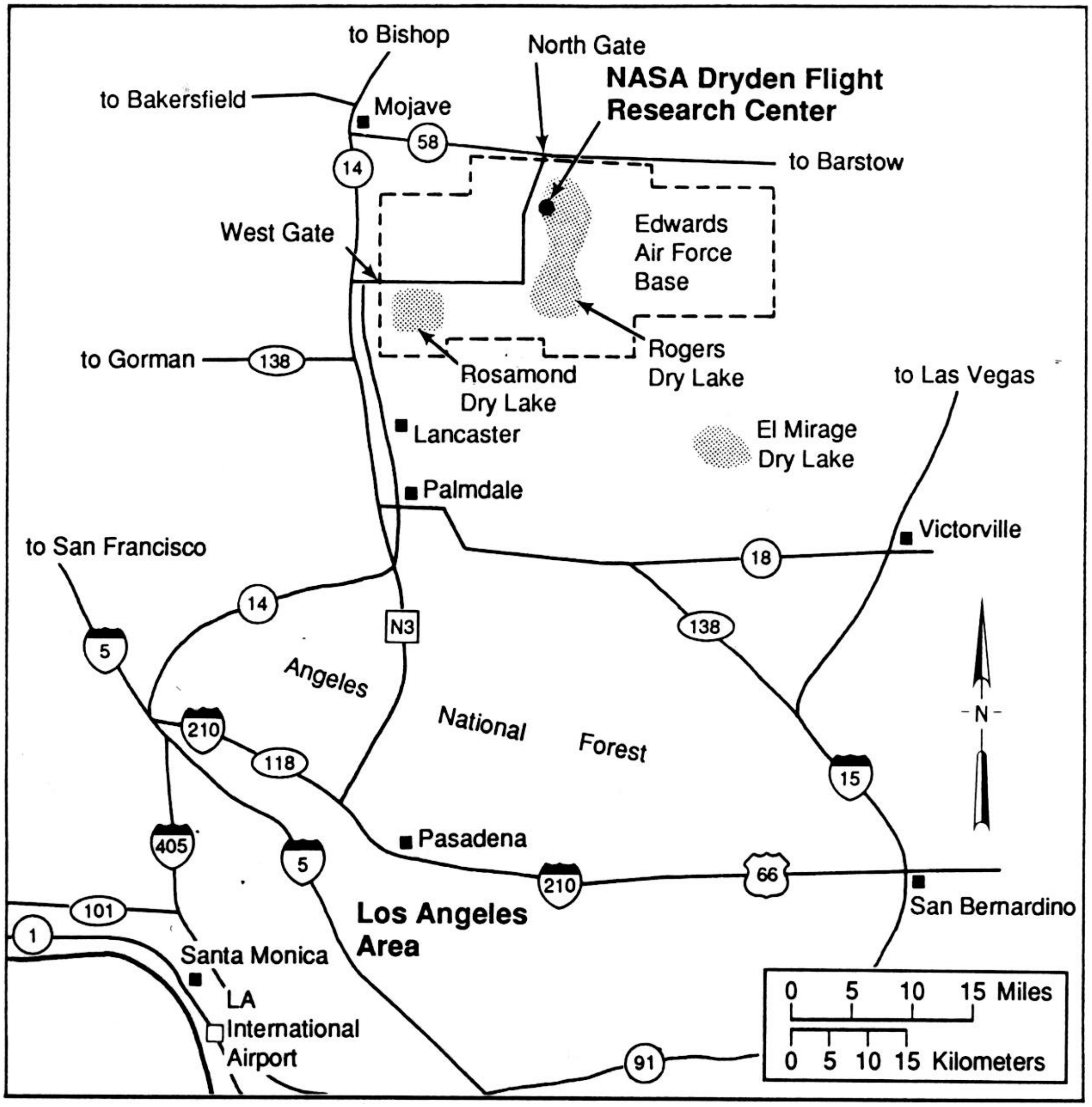


FIGURE 3.1. Edwards Air Force Base and Local Region

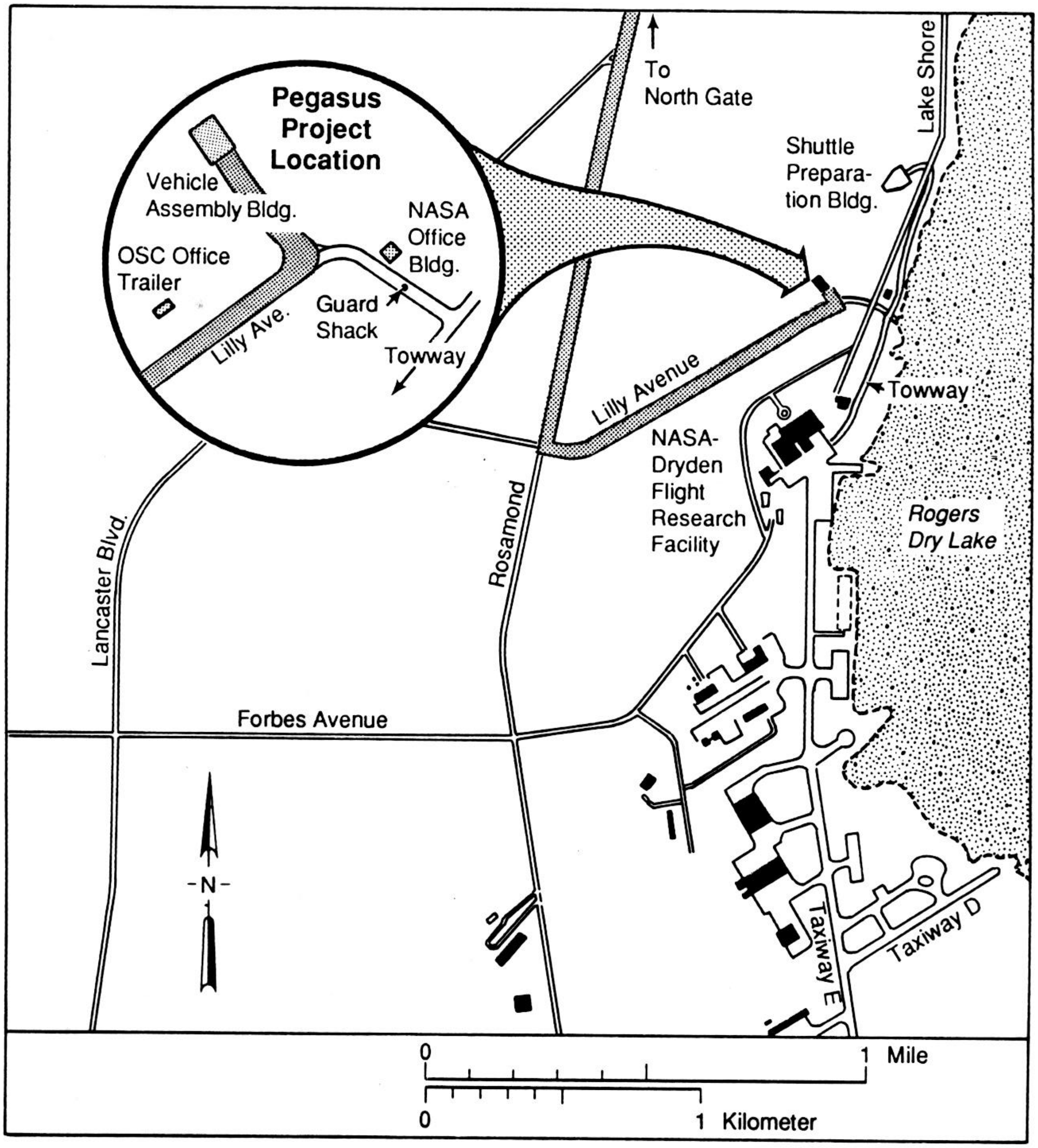


FIGURE 3.2. NASA Flight Research Center

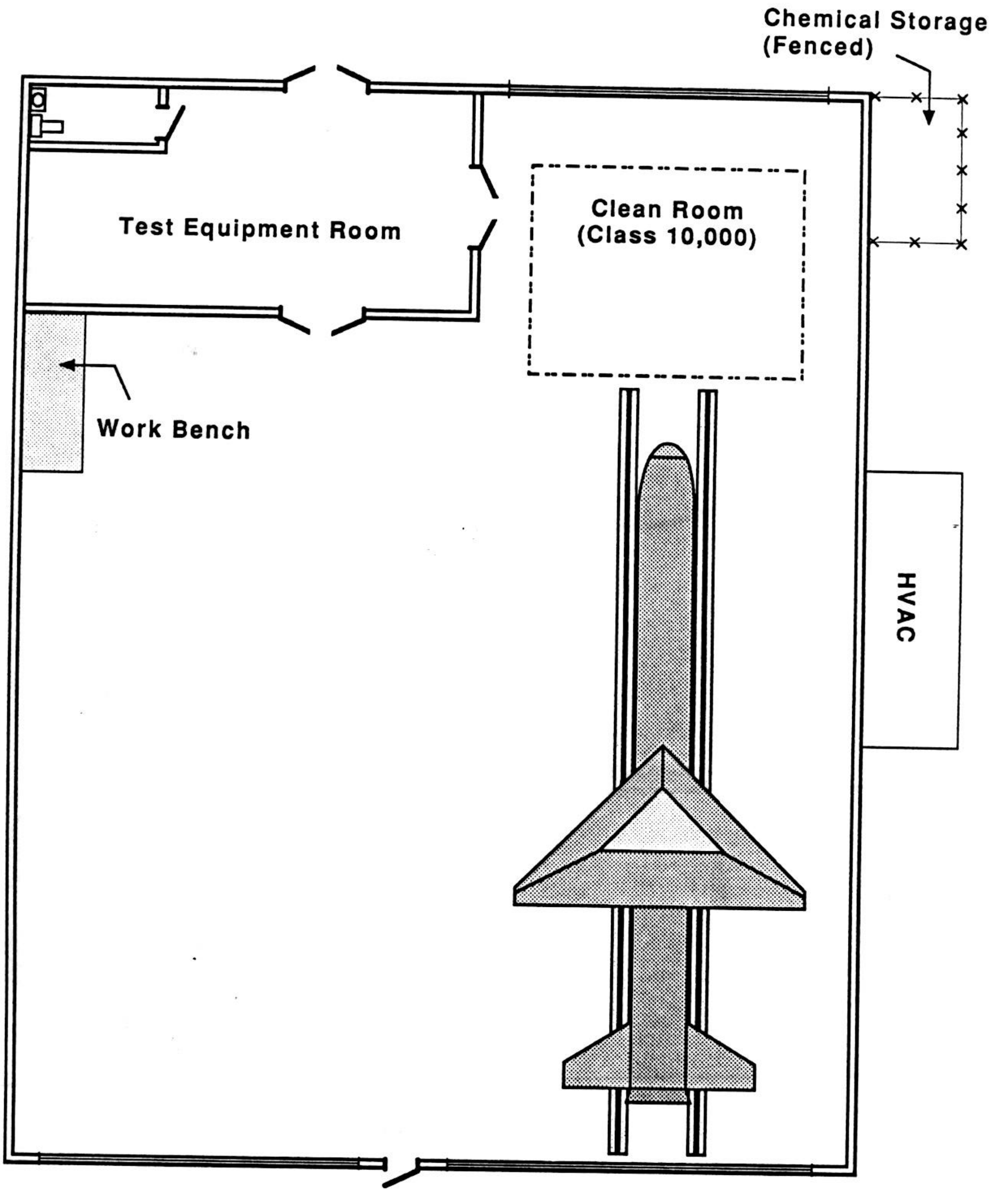


FIGURE 3.3. Interior Layout of the Vehicle Assembly Building

control [heating, ventilating, and air conditioning (HVAC)]. The ordnance grounding system surrounds the entire building and will be particularly important as a source of electrical grounding to rocket components during the assembly process. The floor is painted with a conductive paint.

3.1.2.1 Rocket Assembly

The assembly of the Pegasus air-launched booster will proceed in three steps: 1) motor build-up, 2) testing, and 3) closeout.

Motor Build-up. Upon arrival at Edwards AFB, rocket components will be transported to the VAB. The base will have been supplied with the technical data, and the driver will also have the technical data for that particular motor in accordance with AFFTC Supplement 1 to AF Regulation 125.14. In case of an accident, prior reviews of technical data will inform fire and police departments about the chemical composition of the motors and the best way to combat a fire.

Hercules will construct the nose fairing out of composite materials, then send it to Space Data at Tempe, Arizona, where it will be coated with thermal ablative material (Thermolag™ and SLA™] and sent back to Edwards AFB. The wing, fins, and aft skirt assembly, built by Scale Composites in Mojave, California, will also be coated with Thermolag and SLA in Tempe before being shipped to Edwards AFB.

During Pegasus assembly in the VAB, isopropyl alcohol will be used to clean the electronic mating surfaces and ground connections of any oils or other materials that could interrupt an electrical connection. Chemical usage is quantified in Section 3.1.2.2. Alcohol-soaked rags will be disposed of as solid wastes.

There will be four 28-V silver cell batteries to power the avionics. A premeasured amount of potassium hydroxide (KOH) form plastic bottles will be put into the cells. If the batteries are activated in accordance with the procedures, there should be no spillage of KOH within the VAB. The empty KOH bottles will go to NASA hazardous waste storage for disposal. Before each electronic component is installed on a bracket, the brackets will be cleaned with alcohol and in some cases Contact Renew™ (aerosol Freon™). The Freon will be used only when contacts cannot be reached by hand. It is estimated that four or five small aerosol can [0.47 L (~16 oz)] would be used for each rocket assembly.

Before bonding the wing to the first-stage motor, a perchloroethylene-dampened rag will be wiped over the surface to clean it. The rag will then be disposed of as solid waste. A fiber-glass-like material with resin and hardener (the fillet) will be used to "mold" the wing to the first-stage motor. RF 4000 resin™ and RF 14 hardener™ will be used to install the fillet to the motor. Less than a half a gallon of resin and one-half ounce of hardener will be used to install the fillet.

After assembling fins and the three stages, thin strips in the pretreated surfaces need to be covered with thermal ablative material. The material (Thermolag and SLA) will be kept in small quantities at the VAB for this purpose.

Testing. Component testing will involve a simulated flight with the exception of motor ignition. All components, motor ignition, stage separation, flight termination, and all ordnance events will be electronically simulated. When the tests have been successfully completed, the stages will be mated, and function tests will be run to ensure that all systems are still functional.

Closeout. The last procedure is the ordnance hookup and systems closeout. A portable clean room is installed around the nose of the rocket for payload mating. Isopropyl alcohol, perchloroethylene, and Freon will be available if needed.

3.1.2.2 Materials Usage and Workforce

Chemicals used during certain component assembly procedures are identified above. These chemicals and the estimated volumes used per rocket assembly are also shown in Table 3.1. All chemicals used will be present in quantities ranging from single 0.47-L (16-oz) aerosol cans up to 1 gal for isopropyl alcohol. In all cases, only the amount of chemical required for a specific job will be opened and available for distribution into the work area atmosphere at any one time. All chemical usage will be in accordance with USAF and NASA personnel safety and environmental release procedures.

Manpower requirements for the assembly of the Pegasus rocket include 12 temporary workers who will be flown in for each assembly (about 2 weeks duration) and then flown home. About eight fulltime people will reside in the vicinity of Edwards AFB and use available community services.

3.1.2.3 Chemical Storage

Chemicals will be delivered to the VAB before each rocket is assembled. Chemicals will be stored in chemical lockers on a concrete pad adjacent to, but outside of, the VAD and enclosed in a covered wire-mesh protected area. Chemicals will be stored in a manner that is consistent with AFOSH Std. 161-21, and state and federal regulations. Long-term storage of chemicals is not planned.

TABLE 3.1. Materials Used during Pegasus Assembly

Material	Volumes Used for Assembly
Triethylenetetramine RF-14 hardener™	0.029 L (1 oz)
RF 4000 resin™	<1.9 L (2qt)
Perchloroethylene	<1.9 L (2qt)
Epon (R) resin 828™	0.95 L (<1 qt)
Versamid 140™	0.95 L (<1 qt)
Potassium hydroxide	kit
Isopropyl alcohol	3.8 L (1 gal)
Contact Renew™ Aerosol (Freon™)	4 to 5 0.47-L (16-oz) cans
Woven graphite	1.0 to 1.4 m^2 (10 to 15 ft^2)

3.1.2.4 Hazardous Waste Containment and Disposal

Hazardous wastes will be handled and stored in compliance with NASA and Edwards AFB Regulations, AFOSH Std. 161-21, and 29 CFR 1910.120. Chemical usage will result in the generation of 4.5 kg (<10 lb) of solid hazardous waste per year. No liquid wastes will be generated. Minor atmospheric releases will occur from small open containers of volatile cleaners, Freon, and fiber-glass resin. The solid hazardous wastes will be packaged, labeled, and stored for pickup by base personnel and offsite disposal in accordance with all state and federal regulations and the Hazardous Materials and Hazardous Waste Management Plans for NASA and Edwards AFB. Atmospheric releases are estimated to result from use of chemicals during rocket assembly. An estimate of the resulting personnel exposure to these chemicals is presented in Section 5.2.1.

3.1.2.5 Personnel Safety

Special breathing protection will probably not be required to protect personnel assembling the Pegasus. However, use of air-purifying respiratory protection, airline respirators, and safety clothing is being researched, and these items will be provided if necessary. Eyewash stations are provided in the VAB. All necessary safety equipment will be in place before any chemical use or rocket motor delivery.

3.1.2.6 The Pegasus Booster

The product of the VAB will be a fully functional Pegasus booster. The Pegasus system is an inertially guided three-stage launch vehicle. It is capable of placing approximately a 190-kg (425-lb) payload into a 400-nautical mi circular polar orbit. Vehicle pay load capacity is 1.2 m (46 in.) in diameter and 1.8 m (72 in.) in length, with a volume of 1.8 m^3 (65 ft^3). A Pegasus cutaway is presented in Figure 3.4.

Propellant. The Pegasus booster is composed of three Class 1.3 solid-propellant motor stages. The general stage descriptions are shown in Table 3.2. All three stages have graphite composite cases with aramid-filled internal insulation to encase the solid propellant (Table 3.3) common to all three stages. As shown in Table 3.3, about 95% (wt) of the 115,900 kg (35,000 lb) of propellant is composed of the fuel, oxidizer, and binder. The remaining constituents comprise approximately 5% (wt) of the propellant mixture and include a wetting agent (HX-752™), a free radical initiator (TPB™), and plasticizers (Polyguard HR, ™ DOS, ™ DDI, ™ IPDI, ™ and maleic anhydride).

The booster system employs Class 1.4 separation ordnance for staging. A payload fairing caps the booster assembly and is separated from the booster during the firing of the second stage. Six small cold-gas thrusters are used for rocket control after leaving the earth's atmosphere. The thrusters use nitrogen gas as propellent.

3.1.3 Transport and Mating of the Pegasus to the B-52B

Once final assembly is complete, the Pegasus is ready for transport to the B-52B. The AIT will be raised by six 45,400-kg (50-ton) jacks, then lowered onto wheeled axles. The trailer will then begin its 2.4-km (1.5-mi) trip to the B-52B. The Pegasus will travel about 275 m (900 ft) east to a tarmac strip located on Rogers Dry Lake. During this segment, the Pegasus will pass within 38 m (125 ft) of only one building, the NASA Office Building, which contains about 50

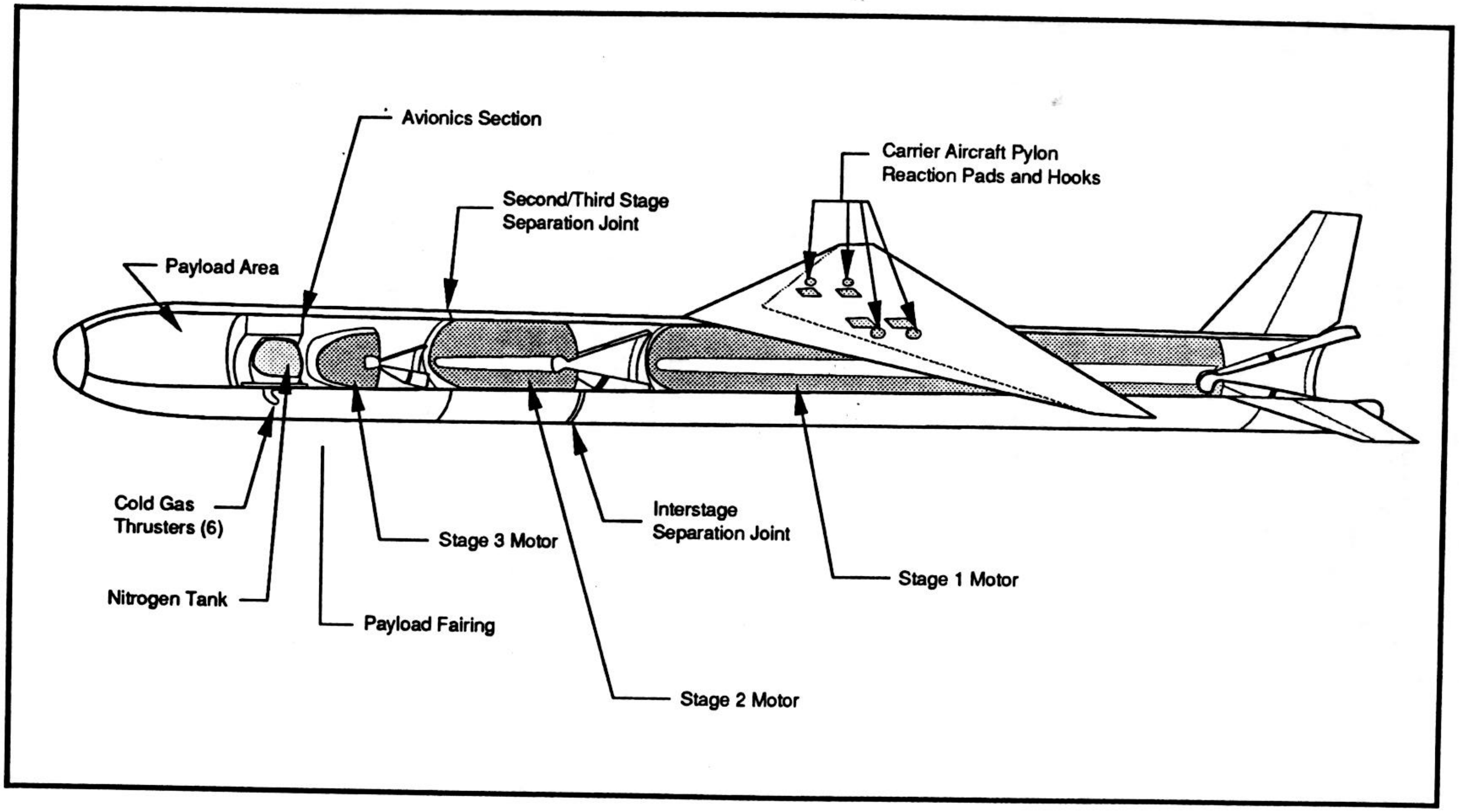


FIGURE 3.4. Pegasus Cutaway Drawing

TABLE 3.2. Physical Characteristics of the Pegasus Rocket

	Length, m (ft)	Width, m (ft)	Solid Fuel, kg (lb)
Stage 1	8.9 (29.2)	1.3 (4.2)	12,000 (26,800)
Stage 2	3.1 (10.3)	1.3 (4.2)	3,030 (6,678)
Stage 3	1.2 (3.8)	1.0 (3.2)	780 (1,725)

TABLE 3.3. Composition of Solid Rocket Fuel

Constituent	Identification	Percent Composition (wt)
Binder		
HTPB	Hydroxyl terminated polybutadiene	7.138
Fuel and Oxidizer		
Al	Aluminum	19.0
NH4ClO4	Ammonium perchlorate	400 m-33.8 200 m-20.0 20 m-15.2
Other Components		
HX-752	Liquid aromatic Difunctional aziridine	0.3
Polyguard HR	Tri (mixed mono- and dinonylphenyl) phosphite with triisopropanolamine	0.12
DOS	2-methoxy sebacate	3.564
DDI	Dimeryl diisocyanate	0.818
TPB	Triphenyl bismuth	0.03
C4H2O3	Maleic anhydride	0.03

people, and pass by one occupied guard shack (Figure 3.5). If the rocket is transported during working hours, occupants of the NASA Office Building will be asked to move to the back of the building during passage in accordance with AF Regulation 127-15.

After reaching the tarmac, the Pegasus will travel about 2.4 km (1.5 mi) to the waiting B-52B, where it will be mounted and carried under the wing of the pylon-equipped aircraft.

3.1.4 B-52B Flight to the Western Test Range

The B-52B will taxi to runway 22, a 4,575-m (15,000-ft)-long runway. The B-52B will begin its takeoff and, upon reaching about 266 km/hr (165 mph), will leave the ground. Accompanying the B-52B aircraft will be an F-18 and/or T-38 chase plane. The B-52B will climb to an altitude of about 6,100 m (20,000 ft) before crossing the Edwards AFB boundary, about 16 km (10 mi) from liftoff.

3.1.4.1 B-52B Launch Vehicle

The B-52B Stratofortress (Figure 3.6) is modified land-based heavy bombardment aircraft originally designed for high-altitude bombing of surface objectives. The B-52B is 47.9 m (157 ft) long and has a wingspan of 56.4 m (185 ft). The top of the tail (vertical stabilizer) reaches a little over 15 m (48 ft) above the ground. The design gross weight of the B-52B with the Pegasus onboard is 140,000 kg (310,000 lb).

3.1.4.2 B-52B Fuel

The B-52B is powered by eight J57-P-19W turbojet engines that burn JP-4 jet fuel. The maximum burn rate occurs during takeoff where about 1,270 kg (2,800 lb) of fuel are used from brake release to best takeoff speed. The USAF lists a variety of combustion products for the B-52B model, as shown in Table 3.4.

3.1.4.3 Noise Generated by the B-52B

Noise generated by the B-52B will be greatest during takeoff. Noise profiles during takeoff are about 140 to 150 decibels (dB) at 30.5 m (100 ft) and 130 to 140 dB at 92 m (300 ft), and decrease to about 120 to 130 dB at 214m (700 ft) from the aircraft.

3.1.4.4 Flight

The flight for the Pegasus will begin at Edwards AFB. The B-52B carrying the Pegasus will take off from Edwards AFB climbing toward the town of Paso Robles. The aircraft will turn northwest about 70 km (40 mi) east of San Luis Obispo at approximately 30 min into the flight. Operating altitude of about 12,200 m (40,000 ft) will be reached over the Pacific Ocean some 44 min into the fight. A turn will be executed near the Farallon Islands 55 min into the flight, resulting in an approximate heading of 0° south-southwest. The Pegasus rocket will be launched in this direction 65 min after takeoff. The launch point is about 160 km (100 mi) off the California coast and about 360 km (220 mi) from the Channel Islands, at an altitude of about 12,200 m (40,000 ft). The airplane will then return to Edwards AFB. Total time from takeoff to landing is expected to be 1 hr and 52 min, with a total distance covered of 1,130 km (610 nautical mi).

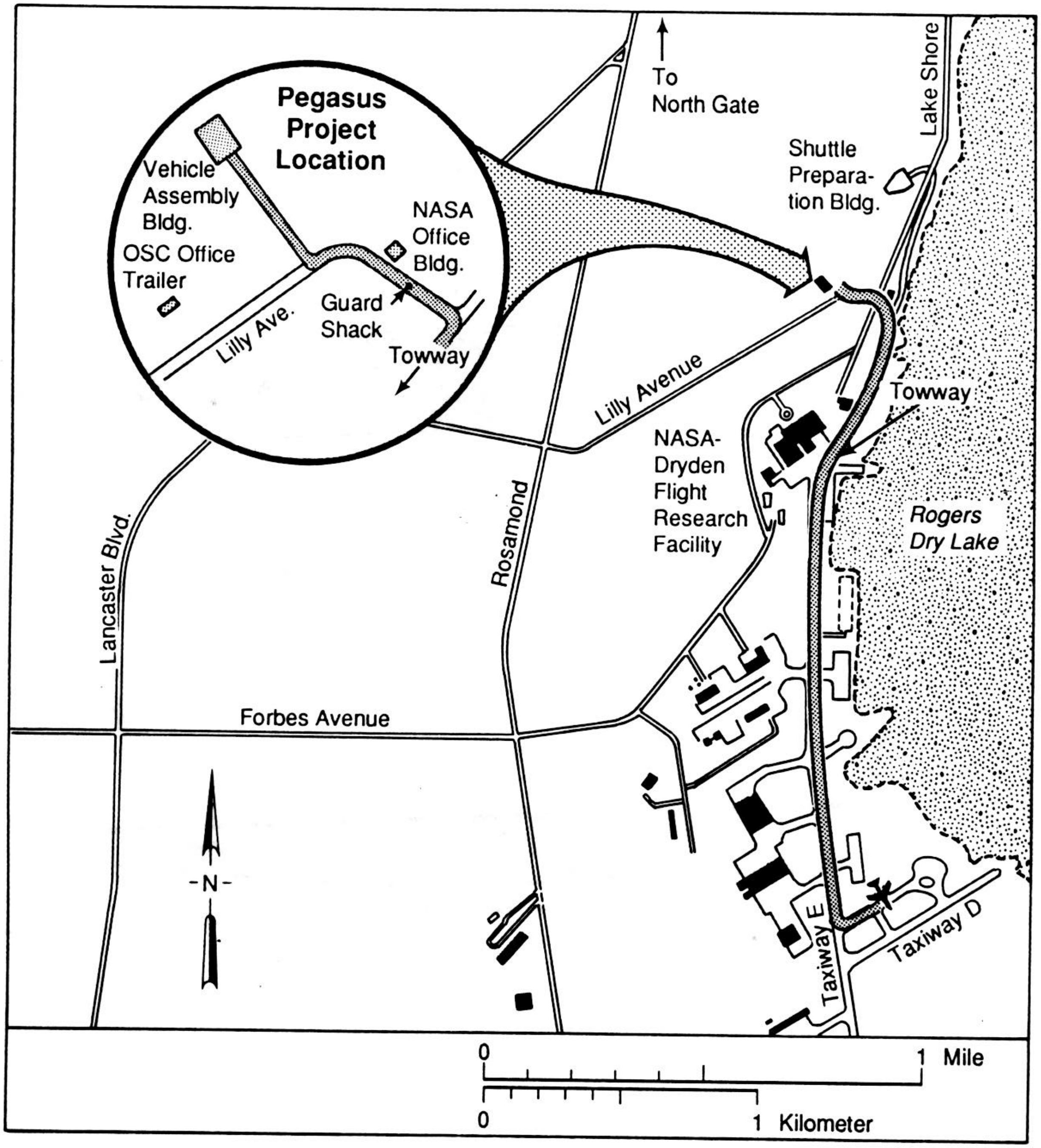


FIGURE 3.5. Transportation Route to the B-52B

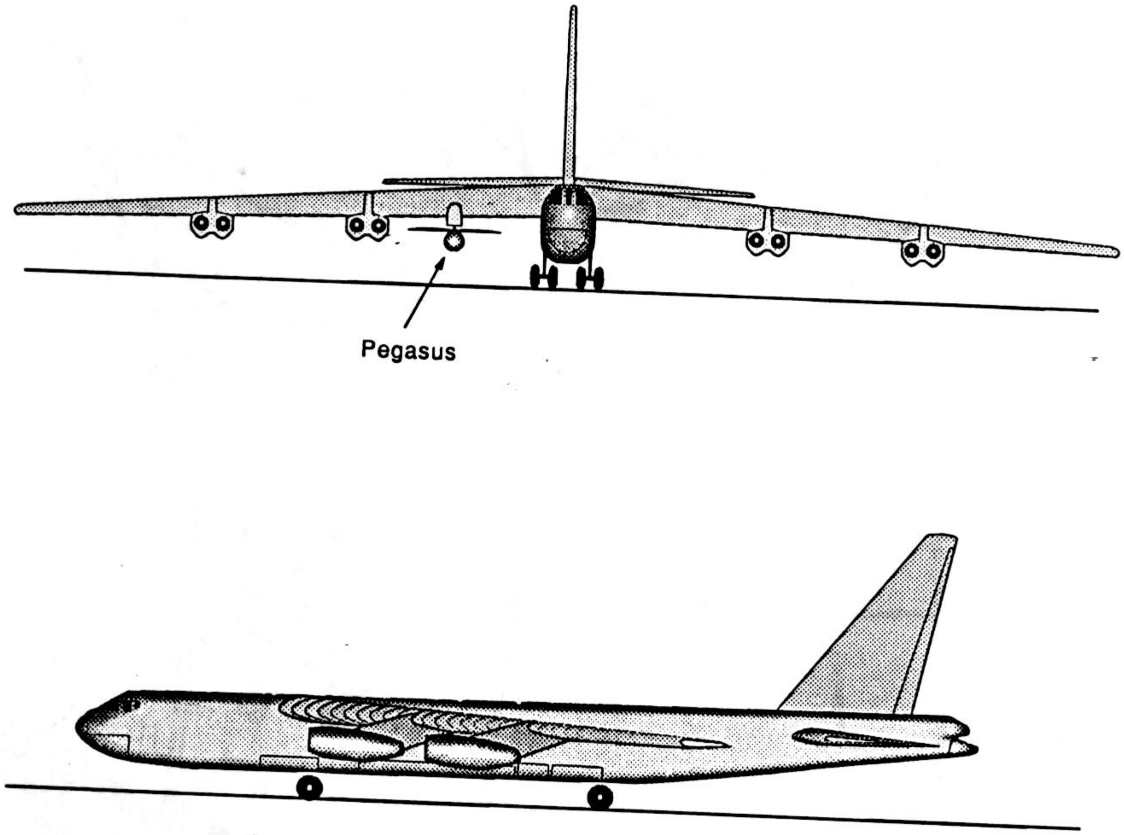


FIGURE 3.6. B-52B STRATOFORTRESS

TABLE 3.4. Combustion Products from a B-52B Model

	Combustion Products, g (lb)/1,000 lb Fuel			
	CO	CxHy	NOx	Total Particulate
J57-P-43W Turbojet Engine	862 (1.9)	45 (0.1)	4,994 (11.0)	781 (1.72)

3.1.5 Pegasus Flight

3.1.5.1 Pegasus Launch and Flight Plans

The first stage of the Pegasus rocket will ignite 5 sec after launch from the B-52B (Figure 3.7). This stage will burn for 77 sec, lifting the craft to an altitude of 68,000 m (223,00 ft). Ignition of the second-stage booster will follow some 3.5 sec later at an altitude of 72,900 m (239,000 ft). The spent first stage will be jettisoned to fall and impact in the ocean (Figure 3.8) (studies are under way to determine if this stage can be recovered).

Burnout of the second stage will come some 160 sec into the mission after reaching an altitude of 210,000 m (689,000 ft) and a velocity of 53,000 m/sec (17,500 ft/sec). During this burn, the payload fairings will be jettisoned. Ignition of the third and final stage will occur 578 sec into the mission, carrying the payload to orbital insertion approximately 643 sec after launch and some 463 km (250 nautical mi) downrange from the launch site. The spent second stage will fall back to impact in the Pacific Ocean (Figure 3.8). Actual launch profiles will vary according to the payload weight and the characteristics of the desired orbit.

3.1.5.2 Rocket Discharges of Combustion Products

The actual measured combustion product data in Table 3.5 are the source terms used to assess potential air quality impacts in Chapter 5.0 from routine Pegasus operations. The Al-containing combustion species include AlCl, $AlCl_2$, $AlCl_3$, AlO, AlOH, AlO_2H, and liquid Al_2O_3, and account for 165.5 g of each lb of fuel. It can be assumed that the equilibrium products of these species will be aluminum oxides. By calculation, combustion of 15,900 kg (35,000 lb) of fuel should yield 5,770 kg (12,700 lb) of Al species. The major gaseous components include CO [3,400 kg (7,480 lb)], CO_2 [318 kg (702 lb)], GCl [2,860 kg (6,290 lb)], H_2 [317 kg (700 lb)], H_2O [1,360 kg (3,000 lb)], N_2 [1,270 kg (2,800 lb)], and NO_X [1,290 kg (2,850 lb)]. Only traces [4.5 kg (<10 lb)] of Bi salts, HNO_3, and H_3PO_4 will be formed. The other three products, Cl, H, and OH, are radicals that would likely react with other fuel combustion products such as Al. Of the major combustion product contaminant groups, Al compounds and hydrochloric acid (HCl) represent no more than 35% and 17%, respectively. Gaseous species, including H_2O (8%), CO (20%), N_2 (8%), and NO_X (8%), account for 46% of the combustion products. The deposited Al material would not likely impact biotic organisms based on the natural abundance of Al in environs. While HCL would not be expected to have any lasting environmental effects once deposited, its acidity could adversely impact both vegetation and animals via inhalation. Therefore, HCl is considered the major contaminant of concern, and its impacts are assessed in Chapter 5.0.

TABLE 3.5. Pressurized Burn Components for Normal Rocket Configuration, 1,000 psi (Hercules Aerospace Company) (a)

Chemical Species		g/lb Fuel
Al		8.5E-2
AlCl	*	6.2
$AlCl_2$	*	3.0
AlCl3	*	4.3E-1
AlH_{28}		1.5E-2
AlN		1.7E-2
AlO	*	2.1E-1
AlOCl	*	2.7
AlOH	*	4.0E-1
AlO_2		7.6E-2
AlO_2H	*	1.3
Al_2O		8.5E-2
Al_2O_2		1.9E-2
Bi		2.8E-2
BiH		2.2E-5
BiO		2.5E-3
Bi_2		6.4E-8
PN		2.8E-3
CH_2O		1.2E-3
CH_4		6.7E-6
CN		4.4E-5
CO	*	97
COCl		1.4E-2
CO_2	*	9.1
Cl	*	7.6
ClO		8.9E-3
Cl_2		5.8E-2
H	*	6.8E-1
HAlO		6.3E-1
HCN		3.9E-3
HCO		1.4E-2
HCP		1.8E-6
HCl	*	82
HNO		8.4E-4
HNO_2		1.2E-5
HOCl		1.5E-2
HO_2		4.8E-4
H_2	*	9.1
H_2O	*	39
N		2.1E-3
NH		1.2E-3
NH_2		2.2E-3
NH_3		4.5-3
NO	*	3.6E-1
NO_2		4.7E-5
N_2	*	36
O		2.1E-1
OH	*	2.7
ONCl		1.2E-4
O_2		7.9E-2
O_2NH		1.1E-5
P		1.8E-4
PCl		8.0E-5
PH		1.3E-4
PH_2		6.7E-5
PO		1.2E-2
PO_2		5.1E-3
P_2		1.1E-7
Al_2O_3		1.5E+2

(a) Mass balance = 450 g components/lb fuel. Major constituents (*) account for 449 g of 450 g fuel.

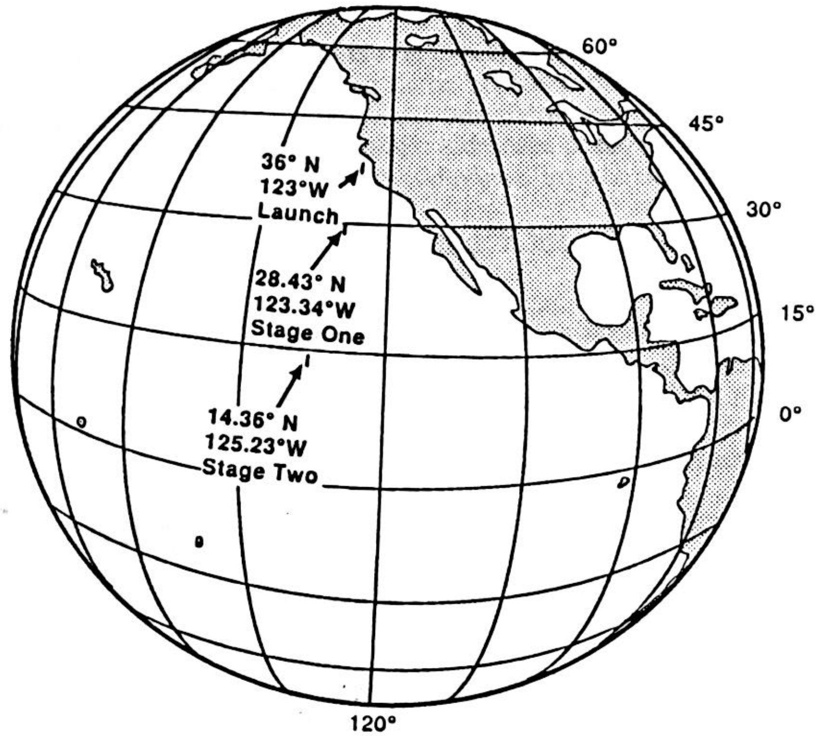


FIGURE 3.8. Expected Impact Locations of the Pegasus Stages

3.1.5.3 Emergency Destruction

Once the Pegasus computer senses loss of electrical ground upon separation from the B-52B, the Flight Termination System (FTS) automatically arms itself. For the duration of flight (until the Pegasus reaches orbit), the FTS will be able to end the flight by destroying the vehicle. The FTS receives and resonds to commands form the command transmitters under the control of the Flight Safety Officer. The FTS is a redundant system.

If it becomes necessary to destroy Pegasus after launch, it is necessary to be able to predict where the pieces of Pegasus will fall. The instantaneous impact points on earth for the Pegasus booster fragments have been calculated for multiple times throughout the flight profile of the preliminary trajectory to be followed by Pegasus after launch (OSC 1988).

3.1.6 Landing of the B-52B

After launching the Pegasus, the B-52B will leave the WTR for its return flight to Edwards AFB.

3.2 ALTERNATIVE LAUNCH VEHICLES

DARPA developed the air-launched booster concept under congressional direction to provide an inexpensive access to space. Air launching has several advantages over launching from the ground, such as less fuel required per mass of rocket (air launches can get rockets above most of the atmosphere and provide forward momentum). Below are the alternatives evaluated.

3.2.1 Use the Scout Booster

The Scout booster is a land-launched vehicle that has been in service since the 1950s providing excellent service into space for small payloads. There are only six Scouts remaining, all of which have been assigned payloads and are not available for new small satellites. The last Scout was built in 1980. The cost to assemble additional Scouts is two to three times that of an air-launched vehicle ($12 to $18 million/vehicle).

3.2.2 Ride Piggyback on Larger Boosters

In the past, small satellites often only had to pay integration costs. Whit the loss of Challenger, as well as the series of expendable launch vehicle accidents, the opportunity to ride piggyback has been diminished. A disadvantage to riding piggyback was that the small satellite had to travel with the larger satellite (launched together) and use whatever orbit the larger satellite was using. For the same cost as integration on a larger booster, a small satellite can fly on an air-launched small booster to its desired target orbit.

3.2.3 Combine Requirements (Satellites) and Buy a Larger Booster

There are not enough small satellites going to the same orbits within a reasonable time period to support this alternative.

3.2.4 Develop a New Ground-Launched Vehicle

Developing a new ground-launched vehicle would require building a new launch facility and would be more costly than an air-launched vehicle.

3.2.5 Develop a New Air-Launched Vehicle Such as the Pegasus

This alternative provides the least-cost alternative (about half the cost of the next most inexpensive alternative), offers safety features that a ground launch cannot supply, and puts twice as heavy a payload into orbit as would a similar sized ground-launched vehicle.

3.3 ALTERNATIVE LAUNCH SITES

3.3.1 Vandenberg Air Force Base

Vandenberg AFB is the traditional launch site for vehicles delivering payloads into polar orbit. Although Vandenberg AFB does have a runaway that can accommodate a B-52B, all control activities and aircraft/Pegasus compatibility testing must be conducted at Edwards AFB after takeoff. The inert flights have to be based out of Edwards AFB for safety reasons and aircraft/Pegasus compatibility testing. Therefore, the use of Vandenberg for B-52B liftoff would require two processing locations.

3.3.2 Cape Canaveral Air Force Station

Cape Canaveral is the launch site for most of the vehicles required to put payloads into equatorial orbits. If a B-52B carrying an air-launched vehicle were to take off from the Cape, it would be required to launch in the Easter Test Range. This range is restricted to launching payloads into equatorial orbit. There is no range set aside for obtaining polar orbits form the Cape.

Using the Cape for B-52B liftoff would also require two processing facilities (Edwards AFB and Cape Canaveral) and then require the B-52B to cross the United States to launch in the WTR.

3.3.3 Non-Military Sites

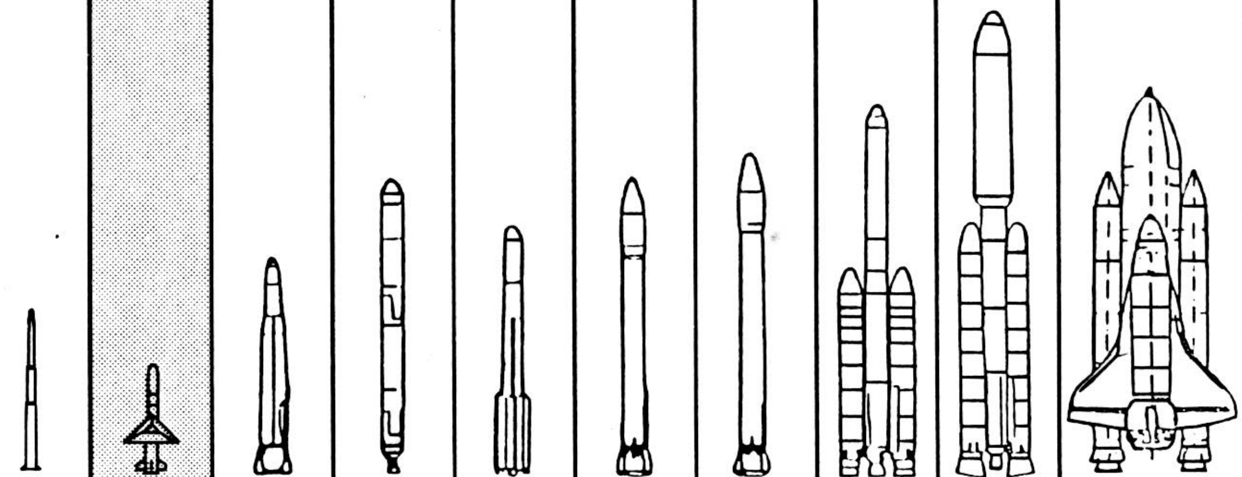
The Pegasus, when commercialized, will be able to be launched from any airport that can accommodate the carrier aircraft. For ease of operations and because of the experimental nature of the first launches, it was deemed best to operate out of a controlled military base.

3.4 NO ACTION ALTERNATIVE

The no action alternative would be contrary to the avowed Congressional intent expressed as follows:

> "It is therefore recommended that DARPA continue with this program (which includes Pegasus) as previously briefed to the Congress and to accentuate involvement of the emerging commercial space industry, in particular private launch firms. In this regard, the conferees direct that not less than $13,000,000 be allocated for SSLV [Standard Small Launch Vehicle]" (Conference report on HR 4781, September 28, 1988).

In addition, small payloads would not be allowed access to space, and the commercialization of space would become more difficult. The current commercial industry is using military-developed boosters, such as Atlas, Delta, and Titan boosters (Figure 3.9). The Pegasus project will follow established procedures for commercial launches and pay for use of government facilities and equipment. Payloads always have the option to launch on larger boosters and even to use foreign boosters. By not implementing Pegasus, users, both government and commercial, will have to pay at least twice as much as the cost of the satellite for the launch. The lower cost of the Pegasus should stimulate the industry to further make use of space.



	Scout	Pegasus	Atlas-E	Titan II SLV	Delta/ Delta II	Atlas Centaur	Atlas Centaur II	Titan 34D	Titan IV (SRMU)	STS
Responsible Agency	NASA	DARPA	USAF	USAF	NASA/ USAF	NASA	USAF	USAF	USAF	NASA
Low Earth (1) Polar Orbit lb of Payload	460	840	3800	4200	5500/ - -	- -	- -	27,600	32,000 (38,600)	~~TBD~~
Low Earth Equatorial Orbit (Due East) lb of Payload	570	1100	- -	- -	7600/ 11,100	12,300	14,300	32,900	39,000 (47,000)	51,000

(1) Less than 500 nautical miles

FIGURE 3.9. Commercial Industry Military-Developed Rocket Boosters

4.0 AFFECTED ENVIRONMENT

The following chapter describes the existing environment within which the proposed action would occur. Information presented here provides the foundation for the analyses of environmental impacts presented in Chapter 5.0.

This chapter is divided into three environments: Edwards AFB, the B-52B flight corridor, and the WTR. Within each of the environmental descriptions will be found only those components of the environment that may be affected by implementation of the proposed action or alternatives.

4.1 EDWARDS AIR FORCE BASE

The activities proposed for Edwards AFB include Pegasus component assembly within the Ground Support Facilities, transport of the booster to the B-52B, and runway use by the B-52B to take the Pegasus to the WTR. The proposed effluents form the Ground Support Facilities and the temporary and permanent workforce added to the Edwards AFB population (see Chapter 3.0) are insignificant; therefore, the ground water, surface water, and socioeconomic environments in and around Edwards AFB will not be characterized.

4.1.1 Geology and Soils

Edwards AFB is located in the western portion of the Mojave Desert of Southern California at an elevation of approximately 700 m (2,300 ft). 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 maintains 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. Rock outcroppings, ranging form small single rocks to small mountain or ridge formations, spot the ground surface.

Soils 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 slopes of mountains have shallow surface soils covering bedrock. Ridge tops are composed primarily of rock, with a sparse covering of soil.

The soil types at the Dryden Flight Research Facility and Edwards AFB have been previously characterized (NASA Land Resources Plan 1979). The soils immediately adjacent to the VAB and transport path to the flightline at Edwards AFB are generally uniform in type. These are composed of 0.6- to 2-m (2- to 7-ft) deep slightly sloping, silty sand topsoils that overlay a quartz monozonite bedrock. These are alkaline well-drained soils down to the bedrock portion.

The site of B-52B/rocket mating and the runway to be used for takeoff occupy portions of Rogers Dry Lake southeast of the VAB. The dry lake is composed of playa clay, a smooth, level, very dense, alkaline material. This region has poor drainage and is devoid of vegetation (NASA Land Resources Plan 1979).

4.1.2 Meteorology

The Tehachapi Mountains to the west and northwest of Edwards AFB and the San Gabriel Mountains to the south generally block the flow of moist maritime air to the Mojave Desert. The climate is characterized by low rainfall with hot dry summers and mild winters.

The temperature in the summer reaches mean maximums of 98°F in July with a minimum in the mean maximum of 56°F in January (Rarick 1984) (Table 4.1). The number of days with temperatures above 100°F average 35 days, while an average number of 66.8 days have a mean temperature below 32°F. The relative humidity tends to be lowest in summer with a maximum of 56% in January and a minimum of 27% in July.

Precipitation can be divided into two main periods. During the first period, between November and March, frontal storms move through the region producing 80% of the year's precipitation of 0.10 m (3.9 in.). [Total precipitation for the year averages 0.12 m (4.9 in.)]. The remaining 0.03 m (1 in.) falls during the second period, from April to October. The area is generally under the influence of high-pressure region during this time. Most of the precipitation throughout the year falls as rain. During November through April, snow will occur with an average of 2.3 days a year with a trace or greater. Thunderstorms are relatively rare with an average of 5.2 thunderstorm days per year. In general they occur during June through September with a maximum in August of 1.5 thunderstorm days. Hail is extremely rare with only 0.5 hail days occurring a year. In general the hail does not occur during the summer, and hence is not associated with the summertime maximum of thunderstorms.

The monthly mean wind speeds (Table 4.1) show a maximum of 12 knots in June and a minimum of 6 knots in November, December, and January. The mean wind direction for all months is from the west between 240° and 260°. One of the most striking meteorological features at Edwards AFB is the number of calm wind conditions as shown in the annual average wind rose (Figure 4.1) Annually 18% of the time the winds are calm. During the months September through February, especially at night, calm conditions average between 19% to 29% of the time. This condition is explained by the rapid cooling at night in the surface layer, which inhibits the transfer of momentum to the surface resulting in the large number of calms.

Severe weather is generally limited to severe winds. No tornado has been reported at or in the vicinity of Edwards AFB (Thom 1963). The maximum peak gust wind speed recorded was 270° at 64 knots in 1957 (Rarick 1984).

4.1.2.1 Weather That May Affect the B-52B Flight

The B-52B will not take off or fly through weather where a potential for icing conditions exist. For Edwards AFB a 0.8% occurrence of a broken ceiling is reported for January, with less than a 0.1% chance for the rest of the year (Rarick 1984). Visibility below 2 mi occurs 1.6% of the time in January, dropping to 0.3% or less for the rest of the months. The average pressure of the freezing level is at 695 mb in April, 575 mb in August, 625 mb in October, and 695 mb in December.

4.1.3 Air Quality

During periods of moderate strong southwesterly winds, pollution from the Los Angeles Basin can reach the Mojave Desert and Edwards AFB. These pollutants are the primary cause of degraded visual ranges at Edwards AFB (Rarick 1984). Because of the rapid nighttime cooling during September through February, a large number of surface-based inversions is expected. The large number of inversions with the associated number of calm winds pose a large air pollution potential for this area.

TABLE 4.1. Edwards Air Force Base Climatology (a)

	Month												
Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Prevailing Wind, Degrees/Knots	250/06	260/07	250/09	250/11	240/11	240/12	240/10	240/08	240/08	240/07	240/06	250/06	245/08
Temperature, °F													
Extreme Maximum	82	81	87	97	105	112	113	112	109	102	87	84	113
Mean Maximum	56	61	64	72	81	90	98	96	91	78	66	57	76
Mean	43	43	51	58	66	74	82	80	74	62	51	44	61
Mean Minimum	60	35	39	44	51	58	66	64	58	46	36	30	46
Extreme Minimum	6	14	17	27	32	40	47	47	34	19	13	7	3
Relative Humidity													
Mean, %	56	52	49	43	37	32	27	31	35	37	47	52	42
Precipitation													
Days with Measurable Precipitation, ≥ T	5.8	5.0	6.0	3.6	1.8	0.7	2.0	2.2	1.8	2.1	3.1	4.2	38.9
Mean	0.95	0.93	0.81	0.27	0.07	0.03	0.05	0.19	0.18	0.18	0.55	0.69	4.86
Mean Snowfall, in.	0.81	0.03	0.07	T	--	--	--	--	--	--	0.05	0.13	1.09
Thunderstorms, Mean Days	0.0	0.0	0.1	0.2	0.3	0.6	1.2	1.5	0.8	0.3	0.2	0.0	5.2
Hail, Mean Days	0.1	0.1	0.0	0.2	--	--	0.0	0.0	--	0.1	0.0	--	0.5
Fog, Mean Days	2.1	1.0	0.1	0.5	0.4	0.2	0.1	0.1	0.3	0.7	1.3	1.8	8.4
Dust/Sand, Mean Days	0.4	0.6	0.7	0.8	0.1	0.3	0.2	0.2	0.2	0.3	0.4	0.4	4.5
Haze/Smoke, Mean Days	2.0	2.5	1.8	1.9	2.0	1.4	0.7	0.7	1.3	2.9	2.5	1.3	21.0

(a) Based on 21 years of data.

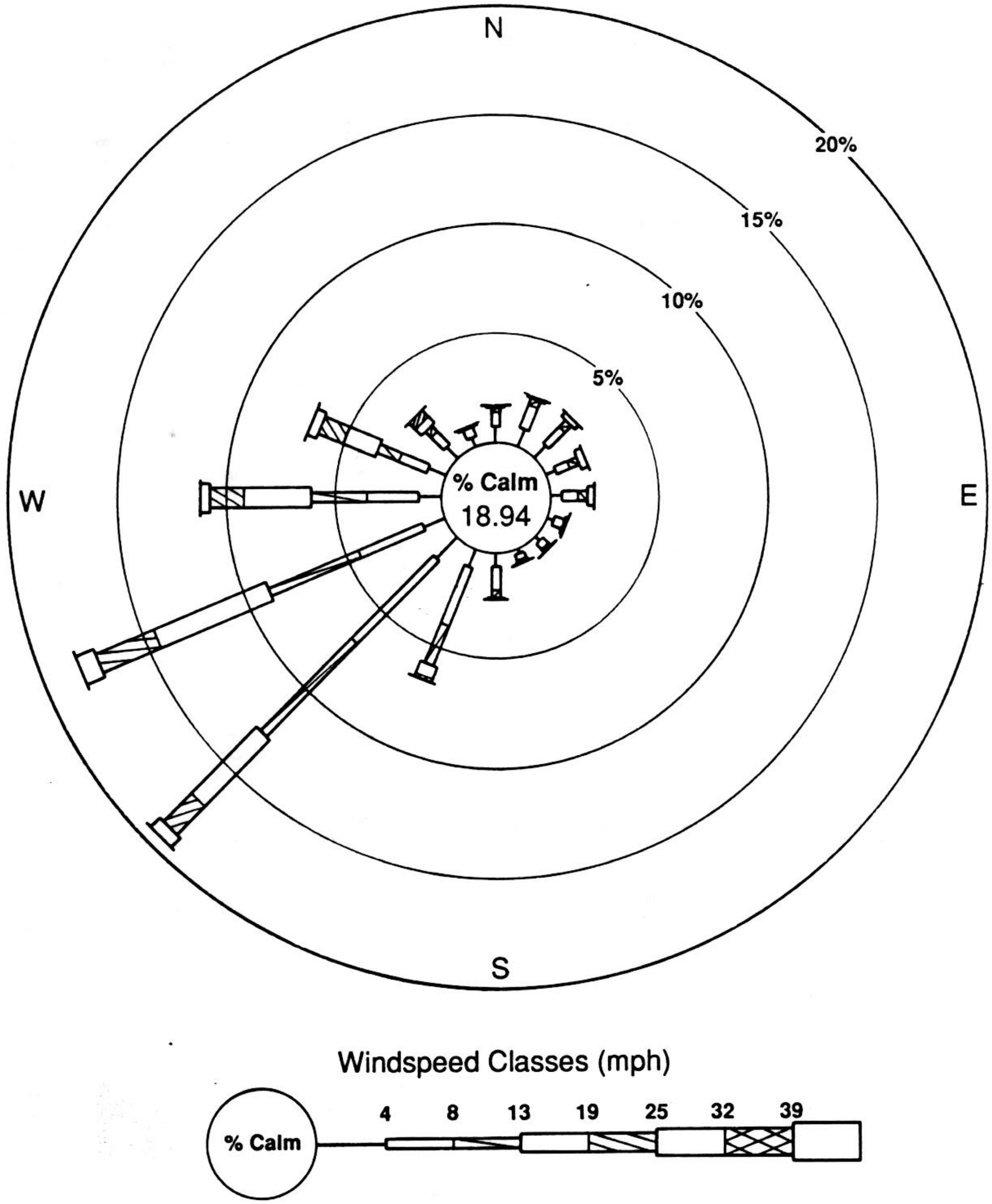


FIGURE 4.1. Annual Wind Rose for Edwards Air Force Base (based on 21 years of data)

Measurements of air concentrations of pollutants considered in determining air quality are shown in Table 4.2 for the Edwards AFB area. Both ozone and total suspended particulate matter <10 m (PM_{10}) have exceeded state standards of <0.10 ppm and <100 mg/m^3, respectively.

4.1.4 Noise

Noise at the Dryden Flight Research Facility is generated during aircraft engine run-ups, trim runs, and test flights. These events are intermittent and of short duration. During this testing, sound levels (noise) may approach about 100 dBA (A-weighted noise pressure levels) in open areas surrounding the hangers and about 90 dBA outside the office and research areas (NASA 1981). Other data show 80 to 85 LDN (Level Day/Night) on ramp south of the NASA Office Building and 70 to 75 LDN in the vicinity of the VAB (Bolt, Beranek, and Newman, Inc 1970; Edwards AFB 1985). In buildings, the noise is screened by building materials, resulting ins sound levels averaging 55 to 75 dB, depending on location (Figure 4.2). Sound readings in the same areas, without operating aircraft, average 5 to 10 dB less (NASA 1981).

4.1.5 Ecology

4.1.5.1 Vegetation

Six primary plant communities are found on Edwards AFB (California Energy Commission 19898; Jaeger 1941; Küchler 1988; ManMahon 1985). These are the Joshua tree woodland, creosote bush scrub, Mojave saltbush scrub, shadscale scrub, desert saltbrush scrub, and desert or alkali sing communities are common in the hot temperate desert region of North America and are discussed in Appendix B.

Joshua trees (*Yucca brevifolia*) occur sporadically throughout the AFB. The creosote bush scrub plant community is primarily confined to slopes, hills, and well-drained sandy flats and washes. The saltbush scrub, shadscale, and alkali sink communities occur in and near low depressions and margins of dry lakes throughout Edwards AFB on alkaline soils.

4.1.5.2 Wildlife

Wildlife in the Edwards AFB area consists primarily of small mammals, reptiles, and birds (Jaeger 1961; NASA 1981). Mammals known or expected to utilize habitats in the area are the desert kit fox (*Bulpes marotis*), coyote (*Canis latrans*), black-tailed jackrabbit (*Lepus calfornicus*), desert cottontail rabbit (*Sylvilagus auduboni*), badger (*Taxidea taxus*), whitetail antelope squirrel (*Ammospermophilus leucurus*), mice (Peromyscus spp.), kangaroo rats (*Dipodomys spp.*), desert woodrat (*Neotoma lepida*), California ground squirrel (*Spermophilus beecheyi*), and Mojave ground squirrel (*Spermophilus mohavensis*). Seed-eating small mammals are particularly abundant because of ephemeral vegetation 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 stanburiana*). The Mojave green rattlesnake (*Crotalus scutulatus*), garter snakes (*Thamnophis spp.*), and coachwhips (*Masticophis flagellum*) occur in the area. Predatory birds common to the area include the ferruginous hawk (*Buteo regalis*), northern harrier (*Circus cyaneus*), red-tailed hawk (*Buteo jamaicensis*), rough-legged hawk (*Buteo lagopus*), American kestral (*Falco sparverius*), turkey vulture (*Cathartes aura*), burrowing owl (*Athene cunicularia*), and the great-horned owl (*Bubo viginanus*). Other common birds in the area include the horned

TABLE 4.2. Ambient Air Quality Monitoring Data

Ozone	1985	1986	1987
Lancaster (a)			
Highest 1-hr Concentration, ppm	0.19	0.20	0.17
Number of Hourly Violations >0.10 ppm	443	434	364
Barstow (b)			
Highest 1-hr Concentration, ppm	0.13	0.15	0.15
Number of Hourly Violations >0.10 ppm	114	138	66
Kramer Junction			
Highest 1-hr Concentration, ppm	NA(c)	0.12 (d)	0.12 (e)
Number of Hourly Violations >0.10 ppm	NA(c)	2 (d)	47 (e)
PM 10			
Boron (f)			
Highest 24-hr Violations >100 ì g/m^3	109 (g)	64 (g)	58 (g)
Number of 24-hr Violations>100 ì g/m^3	5	2	3
Mojave (h)			
Highest 24-hr Violations >100 ì g/ m^3	108	130	171
Number of 24-hr Violations >100 ì g/ m^3	7	10	15

(a) 40,200 m (25 mi) southwest of Edwards AFB.
(b) 8,500 m (55 mi) east of Edwards AFB.
(c) Not available.
(d) Data from October 1 through December 31.
(e) Data from January 1 through October 21
(f) 29,000 m (18 mi) east of Edwards AFB
(g) Converted total suspended particulate (TSP) data with 0.55 (TSP).
(h) 29,000 m (18 mi) northwest of Edwards AFB.

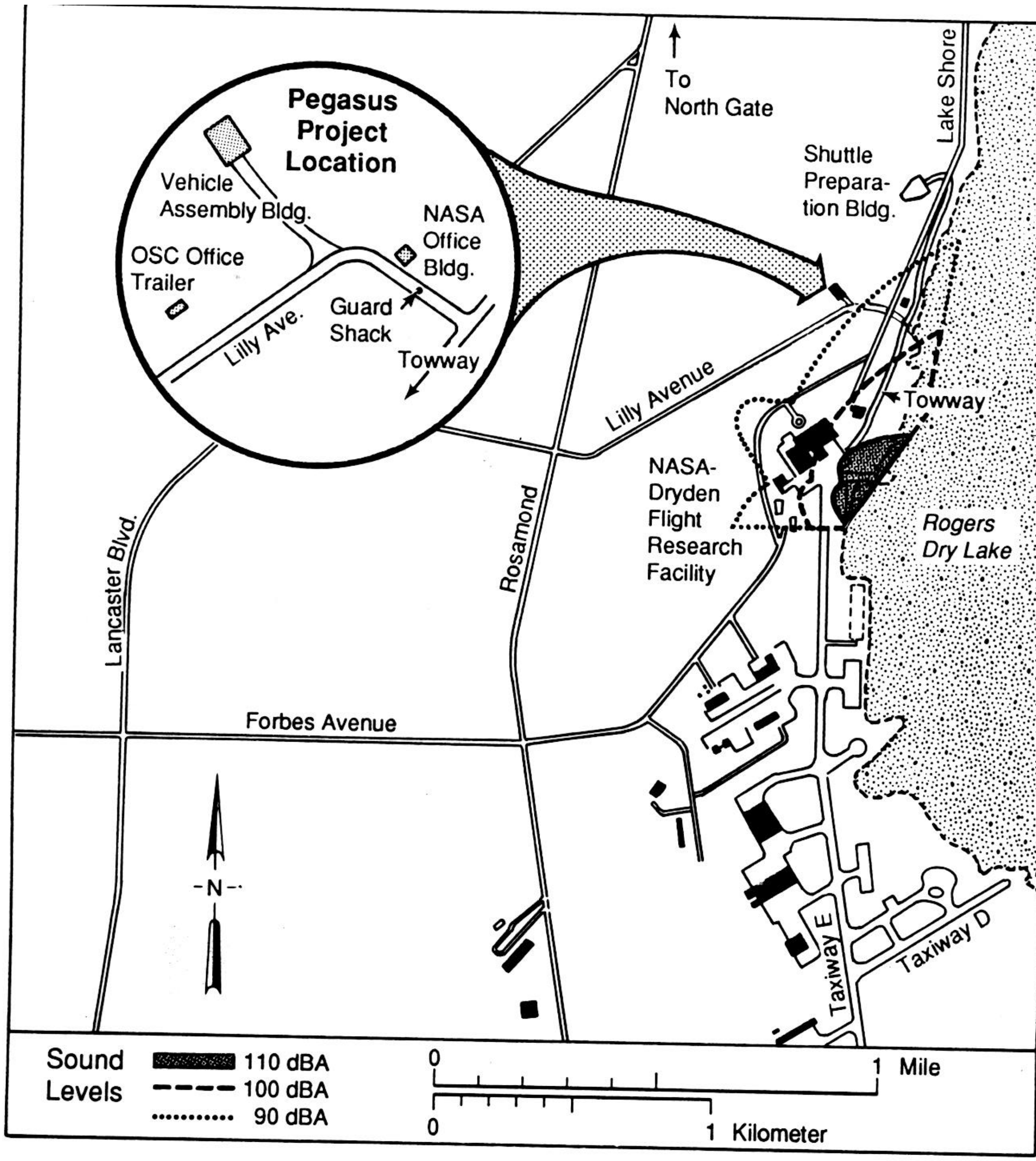


FIGURE 4.2. Noise Levels Around Dryen Flight Research Facility (NASA 1981)

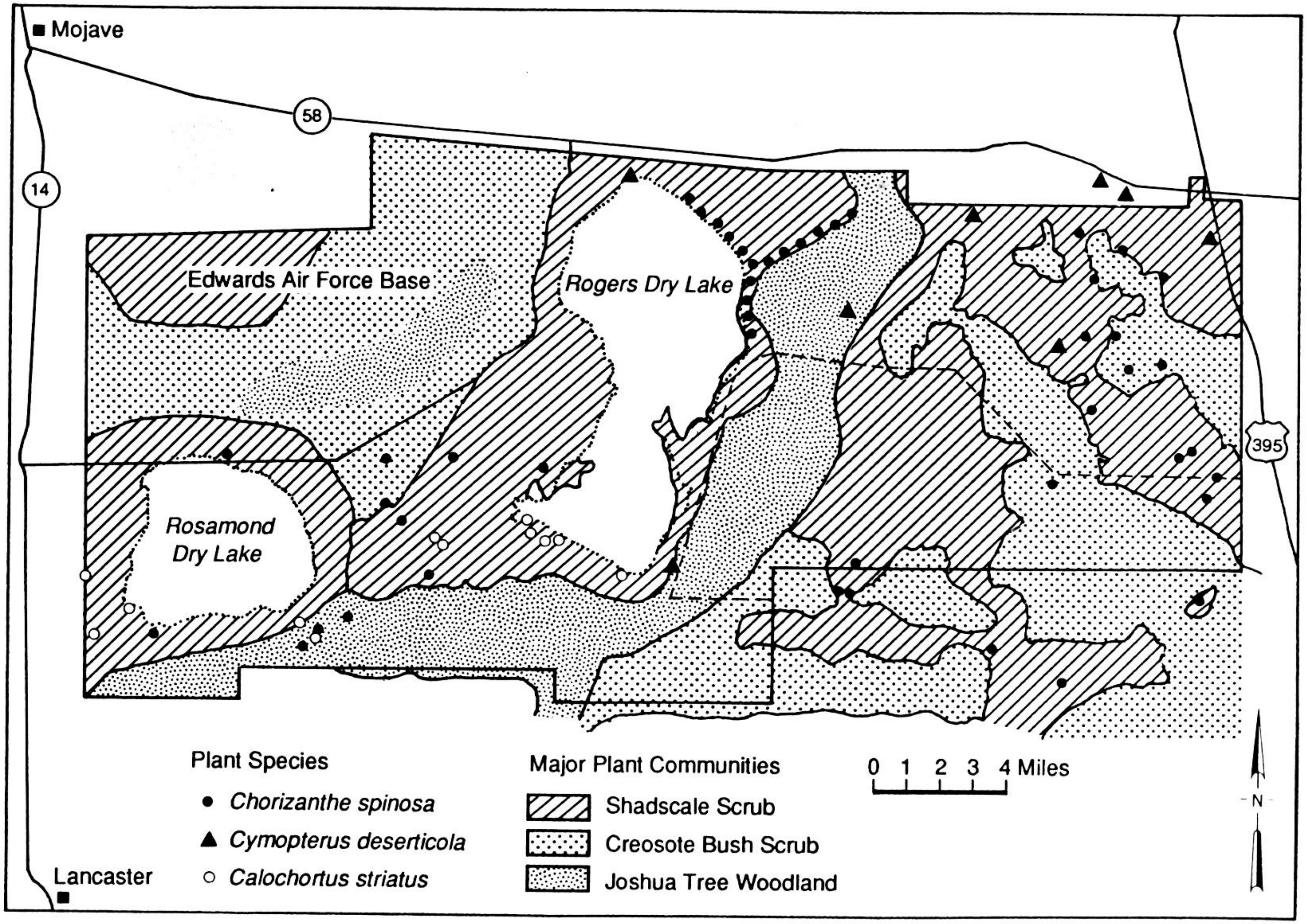


FIGURE 4.3. Vegetation Map of the Edwards Air Force Base Area (USAF 1983)

lark (*Eremophila alpestris*), common raven (*Corvus corax*), roadrunner (*Geococcyx californianus*), white-crowned sparrow (*Zonotrichia Leucophrys*), western meadowlark (*Sturnella neglects*), and the cactus wren (*Campylorhynchus brunneicapillus*). The mourning dove (*Zenaida maroura*) and Gambel's quail (*Callipepla gambelii*) are game birds that have also been observed in the area.

4.1.5.3 Threatened and Endangered Species, and Species With Special Status

The following list of potential special-status plants and animals has been developed based on previous biological studies of the Edwards AFB (USAF 1987) and from information obtained from the National Diversity Data Base, California Department of Fish and Game (DFG):

Plants	
Alkali mariposa lily	(Calochorys striatus)
Mojave spineflower	(Chorizanthe spinosa)
Desert cymopterus	(Cymopterus deserticola)
Mojave fish-hook cactus	(Sclerocactus polyancistrus)
Insects	
Mojave desert blister beetle	(Lytta inseperata)
Reptiles	
Desert tortoise	(Gopherus agassizii)
Mammals	
Mojave ground squirrel	(Spermophilus mohavensis)

These species are characterized individually in Appendix B.

In addition to the species described above, the desert kit fox (*Vulpes marotis*) is classified by the California DFG as a nongame animal that cannot be trapped or hunted. Several species of eagles and falcons that overwinter in the area are listed as federal endangered species by the U.S. Fish and Wildlife Service (USFWS). These include the bald eagle (*Haliaeetus leucocephalus*), golden eagle (*Aquila chrysaetos*), peregrine falcon (*Falco peregrinus*), and prairie falcon (*Falco mexicanus*).

4.2 FLIGHT CORRIDOR

Upon liftoff from Edwards AFB, the B-52B will fly toward the Pacific Ocean within a land corridor described in Section 3.1.4.4.

4.2.1 Topography

Immediately west of Edwards AFB to the foothills of the Sierra Nevada and Tehachapi Mountains are Mojave Desert-type soils. In the uplands and valleys of the eastern slopes of the Sierra Nevada and Tehachapi Mountains the soils are more of a sandy loam, while on the west side of the Sierras the soils of the eastern edge and central portions of the San Joaquin Valley include sandy clay loam. On both the eastern and western foothills of the coastal mountain ranges the soils are well drained and are derived predominantly from sedimentary and granitic rock. Within the eastern portion of the coast ranges the soils include areas of shale loam and shaly clay loam, which are underlain by hard fractured shale. The soils of the central (western portions of the coast ranges) and coastal portions of the San Luis Obispo county have surface layers that range from loam to clay with frequent rock outcropping on the slopes of the mountains.

4.2.2 Meteorology

Large climate variations exist within the land corridor from Edwards AFB to San Luis Obispo, extending from a moderating ocean climate through mountains and desert climates. The coastal zone is classed as dry Mediterranean with hot, dry summers and wet winters. The hot, dry summers are a result of the dominant Pacific high pressure. As the high pressure moves north, it pushes the storm track to the north of California. The eastern edge of the high is off the coast of the corridor, and the high is at its maximum northward movement in the summer. Subsidence within the high heats the air and creates a temperature inversion at approximately 600 m (2,000 ft). The southward-moving air is also responsible for the upwelling of cold water along eh coast. These relatively cold waters flowing southward cool the surface air enhancing the atmospheric stability in the near-surface air off the coast. During the day, solar heating creates a relatively cloud-free environment. As at Edwards AFB, little precipitation falls throughout the corridor during the summer months with the exception of some thunderstorm activity over the mountains.

During winter, the Pacific sub-tropical cyclone weakens and migrates to the south. Frontal storms are now able to penetrate and produce a rainy season. During the winter months, snow can occur in the mountains and in the vicinity of Edwards AFB with less likelihood of snow occurring in the lowlands along the coast.

Annual precipitation in the corridor ranges from approximately 0.13 m (5 in.) at Edwards AFB to a maximum of about 0.6 to 0.8 m (24 to 32 in.) in the coastal range and dropping to about 0.4 m (16 in.) along the coast.

4.2.3 Air Quality

Air quality is not measured within the corridor at operational altitudes of 9,150 to 12,200 m (30,000 to 40,000 ft). Concentrations of most pollutants are expected to be much lower at 9,150 to 12,200 m (30,000 to 40,000 ft) than in the boundary layer, except for ozone, which is high due to its natural occurrence in the stratosphere.

4.2.4 Ecology

4.2.4.1 Vegetation

The vegetation along the flight corridor consists of 18 communities organized into 8 major groups of formations (Figure 4.4) (Küchler 1988). Riparioan or wetland vegetation may be found along perennial streams, lakes, and water courses through the flight corridor. A relatively large expanse of tule marsh occurs along the San Joaquin River, dominated by the common tule (Scirpus acutus) and the cattail (Typha latifolia). The formation common to the Mojave Desert region is the scrub formation, comprised of the desert saltbush community, the Mojave creosote community, Joshua tree scrub community, and the San Joaquin saltbush community. The community classifications for the flight corridor are more coarse than the classifications given for Edwards AFB.

Lower elevations of eastern slopes of the principal mountain ranges such as the San Gabriel and Tehachapi Mountains and the coastal ranges support a chaparral shrub formation dominated

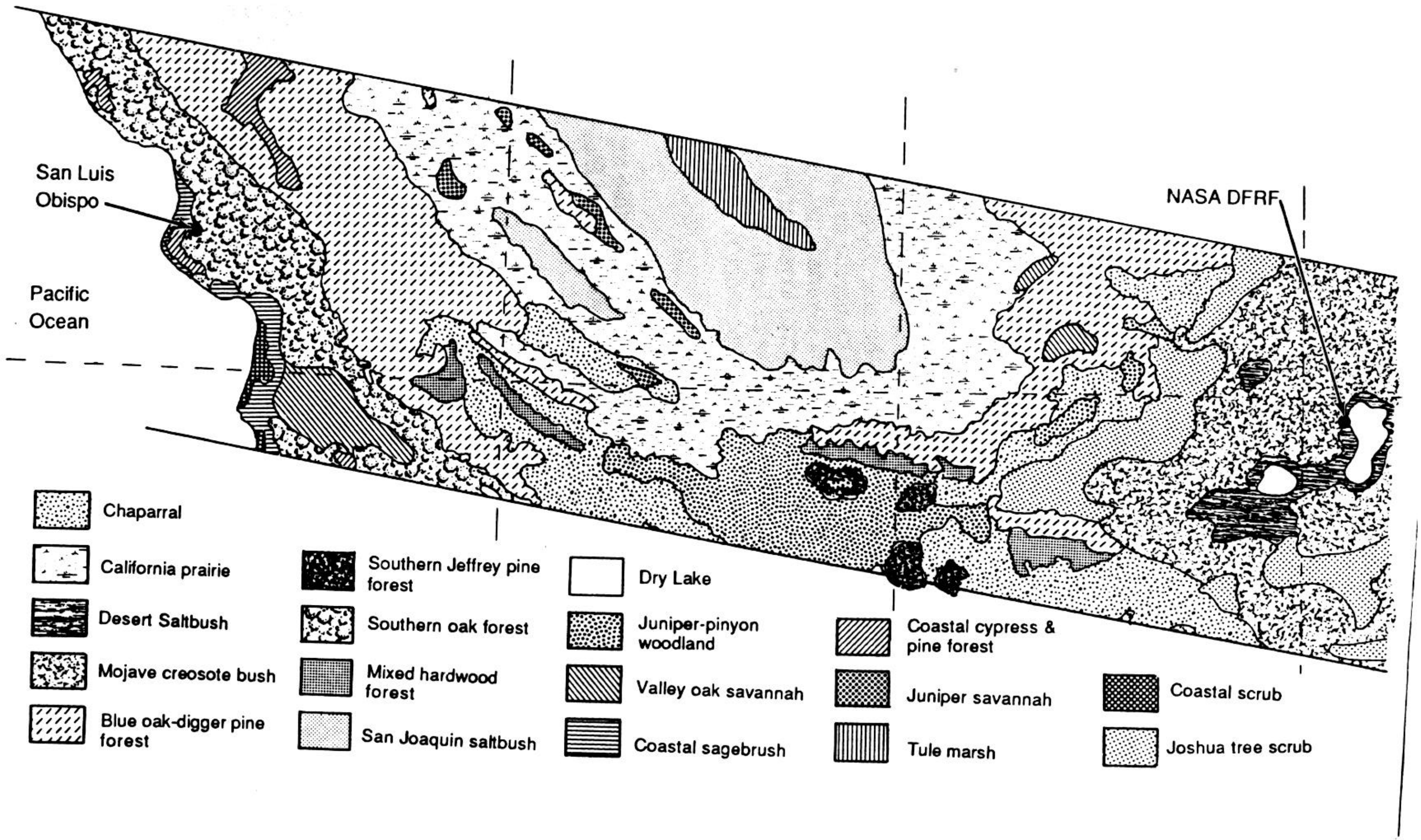


FIGURE 4.4. Terrestrial Vegetation Communities of the Pegasus Flight Corridor (Küchler 1988)

by chamise (Adenostoma fasciculatum), manzanita (Arctostaphylos spp.), and California lilac (Ceanothus spp.). The coastal sagebrush community occurs along the lower elevations of the coastal ranges of central ranges of central and southern California. The broad-leaved forest formation, consisting of the mixed hardwood, southern oak, and the blue oak-digger pine forests, are found on the intermediate slopes of the Tehachapi Mountains and the coastal ranges. The savanna formation, represented by the valley oak savanna and the juniper savanna, occurs in valleys of the coastal ranges and the Tehachapi Mountains and the higher areas of the California prairie. The highest elevations of the coastal mountains and the Tehachapi Range contain the four plant communities belonging to the evergreen needle-leaved formation: the southern Jeffrey pine forest, the southern mountain syalpine forest, the juniper-pinyoun woodland, and the coastal cypress and pine forest community, which occurs in a narrow, interrupted belt along the coast. The final vegetative community found in the Pegasus corridor is the southern seashore community, a complex vegetation type comprised of beach and dune scrub habitats.

4.2.4.2 Wildlife

Vegetative and climatic variation, as well as agricultural practices across the flight corridor combine to produce a diversity of wildlife habitats. Consequently, wildlife along the flight corridor consists of a wide variety of species, both native and introduced. Prominent faunal species of commercial importance include domestic cattle, horses, dogs, cats, poultry, goats, sheep, and rabbits. Other introduced and native species of commercial importance as pests to crops, domestic life, and wildlife include nematodes, insects, other invertebrates, certain birds such as starlings and crows, rabbits, and some rodents. Wildlife important to recreation include mule deer, feral pigs, quail, doves, rabbits, fox, badger, raccoon, and water fowl. Selected examples of wildlife likely to be found along the flight corridor are listed in Appendix B.

4.2.4.3 Threatened and Endangered Species

The following listing of protected plants and animals within the flight corridor has been developed based on information from the National Diversity Data Base, California DFG, and the USFWS, Office of Endangered Species, Sacramento:

Plants

Salt marsh bird's-beak	*Cordylanthus maritimus var. maritimus*

Reptiles

Blunt-nosed leopard lizard	*Gambelia silus*

Mammals

San Joaquin kit fox	*Vulpes macrotis mutica*
Giant kangaroo rat	*Dipodomys ingens*
Tipton kangaroo rat	*Dipodomys nitratoides nitratoides*
Morro Bay kangaroo rat	*Dipodomys heermanni morroensis*

Birds

California least term	*Sterna antillarum browni*
California brown pelican	*Pelecanus occidentalis californicus*

American peregrine falcon	*Falco peregrinus anatum*
Bald eagle	*Haliaeetus leucocephalus*
California condor	*Gymnogyps californianus*

These species are characterized individually in Appendix B.

4.3 WESTERN TEST RANGE

The Western Test Range (WTR) is a military test range controlled by the Western Space and Missile Center at Vandenberg AFB, California. The WTR lies over the Pacific Ocean off the coast of south-central California.

4.3.1 Air Quality

Air quality is not measured over the WTR at operational altitudes exceeding 11,900 m (39,000 ft). Concentrations of most pollutants are expected to be much lower at 9,150 to 12,200 m (30,000 to 40,000 ft) than in the boundary layer, except for ozone, which is high due to its natural occurrence in the stratosphere.

4.3.2 Marine Biota

The biotic regions of the project area can be divided into a coastal/intertidal zone, and continental shelf zone, and an open ocean zone. The intertidal zone includes the greatest diversity of habitat types, including rocky shores, sandy beaches, and lagoons. This zone includes both obligate aquatic species as well as species such as turtles, birds, seals, and sea lions that use the dryland shores for reproduction and resting areas.

The intertidal zone is dominated by invertebrates, primarily mollusks (Rodrigue et al. 1974). The California sea otter is a key predator in this zone. Lagoons in the project region vary in size as will as in species composition. Lagoons characteristically are estuarine, euryhaline, or hyposaline habitats. Therefore, they commonly exhibit gradients in water quality and biota that range from marine at the ocean to progressively fresher water farther inland. These areas serve as key nurseries for many commercially important fishes.

The continental shelf zone also varies greatly in habitat types and biotic composition. A large variety of commercially important fish species are found in this zone, along with whales, dolphins, and sea turtles. This zone contains some of the most important fisheries resources in the western United States. Vertebrate life is abundant as a result of the great concentration of phyto plankton in the zone that occurs in a 500-km-wide band along the North American coast to a point south of San Diego. In winter, this latitudinal boundary lies less than 100 km south of San Diego; in summer the boundary may move as much as 200 to 300 km south (CALCOFI 1969; Peláez and McGowan 1986).

At least 297 species of marine fish occur in the project are (Miller and Lea 1972). The most diverse groups are the surfperches, rockfishes, sculpins, clinids, and flatfishes. Fishes of commercial and recreational importance are discussed later in this section.

Three species of sea turtles are the only marine reptile species that are expected to occur in the region of the WTR potentially to be affected by the Pegasus project. Vagrant loggerhead turtles (*Caretta carretta*), leather-back turtles (*Dermochelys coricea*, an endangered species), and green turtles (Chelonia mydas, a threatened species) may occasionally occur as far north as the project region (Stebbins 1966).

A large variety of marine birds, including California least terns and the California brown pelican, both endangered species, occurs in the project region. These include truly oceanic birds, shorebirds, and a variety of species that frequent coastal lagoons. Shorebirds and gulls are most abundant. These and other prominent marine species are listed in Appendix B.

Numerous seabirds use the California Bight as feeding grounds during the non-breeding season; many northern breeders winter in the Bight and southern hemisphere breeders summer there. The majority of the world population of at least two species, the western brant (*Branta bernicla nigricans*) and pink-footed shearwater (*Puffinus cretopus*), may be traveling offshore of that area at certain times of the year.

A variety of marine mammals occurs in the project region. California sea lions (*Zalophus californianus*) haul out on the beaches along the flight corridor. Harbor seals (*Phoca vitulina*) breed on rocky areas at various points along the shore. Northern sea lions (*Eumetopias jubatus*), California sea lions, and northern elephant seals (*Mirounga angustirostris*) have breeding populations at San Miguel Island (360 km away from the Pegasus launch point). Northern fur seals (*Callorhinus ursinus*), which breed on San Miguel Island, may sporadically occur on the mainland. The project region is within the breeding range of the California sea otters and Guadalupe fur seals (*Arctocephalus philippi*), both of which are protected under the Endangered Species Act. Pupping and breeding for sea lions and fur seals occur from May 20 to August 20, whereas those for northern elephant seals range from December 20 to February 20.

Cetaceans (whales, dolphins, porpoises) also occur in the region. Gray whales (*Eschrichtius gibbosus*) are probably the most conspicuous species. During the spring and fall migrating individuals and small groups are frequently seen in the project region. An estimated 2,900 to 4,500 gray whales pass Point Arguello each migratory season.

4.3.2.1 Commercial and Recreational Species

The region contains extensive marine resources. It also serves as a recreational area. Among the major resources of potential use to man are beds of giant kelp that have served as an alginate source for many industries. The following discussion is derived largely from Best and Oliphant (1965).

Some species of mollusks, such as abalones, cams, and squid, are harvested commercially. Octopus is sometimes taken for food. The crustacean harvest in the south-central coast region is minor in comparison with the fish and mollusk catches. Several species of crabs are taken, as are limited numbers of spiny lobsters and shrimp.

Among the most important commercial fishes are flatfishes, rockfishes, and several other inshore and offshore species. The most valuable flatfish is the California halibut. Other economically important flatfishes include a variety of soles, flounders, and sanddabs. Open ocean fishes include albacore tuna, marlin, and other billfishes.

Flounders, kelp bass, lingcod, and rockfishes represent 64% of all party-boat catches. Between Port San Luis and Point Sal, angler effort is high. South of Point Sal, this activity diminishes somewhat until Point Conception is reached, where party-boat fishing increases again.

Anadromous steelhead trout (*Salmo gairdnerii*) are occasionally taken offshore in the San Luis Obispo area and near Jalama Beach. Surfperches constitute most of the fishes caught by shore anglers between Avila and Point Conception.

4.3.2.2 Protected Marine Vertebrate Species

Sixteen marine vertebrate species that occur in the project area are designated by the California DFG as rare (R) or endangered (E), or by the USFWS as endangered (En) or threatened (T). These species are listed in Table 4.3 and characterized individually in Appendix B.

TABLE 4.3. Rare, Endangered, and Threatened Marine Vertebrates in the Project Region

Category	Scientific Name	Common Name	Status (a)
Reptiles	*Chelonia mydas*	Green turtle	T
	Dermochelys coricea	Leatherback turtle	En
Birds	*Pelecanus occidentalis californicus*	California brown pelican	En, E, T
	Rallus lontirostris levipes	Light-footed clapper Rail	En, E, T
	Laterallus jamaicensis	Black rail	R, T
	Sterna antillarum browni	California least Tern	En, E, T
	Passerculus sandwichensis Bedingi	Belding's savannah Sparrow	E
Marine Mammals	*Physeter catodon*	Sperm whale	En, T
	Megaptera novaeangliae	Humpback whale	En, T
	Balaenoptera borealis	Sei whale	En, T
	B. musculus	Blue whale	En, T
	B. physalus	Finback whale	En, T
	Eubalaena sieboldii	Right whale	En, T
	Eschrichtius robustus	Gray whale	En, T
	Arctocephalus phillipi Townsendi	Guadalupe fur Seal	En, R, T
	Enhydra lutris nereis	Southern sea otter	T
	Mirounga angustirostris	Northern elephant seal	E

(a) T = Designated as threatened by the U.S. Fish & Wildlife Service.
En = Designated as endangered by the U.S. Fish & Wildlife Service.
E = Designated as endangered by the California Department of Fish and Game.
R = Designated as rare by the California Department of Fish and Game.

5.0 ENVIRONMENTAL IMPACTS

The potential environmental impacts discussed in this chapter are those that might result from implementation of the proposed action (i.e., the assembly and launch of the Pegasus three-stage rocket booster) and from alternatives described in Chapter 3.0. The environmental impacts described include those associated with the transportation of rocket motors to Edwards AFB, assembly of the Pegasus, and normal and abnormal activities during operation. These impacts relate to an area between Magna, Utah, and Edwards AFB; to Edwards AFB; to the flight corridor; and to the WTR. Information provided by the USAF, NASA, Hercules, and OSC was used as the primary source for operational parameters, resource commitments, and estimated environmental releases of airborne chemical vapors, engine combustion products, and solid wastes from rocket assembly.

5.1 TRANSPORTATION OF ROCKET MOTORS FROM MAGNA, UTAH, TO EDWARDS AIR FORCE BASE, CALIFORNIA

The three rocket motors will be transported in two shipments form Hercules Aerospace Company, Magna, Utah, to Edwards AFB in the TARVAN as described in Section 3.1.1.

5.1.1 Routine Environmental Impacts of Transport

There will be no routine releases to the environment from the rocket motors during transport. Therefore, no impacts are expected to occur to either humans or the environment as a result of routine transportation of these motors in the TARVAN by commercial truck carriers.

5.1.2 Accidents in Transport

The occurrence of an accident involving the TARVAN has a frequency of about $4 \times 10^{-6}/_{km}$ ($6.4 \times 10^{-6}/_{mi}$) (a) (NRC 1987). Small accidents or accidents with other vehicles are not expected to cause any problems with the rocket motors.

Severe accidents involving the TARVAN may cause environmental impacts from burning of the rocket motor(s). Two accident scenarios were considered: impact with a gasoline tanker truck and impact with a fast-moving train. The train accident scenario was developed. This scenario considers a TARVAN being hit broadside by a train traveling at 80 mph. About 74% of truck accidents are collision accidents for a probability reduction from $6.4 \times 10^{-6}/_{mi}$ to $4.9 \times 10^{-6}/_{mi}$. Collisions with non-fixed objects occur about 88% of the time (4×10^{-6}) with only about 1.2% involving trains (5.0×10^{-8}). It is assumed that the train would have to be traveling at least 80 mph to cause the rocket motor to ignite. Only 0.04% of rail/highway grade-crossings occur at speeds faster than 80 mph with a resulting probability of such an accident occurring at $2 \times 10^{-11}/_{mi}$. Because the first-stage rocket motor contains 69% of the total transported fuel mass, an accident involving the TARVAN carrying the first-stage motor would present the highest potential for maximum environmental impact. Traveling a total of about 1,126,300 m (700 mi) gives a probable accident rate of 7×10^{-8}/rocket assembly. This means that one accident of this nature can be expected to occur once for every 71 million trips involving transport of the first-stage motor to Edwards AFB. This probability of occurrence is clearly insignificant.

(a) The remaining frequencies/probabilities are stated in English units for convention.

The accident scenario assumes that the rocket, spread over 1000 m^2 (10,800 ft^2) because of impact with the train, will burn in a non-pressurized mode. Plume rise was estimated based on an equation developed by Briggs (1981) for a buoyant vertical plume. Heat flux from the burn was estimated to carry the effluent vertically to a height of approximately 200 m (660 ft). A uniform air concentration was assumed in the vertical. This assumption would leave the lower portion of the plume in contact with the ground.

Of all the solid fuel combustion products (see Appendix C) that would be released in large quantities during a fire, HCl is the one produced in the largest quantity. It is toxic and assumed to be of most concern, as identified in Section 3.1.5.2. Therefore, HCl has been assessed for all applicable accidental releases caused by burning rocket fuel. Approximately 2.6×10^6 g of HCl [five times less HCl than is expected from the exhaust during a routine shuttle launch (NAS 1987)] will be released in a complete burn of the Pegasus first-stage motor. The average air concentration of HCl in the cloud (available for transport) at the end of the 4-min burn with a wind speed of 3 m/sec (9.8 ft/sec) will be approximately 400 ppm.

Table 5.1 presents the resulting average centerline ground-level air concentrations from the 1,000-m^2 (10,800-ft^2) burn and the time of plume passage, estimated as a function of distance. The estimates assume no surface depletion of HCl, and Gaussian plume diffusion was assumed with a wind speed of 3 m/sec (9.8 ft/sec) (see Appendix D). These air concentrations are biased toward high air concentrations because of the combination of assumptions, namely that all the fuel is burned and stable atmospheric conditions exist.

The estimated maximum ground-level air concentrations could cause impacts to humans. At the request of the U.S. Army, Navy, and USAF, The National Research Council (NRC) has developed three types of short-term exposure levels that can be used to estimate the potential human health impacts from accidental exposure to HCl (NRC 1987). The emergency exposure guidance levels (EEGLs) are defined as the concentration of a substance in air that will permit continued performance of specific tasks during rare emergency conditions lasting for periods of 10 min to 24 hr. Exposure to an air concentration similar to the EEGL might produce reversible effects that do not impair judgment and do not interfere with proper reposes to the emergency (i.e., upper respiratory tract irritation or eye irritation causing discomfort). For unpredicted, single, short-term, emergency exposure of the general public, the SPEGL (NRC 1987) (previously known as short-term public emergency limit) could be used for exposure guidance. In contrast to the EEGL, the SPEGL takes into account the wide range of susceptibility of the general public. This includes sensitive populations such as children, the aged, and persons with serious debilitating diseases. The EEGLs and SPEGLs are presented for HCl in Table 5.2.

TABLE 5.1. Average Centerline Ground-Level Air Concentrations of Hydrochloric Acid, Collision Accident Scenario

	Distance, km			
	1	5	10	20
Air Concentration, ppm	230	60	40	20
Plume Passage, min	4.5	5	6	8.5

TABLE 5.2. Recommended Exposure Guidance for Hydrochloric Acid (NRC 1987)

Substance	Duration of Exposure	Committee Recommendations, ppm
Hydrochloric acid	10 min	100 (EEGL)
	1 hr	20 (EEGL)
	1 hr	1 (SPEGL)
	8 hr	5 (PEL)
	24 hr	20 (EEGL)
	24 hr	1 (SPEGL)

The SPEGL and EEGL are not standards or judgments of acceptable risk and must not be used as such. For perspective, law states the permissible exposure limit (PEL) [Occupational Safety and Health Administration (OSHA) 1986] for workers of a daily 8-hr exposure ceiling of 5 ppm. The American Conference of Governmental Industrial Hygienists (ACGIH 1986) also recommends a ceiling of 5 ppm.

The potential impacts on humans from this accident depends upon where the person(s) is in relation to the plume centerline and how long the person stays in the plume. By comparing the estimated air concentration from the rocket motor burn (Table 5.1), and the time a person could be exposed tot hat concentration in relation to the EEGLs and the SPEGLs (Table 5.2), one can see that irreversible effects are unlikely, and even reversible effects (i.e., tearing of eyes, irritation of nasal passage) are probably unlikely except for those caused by prolonged exposure to HCl concentrations near the fire. Because most people can detect HCl in air at concentrations of 1 to 5 ppm, and 5 to 10 ppm is disagreeable to them (NRC 1987), they would want to quickly escape the plume. The effects on humans from these accident scenario is expected to be insignificant.

Ecological impacts form HCl will be a function of the type and rate of fuel combustion that affect the composition and particle size of the products as well as the prevailing meteorological conditions during the accident. Natural ecosystems have not been studied during exposure to HCl. However, ecological impacts have been estimated in the laboratory using animal data for rabbits and mice (that would be found in the arid deserts of California). Dramer et al. (1974) found that an HCl concentration of 41,000 ppm was required to kill rats exposed for 5 min. Mice died form a 5-min exposure of almost 14,000 ppm. An HCl concentration of 2,600 ppm was required to produce mortality in mice from a 30-min exposure (five times longer than the plume passage time for this accident). In an old experiment reported by Machle et al. (1942), rabbits and Guinea pigs were exposed for 5 min to 3,700 ppm HCl with no mortality. These concentrations are ten to one hundred times greater than the HCl estimated to be present in the burn cloud itself let alone the transported plume to which animals are most likely to be exposed. Kaplan et al. (1985) assessed the potential of HCl to impair human escape and developed a signal avoidance task for baboons and rats. They exposed baboons for 5 min to HCl at average concentrations from 190 to 17,290 ppm. All animals were able to perform the escape task. Irritant effects were observed at all concentrations except the lowest (190 ppm). Therefore, effects to biotal should be insignificant.

Ecological impacts may also occur through damage to vegetation and soils in the area of the burn, resulting form contamination with the products of propellant combustion. The major components that deposit on vegetation and soil include Al species and HCl. The materials may be deposited to the plant's surface in either a liquid or particulate form. Penetration through the cuticular surfaces of the leaf will be dependent on both the nature of the plant cuticle, which varies from species, as well as the polar/nonpolar solubility of the material on the surface of the plant. Partial water solubilization of the particulate material may occur during subsequent firefighting efforts or a later rainfall. These actions may also promote washing or leaching of the material from the foliage into the soil where it may be more available to the plant through root absorption.

An initial estimate of the major particulate/liquid combustion products form the Pegasus, their relative solubility in water, and reported phytotoxicities are given in Table 5.3. These products include the expected Al salts and hydroxideds as well the HCl from the propellant. With the exception of aluminum chloride (AlCl3) and aluminum perchlorate (AlOCl), the majority of the Al products are relatively insoluble in water and will most likely not be foliarly absorbed by the plants to produce visible phytotoxic effects.

While there is no precise information available dealing with xerophytic types of vegetation common to Edwards AFB and the surrounding Mojave Desert portion of the transport route or the flight path, it may be assumed that the HCl would prove the most deleterious. This would occur even at relatively low concentrations if the material is able to penetrate the thick and often waxy cuticular surface. Further, it has been reported that most leaf cuticles are relatively permeable to HCl (Guderian 1977) and therefore visible impacts in the immediate area could be expected.

TABLE 5.3. Relative Water Solubilities and Vegetation Toxicity Levels of Components Released from Combustion of Pegasus Solid Fuel

Chemical Species	g/lb Fuel	Water Solubility g/100 (a)	Vegetation Toxicity Level mg/L (b)
Propellant			
Aluminum chloride (c)	9.618	69.9	0.1-32.0
Aluminum perchlorate (d)	2.702	Very Soluble	0.1-32.0
Aluminum hydroxide (e)	2.048	Insoluble	0.1-32.0
Aluminum Oxide	151.470	Insoluble	0.1-32.0
HCl	81.580	82.3	>5.0 (f)
	247.418		

(a) From Weast (1986).
(b) From Bowen (1979), defined as toxicity to plants, g in 1 L of nutrient solution.
(c) Sum of AlCl, $AlCl_2$, and $AlCl_3$ Species from Table C.2, Appendix C.
(d) From Table 3.5.
(e) Sum of AlO, AlOH, AlO_2H, Al_2O, and Al_2O_2 species form Table 3.5.
(f) As ppm (NASA 1978).

Indications of damage (impacts) to vegetation form these materials can include leaf tip burn, leaf damage, defoliation, twig death, and plant death, depending on the severity of the deposition and the sensitivity of the species. At this time, the relative damage sensitivity of the species indigenous to Edwards AFB and the surrounding Mojave Desert to either the Al species or to HCl is unknown. However, sagebrush and Ponderosa Pine, species found both in the Edwards AFB area and along portions of the flight path, have been shown to be relatively sensitive to products of phosphorous combustion including phosphoric acid (Van Voris et al. 1988) and may prove similarly sensitive to these components.

HCl species precipitate to the surfaces of vegetation. Similar precipitation, either directly to the surrounding soil or from foliar leaching, may be mitigated to some extent by the soil's alkaline properties at Edwards AFB. Based on the low probability of an accident of this nature, ecological impacts are expected to be insignificant.

5.2 EDWARDS AIR FORCE BASE

Potential environmental impacts that may occur within Edwards AFB were assessed including assembly of the Pegasus rocket, transportation of the booster to an awaiting B-52B, and the flight along the land corridor towards the WTR.

5.2.1 Pegasus Assembly

Several chemicals will be used in the assembly of the Pegasus (Table 3.1). While some of the chemicals listed may pose hazards (Table 5.4) to the workforce, the hazards of most are sufficiently will understood to ensure health of workers and the general public by application of appropriate administrative and engineering controls. Volatile compounds represent a hazard from vapor inhalation. Versamid 140, triethylenetetramine, and RF 4000 Resin, Epon Resin 828 are not volatile liquids and do not constitute an inhalation hazard. Contact with skin and eyes should, however, be avoided. Working with woven graphite may expose workers to graphite dust and fibers. Graphite composite dusts are capable of adversely affecting the lungs via inhalation. Epidemiological studies of carbon-fiber factory workers (Jones et al. 1982) found no clear evidence of effects from long-term exposure to 0.16 mg/m^3 respirable dust. The potential intermittent exposure to low levels of graphite composite dust should not pose a health threat. However, use of respirators, goggles, and gloves will be enforced if graphite dust becomes a problem.

For estimating the potential air concentrations within the VAB from the routine use of volatile chemicals, it is assumed that these chemicals will be released into the VAB atmosphere during an 8-hr work day, over 10 working days (rocket assembly period). Two air exchanges per hour are assumed in the VAB; total volume is 2,160 m^3. An estimate of the indoor air concentration of these chemicals is compared to applicable standards (where standards exist) in Table 5.5. During assembly of the Pegasus within the VAB, OSC will be required to meet OSHA guidelines for occupational exposure to chemicals in the work place (OSHA 1989). Because the routine levels given in Table 5.5, which are a factor of over 100 below OSHA guidelines, it is not necessary to estimate the potential atmospheric exposure to personnel in the surrounding environment [i.e., the OSC office trailer (about 100 m SSW) or the NASA office building located about 300 m E of the VAB].

TABLE 5.4. Characteristics of Chemicals Used in Vehicle Assembly Building

Material	Chemical Characteristics
Triethylenetetramine RF-14 hardener	The chemical is a strong, caustic irritant. Inhalation may cause nausea and vomiting. Contact with the skin or eyes may lead to allergenic sensation.
RF 4000 Resin	This material consists of >90% Bisphenol A/Epichlorohydrin Resin and <10 % Neopentyl Glycol Diglyoidyl Ether. Because of its low volatility, this product is not likely to produce adverse effects by inhalation. The product is moderately irritating to skin.
Perchloroethylene	This material consists of 99.5% tetrachloroethylene and 0.5% tert butylglycidyl ether. May be irritating to eyes at 100 ppm, dizziness may occur at 200 ppm. Excessive exposure may lead to hepatic, renal, or nervous system disfunction.
Epon (R) Resin 828	The material is moderately irritating to eyes and skin and may lead to sensitization. The material has a low volatility.
Versamid 140	This material is a mixture of 89 +/- 5% polyamide resin and 11 +/- 5% triethylenetetramine. The material has the potential to cause severe eye irritation.
Potassium hydroxide	This caustic agent is used as a battery electrolyte. Contact with skin, eyes, or ingestion is hazardous and should be avoided.
Isopropyl alcohol	This solvent (ordinary rubbing alcohol) will be used for cleaning surfaces that will receive applications of resins.
Contact Renew, aerosol (Freon)	This fluorinated hydrocarbon is used as a nonflammable inert gas for cleaning electrical contacts. This material has a potential for being a simple asphyxiant in the parts per hundred range.
Woven graphite	This fabric will be used to assemble the stages of the Pegasus. It is considered a nonhazardous material.

5.2.2 Air Quality at Edwards Air Force Base

No environmental impacts on air quality of Edwards AFB are expected to occur during routine Pegasus assembly or pre-flight testing. The transport of the rocket to the B-52B will be accomplished by routinely used tow vehicles. Therefore, no significant additions of air pollutants are expected to be made to the local atmosphere. Because Edwards AFB is an aircraft flight test center, experiments are routinely done on B-52Bs and many types of experimental jets and rocket aircraft. Jet engine emissions are listed in Table 3.4 for the B-52B carrying Pegasus. The amount of pollutant added to the atmosphere from take off and landing of the B-52B will not add significantly to the atmospheric burden. These releases should not cause air quality standards at Edwards AFB to be exceeded.

TABLE 5.5. Estimated Average Air Concentrations Within the Vehicle Assembly Building (mg/m^3)

Chemical	VAB Air Concentration	TLV-TWA (a) (ACGIH 1987)	OSHA Guidelines (PEL)
Isopropyl alcohol	4.0	980	980
Perchloroethylene	2.2	335	168
Triethylenetetramine	NV (b)	---	---
Versamid 140 (11% Triethylenetetramine)	NV	---	---
Epon Resin	828	NV	---
Graphite dust	Low (c)	10	---

(a) TLV-TWA = Threshold limit value-time-weighted average.
(b) NV = nonvolatile. These chemicals, although odoriferous, have such low vapor pressures as to be nonvolatile for the purpose of this assessment.
(c) Lightly sanding edges of graphite material will produce unquantifiable amounts of graphite dust.

5.2.3 Noise at Edwards Air Force Base

Jet engine noise from the B-52B launch vehicle is characterized in Section 3.1.4.3. The addition of this noise to the intermittent and short-duration noise already generated at Edwards AFB as a result of aircraft engine run-ups, trim runs, and test flights (Section 4.1.4) is not expected to result in long-term environmental impact. To characterize potential impacts of noise on human populations, the U.S. Environmental Protection Agency (EPA) ahs proposed a Noise Pollution Level (NPL) for typical construction activities (EPA 1971). Table 5.6 is a description of NPL levels [in decibels (dB)] that may be used in evaluating noise impacts to the general public. The table shows that during these intermittent noisy events at Edwards AFB, the "background" levels would be unacceptable if these noise levels occurred within a population of the general public. Noise generated by the Pegasus-carrying B-52B during taxiing and takeoff operations quickly decreases with the distance squared from eh engine (Section 3.1.4.3). If these data are plotted in semilog format, it is estimated that the noise level would be about 115 dB at a distance of exposed to 115 db for 8 min each day and 100 dB for 1 hr each day with no expected adverse effects (ACGIH 1987). However, because takeoff operations are several thousands of feet from Edwards AFB buildings and several miles from populations of the general public, no environmental impacts caused by noise from B-52B operations resulting form the Pegasus project are expected.

TABLES 5.6. Description of NPL Levels (EPA 1971) (a)

Clearly Acceptable: The noise exposure in such that both the indoor and outdoor environments are pleasant.	NPL less than 62 dB
Normally Acceptable: The noise exposure is great enough to be of some concern, but common building constructions will make the indoor environment acceptable, even for sleeping quarters, and the outdoor environment will be reasonably pleasant for recreation and play.	NPL between 62 and 74 dB
Normally Unacceptable: The noise exposure is significantly more severe so that unusual and costly building constructions are necessary to ensure some tranquility indoors, and barriers must be erected between the site and prominent noise sources to make the outdoors environment tolerable.	NPL between 74 and 88 dB
Clearly Unacceptable: The noise exposure at the site is so severe that the construction costs to make the indoor environment acceptable would be prohibitive, and the outdoor environment would still be intolerable.	NPL greater than 88 dB

(a) These criteria have not been officially or unofficially adopted as "standards," but are used as an aid in determining the amount of acceptable noise.

The closest community to the Edwards AFB complex is North Edwards, about 6,400 m (4 mi) north. The noise from flight testing at Edwards AFB is clearly acceptable at this location. Rosamond, about 28,900 m (18 mi) west of the test site, is also unaffected by noise from Edwards AFB flight test operations. Noise levels for sound tests made at the west entrance of the base during flight takeoffs were not measurable above the local Rosamond background noise levels (NASA 1981).

5.2.4 Ecology at Edwards Air Force Base

Atmospheric emissions derived from operations involved in the routine assembly, pre-flight testing, transport of the rocket to the flight line along pre-existing roads, and mating of the rocket to the B-52B on the flight line are expected to be below current standards and could be considered not significant. No resulting impact is expected on either the vegetation or wildlife of Edwards AFB.

Engine emissions from the B-52B during takeoff are small and quantified in Table 3.4. Testing of the B-52 is a routine operation at Edwards AFB; testing has been conducted many times in the past with no apparent environmental impact evident to vegetation and wildlife in the immediate area. Therefore, it is estimated that the addition of six B-52B flights during the Pegasus project will have no additional environmental impacts.

5.2.5 Hazardous Waste Containment and Disposals at Edwards Air Force Base

Hazardous wastes will be stored and disposed of in compliance with NASA and USAF regulations. Chemical usage will result in the generation of <10 lb of solid waste per year. No

Liquid wastes will be generated. Minor atmospheric releases will occur as described in Section 5.2.2. The solid wastes will be packaged, labeled, and stored for pickup by base personnel in accordance with the Hazardous Materials and Hazardous Waste Management Plans for NASA and Edwards AFB.

5.2.6 Accidents at Edwards Air Force Base

Four accident scenarios have been considered involving the Pegasus at Edwards AFB: 1) inadvertent spill of the entire contents of a chemical container within the VAB during Pegasus assembly, 2) inadvertent ordnance detonation during assembly of the rocket while attached to the AIT within the VAB (worst possible accident), 3) drop of the Pegasus during mating to the B-52B, and 4) drop of the Pegasus shortly after the B-52B leaves the runway.

5.2.6.1 Inadvertent Chemical Spill

An accidental spill of the entire gallon (Table 3.1) of isopropyl alcohol can cause air concentrations within the VAB to reach about 1,840 mg/m^3, exceeding the 1987 adopted short-term exposure level (STEL) of 1,225 mg/m^3 (ACGIH 1987). In this case, remedial action will be needed to reduce the air concentrations to below the STEL (a) levels. Outside air concentrations resulting from this spill were estimated using the plume model (Appendix D) for the two closest locations for site personnel exposure, the OSC office trailer [100 m (328 ft) SSW of the VAB] and the NASA office building [300 m (984 ft) E of the VAB]. In this case, the air concentration was estimated on the assumptions that 1) the chemical is uniformly mixed throughout the VAB, 2) two air exchanges occur per hour, and 3) 50% of the air in the VAB would be released during 30 min at approximately 5-m (16-ft) release height through the ventilation system. The resulting air concentrations for this chemical at the OSC office trailer and NASA office building would be at least four orders of magnitude below the standards. Therefore, impacts on personnel in the offices downwind of the VAB during an accidental chemical spill is not expected.

5.2.6.2 Inadvertent Ordnance Detonation of Pegasus Motor

If an inadvertent ordnance detonation took place during assembly, the non-pressurized engine ignition (hole in motor casing adjacent to the nozzle) would probably blow the steel sides and roof off the VAB. It is also assumed that 1) the burn is confined to 100 m^2 ((1,076 ft^2), 2) 20% of the burn products are located in the surface layer (5 m) of the atmosphere, and 3) the equilibrium height of the plume reaches approximately 200 m (656 ft). In this case, there would be an elevated plume and a surface release portion of the plume. The average centerline ground-level air concentrations resulting from the 20% release at ground level are presented in Table 5.7. The maximum air concentration from the elevated plume fumigating to the ground is shown in Table 5.8. The elevated plume may not be traveling in the same direction as the surface portion of the plume because of wind shear; therefore, the concentrations are not additive. For a conservatively high estimate of air concentrations, the two may be added together. The pressure and heat developed from the 4-min burn could cause severe injury or possibly death to personnel in the vicinity of the rocket motor.

The potential impacts to humans and the environment form an HCl plume resulting from this scenario should be acceptable as an emergency within Edwards AFB as described in detail in Section 5.1.2.

(a) STEL = 15-min time weighted average exposure that should not be exceeded at any time during a work day even if the 8-hr time-weighted average is within the threshold limit value.

TABLE 5.7. Average Centerline Air Concentrations of Hydrochloric Acid and Time of Plume Passage, Inadvertent Ordnance Scenario

	Distance, km			
	1	5	10	20
Air Concentration, ppm	1200	125	60	25
Time of Plume Passage, min	4.5	5.2	6.2	8.5

TABLE 5.8. Maximum Ground-Level Air Concentrations of Hydrochloric Acid Due to Fumigation, Inadvertent Ordnance Scenario

	Distance Traveled Before Fumigation, km			
	1	5	10	20
Air Concentration, ppm	50	25	20	10

5.2.6.3 Premature Rocket Motor Ignition

During assembly of the rocket in the VAB, grounding is employed to eliminate any electrostatic-induced ignition. Similarly, during assembly, relative humidity is maintained at about 55% to preclude static discharge. Assembly would be discontinued if relative humidity fell below 30%. However, ignition of the pyrogen igniter could occur from a higher than needed current in the LINCO™ test meter employed for circuit analysis. Should static build up or the test meter malfunction, the first stage and/or second and third stages could be ignited. The thrust-developed ignition of the first stage via the pyrogen igniter would propel the Pegasus and AIT out of the VAB. At some point, the duo would tumble, destroying the integrity of the rocket housings, resulting in uncontrolled burn/detonation.

It is assumed that the ignited motor would destroy the VAB before or while it is being propelled from the building. Burn rates would be more or less independent of the design fuel burn rate and could last for several minutes. The combustion products from pressurized or atmospheric burning of propellant are the same, only the quantities are different (see Table 3.5 and Table C.2, Appendix C). The pressure and heat developed from the explosion and/or the burn could cause severe injury or possibly death to personnel in the vicinity of the rocket motor.

Potential impacts from combustion products were estimated. If the rocket left the VAB and began to tumble, burning fuel may be distributed over an area of about 1,000 m2 (10,764 ft2) some distance northwest of the VAB, away form NASA buildings and the dry lake. Plume rise was estimated based on an equation developed by Briggs (1981). Heat flux from the burn was estimated to carry the effluent vertically to a height of approximately 200 m (656 ft). Because of the large burn area, a uniform air concentration was assumed in the vertical. By making this assumption, the plume is assumed to be in contact with the ground.

About 3.4×10^6 g of HCl will be released in a complete burn of all three rocket motors. The average air concentration in the cloud at the end of a 4-min burn will be about 500 ppm. The average centerline ground-level air concentrations were estimated downwind assuming no surface depletion of HCl (Table 5.9). Gaussian plume diffusion was assumed using parameters for a stable atmospheric condition.

These estimated air concentrations of HCl and the times of plume passage are well within the range of short-term reversible effects to humans as described in detail in Section 5.1.2. However, escape from the plume would be desired.

The ground-level air concentrations for the surface portion of the plume are biased toward higher air concentrations because it was assumed that all the fuel involved in the fire burns and stable atmospheric conditions exist. Either of these assumptions will produce high ground-level air concentrations.

The potential impacts to humans and the environment form an HCl plume resulting form this fire scenario would be acceptable as an emergency within Edwards AFB as described in detail in Section 5.1.2.

5.2.6.4 Drop Pegasus During Mating With the B-52B

The AIT will be jacked up to the B-52B wing pylon for mating. The rocket will not be lifted by a crane. Therefore, there is almost no possibility of an accident drop of the rocket. If, however, Pegasus were dropped to the ground during mating, it would sustain severe impact damage, but it would not burn or detonate. There would be no impact to nearby personnel or the environment.

5.2.6.5 Drop Pegasus Soon after Takeoff

Two scenarios were considered for an accident during B-52B takeoff. Both scenarios assume the rocket would be dropped during takeoff and tumble down the flight line. This would result in fragmentation of the rocket housing and ignition of the fuel.

The first scenario assumes some fragmentation of the first and second stage resulting in no burn, and the third stage remaining nearly intact and beginning a non-pressurized burn. A fragmentation of rocket part and fuel before ignition could result in dispersal of 10 to 50% of the fuel in the unburned state. Open, non-pressurized, low-temperature burning will occur, with pieces of the third stage of the rocket contained within a 100-m^2 (1076 ft^2) area. Plume rise was estimated using an equation developed by Briggs (1981). Heat flux form the burn was estimated to carry the effluent vertically to a height of approximately 150 m (492 ft). A uniform air concentration was assumed in the vertical. This assumption would leave the lower portion of the plume in contact with the ground.

TABLE 5.9. Average Centerline Ground-Level Air Concentrations of Hydrochloric Acid and the Time of Plume Passage, Premature Rocket Ignition Scenario

	Distance, km			
	1	5	10	20
Air Concentration, ppm	290	75	50	20
Time of Plume Passage, min	4.5	5.2	6.2	8.5

HCl will be released in a complete burn of approximately 1.7 x 10^5 g. The average air concentration in the cloud at the end of 2 min of burning will be approximately 200 ppm. Maximum ground-level air concentrations were estimated downwind of the burn. Because transport times being considered are relatively short and the local surface dry, little effects on the air concentrations are expected as a result of surface deposition of HCl. Gaussian plume diffusion was assumed with a mean wind speed of 3 m/sec (9ft/sec).

The resulting average centerline air concentrations during plume passage from the 100 m^2 (1,076 ft^2) burn are shown in Table 5.10.

The second scenario assumes all the fuel from all three stages is involved in the fire, the rocket comes to rest nearly intact, the rocket burns in a 100-m^2 (1,076-ft^2) area, and the fuel burns over a 4-min period producing 3.4 x 10^6 g of HCl. Also assumed was mixing with environmental air during the burn, leaving 20% of the burn products in the surface layer. As before, an elevated plume was estimated. An equilibrium height of approximately 300 m (984 ft) was estimated, resulting from the greater intensity of the fire. In this case, the two portions of the plume's effect on surface air concentrations were considered: the elevated plume and the surface (5-m) (16.4-ft) plume. Again diffusion calculations were based on a Gaussian plume under stable, "F," conditions. The resulting estimated average centerline ground-level air concentrations are presented in Table 5.11.

The second portion of the plume was assumed to reach the surface during fumigation at the distances noted. The air concentrations form fumigation were based on estimates of maximum surface air concentrations from Turner (1969) and are shown in Table 5.12. The fumigation maximum air concentrations generally will not be additive to the air concentrations of the surface

TABLE 5.10. Average Centerline Air Concentrations and Time of Plume Passage, Drop After Takeoff, Scenario One

	Distance, km			
	1	5	10	20
Air Concentration, ppm	30	7	4	2
Time of Plume Passage, min	2.5	3.5	4.1	6.5

TABLE 5.11. Average Centerline Air Concentrations and Time of Plume Passage, Drop After Takeoff, Scenario Two

	Distance, km			
	1	5	10	20
Air Concentration, ppm	1200	140	80	30
Time of Plume Passage, min	4.5	5.2	6.2	8.5

TABLE 5.12. Average Maximum Air Concentration, Drop After Takeoff, Scenario Two

	Distance Traveled Before Fumigation, km			
	1	5	10	20
Air Concentration, ppm	50	25	20	10

portion of the plume. There are two reasons for this. The first is that the elevated portion of the plume may be transported in a different direction than the surface plume. Secondly, the vertical mixing required for fumigation would also cause increased vertical mixing with a resulting decrease in air concentration for the surface portion of the plume. However, for a conservatively high estimate of air concentration.

These air concentrations are biased toward higher air concentrations as a result of assuming all the fuel is burned and a stable atmosphere exists. Either of these assumptions will produce high surface air concentrations.

The potential impacts to humans and the environment that may result from this fire scenario form an HCl plume with the air concentrations and plume travel times estimated above should be acceptable as an emergency within Edwards AFB as described in detail in Section 5.1.2. The fire would be located on the runway or apron and is not expected to burn any habitat or harm the desert ecosystem. However, leaf and soil interactions with some of the combustion products are of potential concern. This is discussed in detail in Section 5.1.2.

Based on the environmental analyses conducted for Edwards AFB, no significant environmental impacts from the proposed action are expected.

5.3 FLIGHT CORRIDOR

Upon liftoff from Edwards AFB, the B-52B will fly toward the Pacific Ocean via the land corridor described in Section 3.1.4.4

5.3.1 Air Quality in the Flight Corridor

Because the only impact on air quality during normal operations is caused by the jet engine combustion products at flight altitude across the flight corridor, no long-term impact is expected with respect to air quality.

5.3.2 Ecology in the Flight Corridor

The B-52B will be flying at such an altitude [9,150 to 12,200 m (30,000 to 40,000 ft)] as it passes through the flight corridor that its emissions would have no impact on the terrestrial environment of the corridor.

5.3.3 Accidents in the Flight Corridor

The two potential accident scenarios that may occur over the flight corridor are 1) a crash of the mated B-52B/Pegasus rocket, and 2) a separation of the rocket from the B-52B followed by a direct impact of the intact rocket on the ground. While precise information on the results of a B-52B crash are not available at this time, the NASA hazard report (a) indicates a loss of B-52B and crew, property damage, injury, and loss of life in the impact area can be considered as possible results.

Based on the contact with OSC, (b) impact of the rocket with water or land surfaces will result in explosion of the propellant. The explosion caused by impact of the rocket is likely to disperse significant quantities of unburned propellant. This is analogous to the fate of the solid rocket boosters form the Challenger accident.(c) It has been estimated that the maximum force of the explosion could equal 100% (35,000 lb) TNT.(b)

In a worst-case situation, this amount of force, if occurring along the overland flight corridor to the WTR, would likely level or structurally weaken concrete/brick structures within 500 to 1,000 m (164 to 3,279 ft) of the impact point. Wooden structures would be at risk to approximately 2 km (7 ft) from the impact point. Heat and flying debris from the explosion would likely ignite combustible materials within 100 m (328 ft) of the impact point. In populated areas, structural fires would result. Impact in irrigated agricultural areas would likely not cause significant fire damage. Impact in the drier grass and scrub/brush areas of the Pacific Coastal Ranges would likely cause severe fires if not rapidly suppressed.

The flight corridor to the WTR lies just south of Bakersfield, the Elk Hills Naval Petroleum Reserve, and San Luis Obispo. Other than the two cities, the intervening terrain consists of lightly timbered mountains, scrub lands, and dry and/or irrigated agricultural lands. Interspersed throughout the flight path are widely spaced oil fields. Inflight loss of the Pegasus and subsequent explosion would result in little property loss other than from the resulting fire. The only exceptions are the sparsely populated areas south of the two cities. The remote chance of impact in these two areas could result in a significant loss of life and property. No estimates of population density are available.

In addition to direct effects resulting form the probable rocket explosion, a secondary effect would include a fire initiated either by the heat of the actual explosion, or through the dispersal of non-exploded but ignited combustible material to the area surrounding the crash site. While the extent of such an occurrence may not be too great if the impact took place in dryland farming portions of the San Joaquin Valley, much more extensive damage may occur if the accident took place in some of the oil fields in this area or in the forested regions of the Southern Sierra Nevada and eastern slopes of the Coastal Ranges. These latter areas receive low amounts 0.2 to 0.3 m (8 to 12 in.) of precipitation yearly and can have severe forest/brush fire hazards in the summer and fall.

Aside from the immediate and direct phytotoxic effects of a crash-initiated explosion/fire, there will be an accompanying release to the atmosphere of the same combustion products described above. The effects of these releases on the vegetation over these areas will be similar to that described above and will be a result of the aforementioned factors of severity (length and amount) of exposure and species sensitivity of the contaminated plants. There will be higher

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(a) NASA-Ames Research Center, Dryden Flight Research Facility. nd. Hazard Report (HR). Layton/PRC originators, HR No's. 001 through 008.

(b) Personal Communication from Donald L. Thoma, Manager, Flight Operations, OSC, to Charles Brandt, PNL, April 5, 1989 (letter).

(c) Personal Communication from William Robins, Chemical Sciences Department, PNL to Dom Cataldo, Environmental Sciences Department, PNL, April 1989.

incidence of mesophytic types present in the western portions of the flight path as opposed tot the eastern portions; however, these may not be of higher sensitivity as indicated above.

No significant environmental impacts have been identified from the environmental analyses conducted in the Pegasus flight corridor.

5.4 WESTERN TEST RANGE

The WTR is a military test range controlled by the Western Space and Missile Center at Vandenberg AFB, California. The WTR lies over the Pacific Ocean off the coast of south-central California.

5.4.1 Air Quality in the Western Test Range

The B-52B, carrying the Pegasus rocket, will launch and ignite the rocket while traveling at Mach 0.8 (264 m/sec). Ignition of the first stage will accelerate the rocket to 2,650 m/sec (Mach 8) after 78 sec. At first-stage burnout, the rocket will be at a 62,200-m height (from an ignition altitude of 12,200 m) 65 mi downrange, and have traveled 115 km (72 mi) (26 rise angle). First-stage burnout will occur approximately 267 km (250 mi) off the coast of Baha. During this interval, the first stage expends its full propellant load of 12,170 kg (26,800 lb). Neglecting gravitational effects, drag, and changes in acceleration caused by changes in vehicle weight, a first approximation of fuel consumption rates and distances can be calculated. This represents a burn rate of 156 kg/sec (343 lb/sec) (Figure 5.1).

Figure 5.2 shows the estimated relationship between vehicle speed and distance traveled. Only the first stage is of concern, because combustion products from the second and third stages will be at altitude greater than 40 mi and be of no impact.

Figure 5.3 provides data on distance traveled (vertical and horizontal) versus flight time. Figure 5.4 provides rate of fuel consumption based on travel distance. Approximately 95 kg (210 lb) of fuel will be consumed in the first kilometer of flight, 885 kg (1,950 lb) consumed in the next 9 km, and 11,190 kg (24,640 lb) consumed in the last 90 km. Figure 5.5 provides fuel usage with altitude following launch at 12,200 m (40,000 ft).

Based on these plots, and the combustion products defined in Table 3.5, estimates of contaminant concentration can be made for specific masses of air both horizontally and vertically form time of ignition.

In a normal launch, airborne emissions will be produced during the burn phase of the Pegasus rocket. The combustion products Al_2O_3, HCl, and NO_X are recognized as potentially hazardous. Because of the initial high temperatures and the abundance of O_2, it is expected that CO will rapidly oxidize to CO_2. For the purpose of analysis, the plume, containing HCl and NO_X, is assumed to be 37 m (40 yd) wide and the emissions distributed along the flight path (USAF 1988). Because of vehicle acceleration, the maximum concentrations of HCl and NO_X are expected near the ignition pint with a continuous decrease along the flight path. The release of HCl and NO_X by the Pegasus rocket into the stratosphere may affect the ozone in this region. The potential depletion of ozone may allow more ultraviolet radiation to reach the earth's surface. The resulting increase of ultraviolet radiation may cause a variety of health problems including a potential increase in skin cancers. Previous studies on the effects of shuttle launches on the ozone

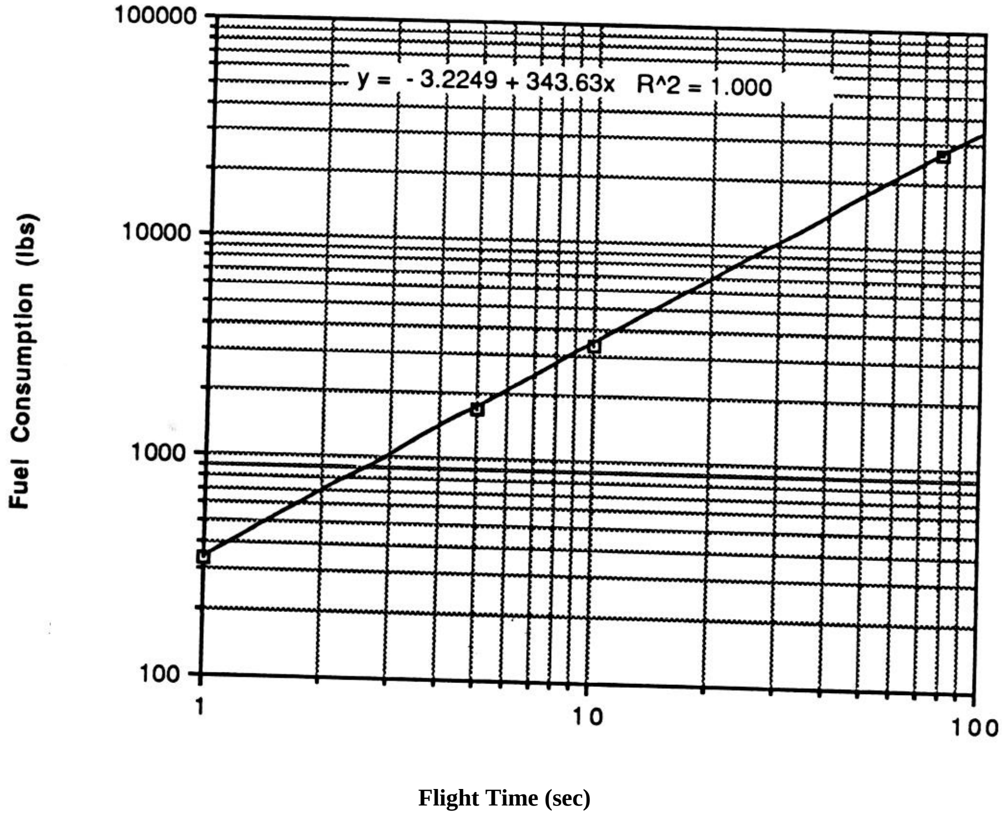

FIGURE 5.1. Pegasus First Stage-Fuel Consumption Versus Flight Time

layer and its potential increase in skin cancer found these effects to be below commonly acceptable level of deaths from skin cancers (NASA 1978). The amount of pollutants released by Pegasus from all six potential launches will be a factor of 10^{-2} less than the effect of a comparable numbered shuttle launches, assuming all of the exhaust pollutants were injected into the stratosphere. An analysis of the effect of three shuttle launches on ozone depletion and subsequent deaths from skin cancer found that the ozone depletion form these launches would cause approximately 0.01% loss of ozone (NASA 1978). The resulting estimated increase of deaths from skin cancer for the shuttle was less than the commonly used level risk (10-6) judged to be acceptable (Anderson 1983). Therefore, the impact of the Pegasus rocket on potential skin cancer mortality is clearly acceptable.

Because the launch of the Pegasus from a B-52B will occur at an altitude greater than 12,200 m (40,000 ft), the concentrations of the rocket combustion products at ground level would be so diluted that the resulting air concentration at the ground surface is expected to be several orders of magnitude lower than the National Academy of Sciences recommendations for short-term exposure (NAS 1977) and the OSHA current permissible exposure limit.

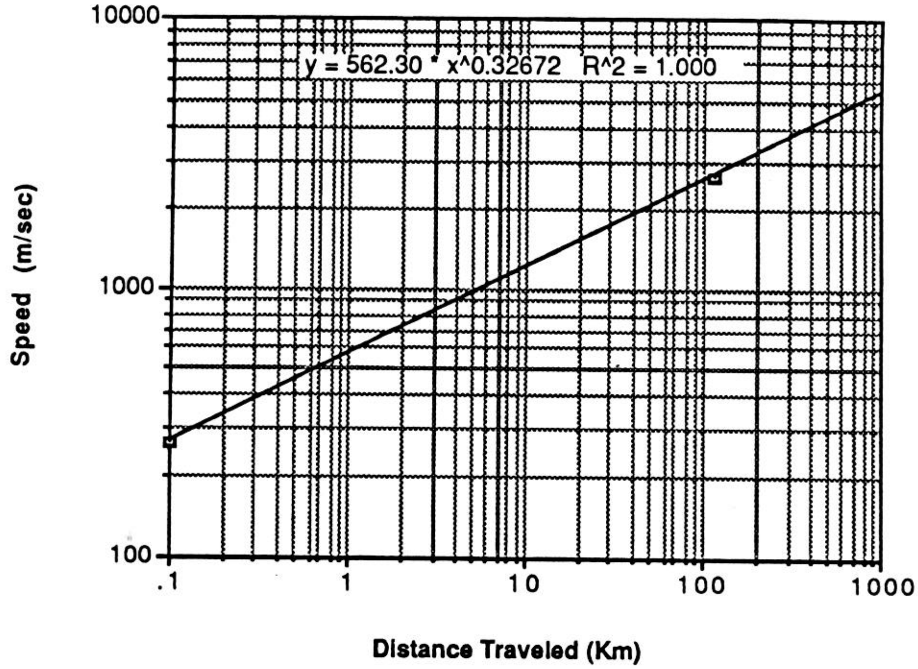

FIGURE 5.2. Pegasus First Stage - Speed Versus Distance Traveled

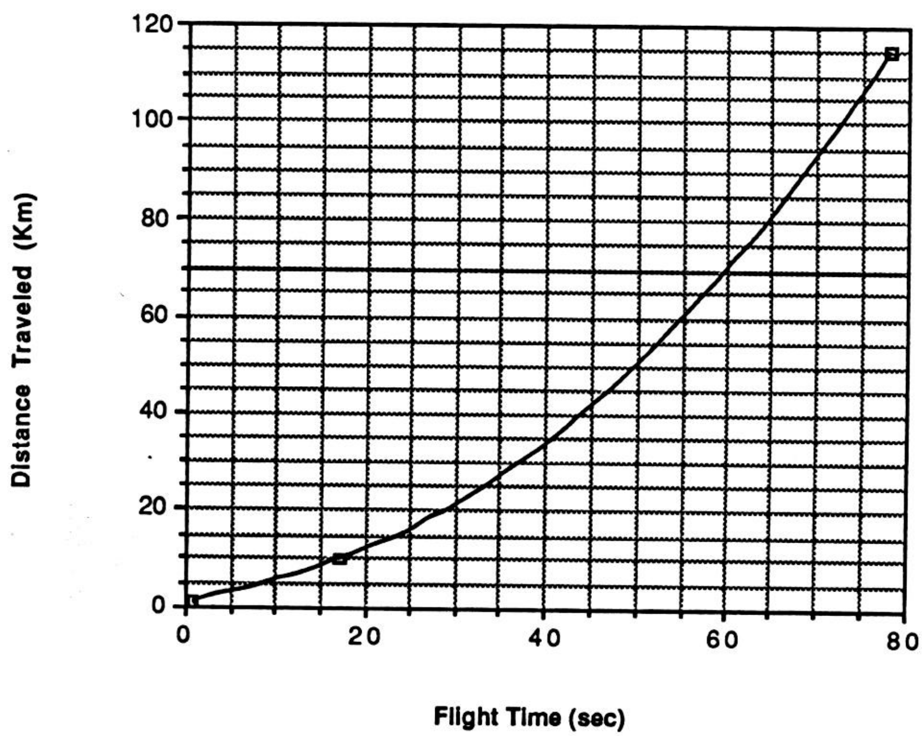

FIGURE 5.3. Pegasus First Stage - Flight Time Versus Distance Traveled

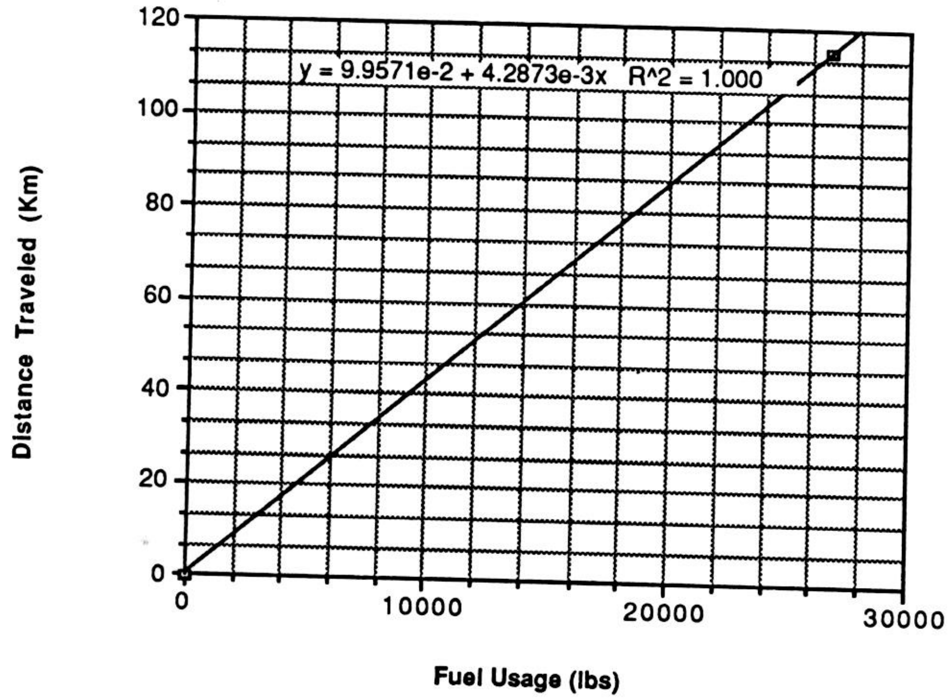

FIGURE 5.4. Pegasus First Stage - Fuel Consumption Versus Distance Traveled

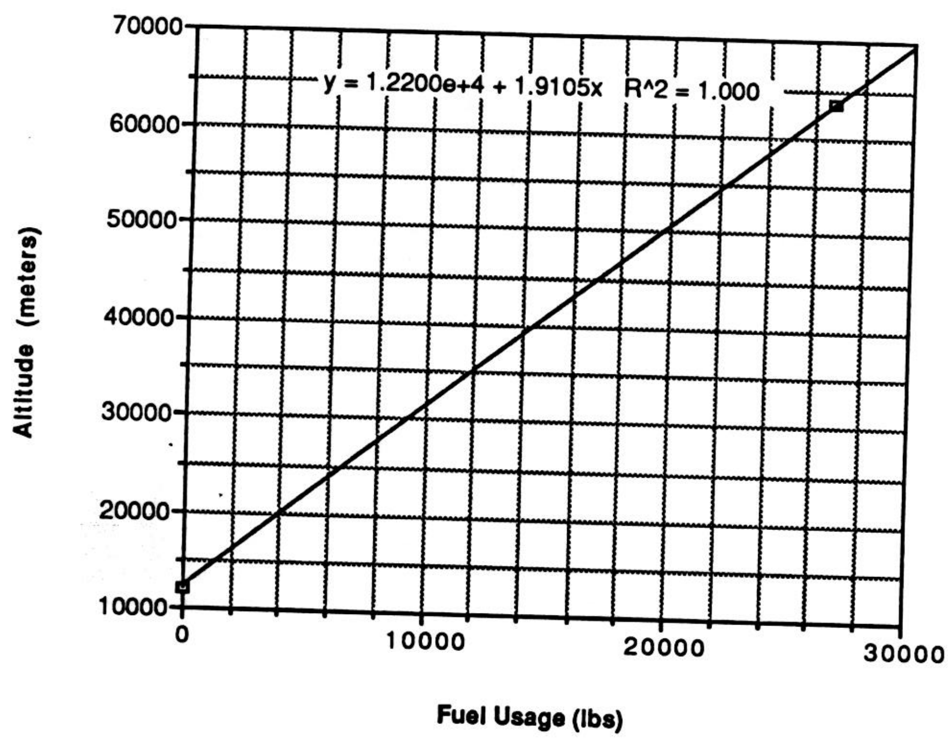

FIGURE 5.5. Pegasus First Stage - Fuel Consumption Versus Altitude

Particulate concentrations are also not expected to exceed the 24-hr average National Ambient Air Quality Standards (NAAQS) of 150 g/m3 because of the short and intermittent nature of the launches. Elevated particulate levels are expected for a short period along the trajectory of the vehicle. Therefore, there will be no environmental impacts form the routine launching of the Pegasus rocket over the Pacific Ocean within the WTR.

5.4.2 Ecology in the Western Test Range

Potential emissions form a routine B-52B flight at the altitude projected for the WTR are below those considered significant and should not constitute an environmental impact. Emissions form the coupled rocket at this time should also be minimal.

Noise effects on sealife as a result of sonic booms over the water were studied extensively for the space shuttle and were found to be insignificant (NASA 1978). Noise levels from the Pegasus will be well below levels from the shuttle.

Under routine flight conditions, vehicles stages that do not go into orbit will impact in the Pacific Ocean (Figure 3.9).

Corrosion of stage hardware will contribute various metal ions to the water column (USAF 1988). Because of the slow rate of corrosion in the deep ocean environment and the large volume of water available for dilution, toxic concentrations of metals are not likely to occur. Relatively small amounts of rubber-based propellant may be released into the ocean along with various spent stages (USAF 1988). If concentrations in excess of toxic levels for marine organisms will occur at all, they will be limited to the immediate vicinity of the spent stage. Because of the limited number of launch events scheduled, the small amount of residual propellants present, and the large volume of water available for dilution, no significant environmental impacts are expected to occur as a result of spent stages entering the oceans.

The launch of the Pegasus booster will occur 360 km (220 mi) from the Channel Islands, with a trajectory leading away for the islands. Any significant level of noise will be dissipated before reaching the vicinity of the islands. Because of the great distance and small size of he booster, no environmental impacts are expected to the animal species of the islands.

5.4.3 Accidents in the Western Test Range

Following normal release and ignition of the Pegasus, it will be armed for destruction. Should the rocket fly off course the flight termination system explosive charge will detonate at the separation joints between adjacent motor stages causing the errant rocket to tumble with little forward velocity. The first stage will continue to burn in the atmosphere and impact the Pacific Ocean. The propellant in the second and third stages will likely ignite (OSC 1988); these stages will also impact the Pacific Ocean.

During the time the burning rocket motors are falling toward the ocean, the gaseous effluent plume components rapidly mix with atmospheric moisture, forcing their equilibrium reaction. Major products would likely include Al oxides, hydroxides and chlorides, and HCl. Because of the moisture content of the plume, much of these materials would settle to the ocean surface faster than during an over-land event. The fragments of the motors would likely sink in the sea. Small fragments of fuel may float on the surface of the sea for a time, and some dissolution may occur; however, fragments would eventually become water logged and sink. It is expected that the concentrations present in the plume at the initial site of impact will have little impact on the composition of the seawater in the immediate vicinity because of a rapid dilution effect and natural buffering capacity of the ocean. It is unlikely that a significant portion of the flotsam would travel the 96,540 m (60 mi) to land (Figure 4.5). There is no information available on the solubility/toxicity of the propellant material in seawater at this time. However, the probable wide distribution of the destroyed rocket over the ocean given the high altitude of probable destruction will minimize potential effects.

An alternate scenario would be normal release, but no ignition, causing the rocket to fall into the ocean. Under these conditions, the destruct charges would likely not be used, particularly over water. The rocket propellant would most likely detonate on impact with the ocean, resulting in the impacts discussed above. Another scenario would be for the Pegasus to be inadvertently dropped while in flight over water. In this situation, the rocket would reach a terminal velocity and explode on impact with the water. The propellant in all three stages would likely detonate, resulting in the impacts discussed above.

Therefore, this type of accident over the WTR appears to result in insignificant long-term environmental impacts.

5.4.3.1. Collision of Pegasus with the B-52B Aircraft

Following release from the B-52B and subsequent ignition of the Pegasus, attitude control failure or unexpected turbulence could cause the rocket to pitch up and collide with the B-52B. Under these conditions, both the vehicle and aircraft could be severely damaged. More probably, the impact would be sufficient to ignite fuel aboard the aircraft and/or detonate the fuel aboard the Pegasus. In either case, the vehicle and aircraft would likely be destroyed. Because this scenario would occur only at altitude over the WTR, combustion products and burning debris would be spread over a large area of the ocean, but likely not in proximity to land.

5.4.3.2. Inflight Fire Aboard the B-52B

Any fire aboard the B-52B would necessitate either an emergency landing at Edwards AFB, or ditching of the aircraft following crew extraction. Serious fire aboard the aircraft while Pegasus is still attached would require and emergency landing, if the aircraft were still in the proximity of Edwards AFB. If should occur while within the flight corridor to the WTR, and the aircraft could make an emergency landing, the Pegasus vehicle would likely be jettisoned either over the Pacific Ocean or over a designated unpopulated area. While over the WTR, an aircraft fire would necessitate the release of the Pegasus, the aircraft would like be abandoned over water or designated unpopulated areas, assuming that an emergency landing could not be attempted at Edwards AFB or an alternate AFB. The release of Pegasus in each of these situations, whether over land or water, would result in impact and explosion of the vehicle as described Section 5.3.3.

5.5 CUMULATIVE IMPACTS

The Pegasus air-launched space booster project is one of many programs being considered for Edwards AFB and one of a number of ongoing flight test and research programs being conducted there. To meet the requirements of the National Environmental Policy Act, potential adverse impacts that may be contributed by the proposed Pegasus project must be considered in combination with those of other current and proposed projects in the area, such as starting a new phase of research on the X-29 aircraft and FB-111 ejection seat recertification testing using the same B-52B.

The routine operations of the proposed Pegasus air-launched space booster project is not expected to significantly impact the natural environment. Potential minor impacts to the Edwards AFB environment include intermittent air emissions form the VAB and the production of a small amount (<10 lb/yr) of solid hazardous wastes. In addition, a temporary increase of air emissions and noise will occur from the B-52B during taxiing and take off from Edwards AFB. The B-52B jet engine emissions and noise are expected to be the only potential impacts to the atmosphere [9,150 to 12,200 m (30,000 to 40,000 ft)] over the flight corridor. Potential impacts to the atmosphere over the WTR [12,200 to 13,700m (40,000 to 45,000 ft)] include the routine jet engine emissions and noise from the B-52B and the exhaust (combustion products) from the launched Pegasus. These potential impacts are of short duration and common from aircraft and rockets, both commercial and military, that fly over California and the WTR continuously. Degradation of the ozone layer due to the routine operation of Pegasus has been shown to be insignificant. This impact multiplied by all Pegasus launches and those of much larger rocket boosters do not constitute a significant cumulative impact upon the ozone layer. Therefore, there will be no measurable net increase in adverse impacts to the environment as a result of the proposed project and, therefore, no measurable cumulative impact.

5.6 ENVIRONMENTAL IMPACTS FROM ALTERNATIVES

Alternative launch vehicles and launch sites were considered in this EA.

5.6.1 Alternative Launch Vehicles

Alternative launch vehicles were considered for the Pegasus project (Section 3.2). These alternatives would consist of either modifications of existing space launch vehicles or development of new space launch vehicles. Implementation of this alternative would result in the same basic types of environmental impacts as the proposed action.

Other developed booster options are all significantly larger than the Pegasus (Figure 3.9). The environmental impacts of these alternative rocket boosters would be greater than from the Pegasus air-launched vehicle. A ground-launched booster rocket must overcome gravity and thousands of meters of atmosphere that an air-launched vehicle avoids to put a payload into earth orbit. Therefore, a much greater amount of rocket fuel must be burned per pound of payload during a ground-launched than during and air launch. In addition, the routine rocket engine emissions from a ground launch vehicle will be much closer to humans and the natural environment, thus allowing significantly less dilution in the atmosphere before contact with terrestrial or aquatic life. These potential impact differences are partially compensated for by the additional jet engine emissions from the B-52B launch vehicle used for the Pegasus air launches. However, these emissions are mitigated by the large increase in dilution potential of the atmosphere [11,300 m (7 mi) of vertical dispersion].

Many ground-launched rockets require an additional resource use. Large quantities of water are used to suppress noise and to cool the launch pad structure. This water is generally collected in basins or ponds and allowed to evaporate. The potential environmental effects of the Delta and the Titan boosters have been discussed in detail elsewhere (USAF 1987, 1988). These arguments suggest that the routine operation of the Pegasus will cause less environmental impact than the alternative rocket boosters.

5.6.2 Alternative Launch Sites

Alternative launch sites considered for the Pegasus are discussed in Section 3.3. A West Coast launch site must be used to put a payload into polar orbit. One potential alternative would be Vandenberg AFB, California. This alternative would generate the same amount of potential air pollutants form takeoff of the B-52B as would the proposed action. However, Vandenberg AFB is much closer to significant numbers of people and therefore the B-52B jet engine emissions and noise would not have the distance for mitigation as they would at Edwards AFB. In addition, the B-52B would be flying over sensitive habitat at a much lower altitude than if the aircraft took-off from Edwards AFB.

5.6.3 No Action Alternative

If the Pegasus project is not implemented as planned, the United States would be forced to depend on other launch capabilities for launching small commercial or military payloads form the West Coast. Under the no action alternative, payloads scheduled to be carried on Pegasus would have to be launched form Atlas, Delta, or Titan vehicles, or foreign vehicles, or required to wait for another newly developed vehicle. As shown above, implementing these alternatives would cause greater environmental impacts than implementing the proposed action.

The United States has determined that there is a need for space commercialization together with a need to cost effectively launch small commercial and military payloads into polar orbit. The Pegasus air-launched booster would satisfy both these needs. The no action alternative would not fulfill the intent of the Commercial Space Launch Act of 1984 (Public Law 98-575).

6.0 ENVIRONMENTAL PERMIT AND REGULATORY REQUIREMENTS

In this section, we discuss environmental permit requirements and other environmental regulatory requirements pertinent to the Pegasus project.

6.1 AIR QUALITY

No air quality permits or authorizations will be required for the Pegasus Ground Support Facilities, because no emissions regulated under the Clean Air Act will occur. No air quality permits or authorizations will be required for the B-52B taking off from Edwards AFB.

6.2 WATER QUALITY

Water for the Pegasus project is intended for sanitary use in the office and assembly buildings (Pegasus Ground Support Facilities) and will be discharged to the base sanitary sewer system. No discharges of liquids to waters of the United States are planned, so no national pollutant discharge elimination system permit will be required. No underground injections of liquids are planned, so no underground injection control permit will be required.

Any hazardous material in liquid form will be handled according to the base Hazardous Materials and Hazardous Waste Management Plans for Edwards AFB and NASA (see Section 6.3).

6.3 HAZARDOUS WASTES

Edwards AFB has a permit issued by the California Department of Health Services for the storage of hazardous wastes generated at the base. This permit requires that hazardous wastes be packaged, stored at the hazardous waste facility, and then transported offsite by a registered hauler to an approved disposal site. There are no hazardous substances, as defined under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Clean Air Act, or the Resource Conservation and Recovery Act, to be used in the Pegasus Ground Support Facilities other than rocket fuel. Should any of this material become waste, it will be handled, stored, and disposed of in accordance with the hazardous waste facility permit.

Hazardous waste minimization plans are incorporated into the February 1988 Hazardous Materials and Hazardous Waste Management Plan for Edwards AFB. Handling and minimization of hazardous wastes will be in accordance with this document. Protection of workers will be in accordance with appropriate Air Force regulations including AFOSH 161-21, “Hazard Communication,” and AFOSH 127-66, “Air Force Occupational Safety and Health Standard.”

6.4 TRANSPORTATION

Transport of the Pegasus booster components to Edwards AFB and transport of any hazardous wastes away from Edwards AFB to a disposal site will be in accordance with DOT regulations, specifically those in 49 CFR 171-179, “Hazardous Materials Regulations,” and in 49 CFR 350-399, “Federal Motor Carrier Safety.”

6.5 UNDERGROUND STORAGE TANKS

No underground storage tanks will be constructed for use at the Pegasus assembly site, so there are no federal or state notification requirements to be met.

6.6 ENDANGERED SPECIES

A field survey was conducted on August 25 and 26, 1988, to identify flora and fauna on the site of the Pegasus Ground Support Facilities. Approximately 80% of the project site has already been cleared for NASA parking lots. No federal or state listed rare, threatened, or endangered plant or animal species was observed or is known to exist within the project site [approximately 1,115 m^2 (12,000 ft^2)].

6.7 NOISE IMPACTS

B-52B flights will either be routed around the California Condor Refuge (all condors are now in captivity) or will be at an altitude greater than 915 m (3,000 ft) over the condor refuge to avoid noise impacts to this critical habitat. Pegasus release points will be at altitudes greater than 12,200 m (40,000 ft) and more than 92,000 m (50 nautical mi) offshore to avoid impacts when the booster enters supersonic flight.

6.8 HISTORIC PRESERVATION

A field survey of cultural and historic resources was conducted on June 15, 1988, over an area of 27 acres that includes the Pegasus project area. As a result of this survey and a prior literature search and review, no historic or cultural resources were found either within or near the Pegasus project area. Subsurface occurrences are not expected. The California Office of Historic Preservation concurs in these findings.

6.9 COASTAL MANAGEMENT PROGRAM

A Coastal Consistency Determination has been considered by the USAF in compliance with the Federal Coastal Zone Management Act (16 USC 1451 et seq.) and with the National Oceanic and Atmospheric Administration (NOAA) Federal Consistency Regulations (15 CFR 930). These regulations require federal agencies to ensure that their undertakings are consistent to the "maximum extent practicable" with the NOAA-approved state Coastal Management Program (CMP) for actions that may have direct impact on a state's coastal zone.

In California, the California Coastal Commission, as lead agency for the CMP, coordinates the evaluation of a determination and develops a formal state consistency response. As stated in 15 CFR 930, federal activities on federal activities on federal property are excluded from state-designated coastal zones. If a federal activity has a direct impact on the state coastal zone, this activity must be consistent.

The Pegasus project does not involve any construction in the coastal zone nor will it have direct impacts on the coastal zone. Therefore, a Consistency Determination is not required.

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Dr. D. A. Cataldo	Plant Physiology	21 yr	Accident Scenario and Source Terms
Dr. W. E. Davis	Atmospheric Physics/ Chemical Engineering	24 yr	Meteorology/Atmospheric Diffusion (3.0, 4.0, 5.0) Air Quality and Air Quality Impacts
R. W. Fellows	Plant Physiology	19 yr	Affected Environment (Vegetation) (4.0), Routine Impacts on Vegetation (5.0), and Accident Impacts on Vegetation
R. E. Lundgren	Technical Communication	5 yr	Editing/Production
Dr. P. J. Mellinger	Oceanography/ Radioecology	23 yr	Project Management, Description of Proposed Action and Alternatives, and Accident Impacts on Man
Dr. E. B. Moore	Environmental Regulation	33 yr	Regulations and Permits (6.0)
T. M. Poston	Aquatic Toxicology	12 yr	Toxicology (5.0)
W. H. Robins	Solid Propellants and Explosives	5 yr	Propellant Technology (3.0 and 5.0)

APPENDIX A

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APPENDIX B

BIOTIC DESCRIPTIONS OF THE PROJECT AREA

APPENDIX B

BIOTIC DESCRIPTIONS OF THE PROJECT AREA

This appendix contains additional information on the biota of Edwards Air Force Base (AFB), the flight corridor Pegasus would travel to the Western Test Range (WTR), and the WTR itself.

B.1 VEGETATION OF EDWARDS AIR FORCE BASE

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

The creosote bush scrub plant community is primarily confined to slopes, hills, and well-drained sandy flats and washes. Shrub species commonly associated with the creosote bush include the burrobush, Mormon tea, brittlebush (*Encelia fainosa*), snakeweed (*Gutierrezia* spp.), shadscale (*Atriplex canescens*), winterfat (*Eurotia lanata*), cheesebush (*Hymenoclea salsola*), and rabbitbrush (C*hrysothamnus* spp.). Herbaceous species common to the creosote bush scrub community include those found in the Joshua tree woodland, with the addition of the desert evening primrose (*Oenothera deltoids*) and the alkali mairposa lily (*Calochortus striatus*).

The Mojave saltbush scrub assemblage is dominated by spiny salybush (*Atriplex spinifera*). This species forms sizeable, nearly monotypic stands at low elevations surrounding playas. This species occurs in more alkaline soils than other saltbush species found in the area. The community intergrades with desert saltbush scrub at higher elevations and shares many of the same species.

The shadscale scrub occurs on poorly drained flats or well-drained slopes at higher elevations. It dominated by shadscale (*Atriplex confertifolia*). Other species present include ephedra (*Ephedra nevadensis*), winterfat, small-headed matchweed (*Gutierrezia microcephala*), Indian ricegrass, and bald-leaved felt-thorn (*Tetradymia glabrata*).

The desert saltbush scrub community covers low depressions and margins of dry lakes throughout Edwards AFB on soils intermediate in alkalinity between Mojave saltbrush scrub and shadscale scrub. Dominant shrub species of this community include a variety of Atriplex species other than shadscale or spiny saltbush. Shrub species common to this community include cheesebush, goldenhead (*Acamptopappus sphaerocephalus*), burrobush, spiny hopsage (*Grayia spinosa*), winterfat, and thornbush (*Lycium* spp.). Herbaceous species include scale bud (*Anisocoma acaulis*), pebble pincushion (*Chaenactis carphoclinia var attenuata*), Remont pincushion (*Chaenactis fremontii*), fiddleneck, forget-me-not, matted cryptantha (*Cryptantha circumscissa*), phacelia (*Phacelia* spp.), buckwheat, and desert eriastrum (*Eriastrum eremicum*).

The desert alkali-sink scrub consists of widely spaced low shrubs that occur on poorly drained soils with extremely high alkalinity and/or salt content. This association occurs primarily on the margins of dry lake beds or playas. Typical species include allscale (*Atriplex polycarpa*), arrow scale (*Atriplex phyllostegia*), inkweed (*Suaeda torreyana*), blunt-leaf stinkweed (*Cleomella obtusifolia*), pepper-grass (*Lepidium dictyotum*), and Chinese pulsey (*Heliotropium curassavicum* var. *oculatum*).

B.1.1 Threatened and Endangered Species, and Species With Special Status

Alkali Mariposa Lily. The alkali mariposa lily is a small, smooth, perennial herb, 0.10 to 0.45 m (r to 18 in.) 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 spring-moistened areas at elevations of 760 to 1,300 m (2,500 to 4,300 ft) and is associated with the creosote bush scrub habitat (Munz and Keck 1965). Alkali mariposa lily is a candidate for federal protection. It is in the U.S. Fish and Wildlife Service (USFWS) Category 2, plants that may warrant listing but for which substantial biological information to support such listing is lacking.

Mojave Spineflower. Mojave spineflower is a prostrate annual. During April through July small flowers with three white, ptal-like sepals appear. This plant occurs in sandy and gravelly places at elevations of 760 to 1,070m (2,500 to 3,500 ft). It is associated with the creosote bush scrub and Joshua tree woodland habitats in the Mojave Desert (Munz and Keck 1965). It is in USFWS Category 3C, plants that 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, 0.10 to 0.15m (4 to 6 in.) 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 760 to 945 m (2,500 to 3,100 ft). 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 1965). Desert cymopterus is a candidate for federal protection. It is in USFWS Category 2.

Mojave Fish-Hook Cactus. The Mojave fish-hook cactus occurs on gravelly mesas and slopes primarily in the eastern Mojave Desert. It is listed by the USFWS as a Category 3C species.

Mojave Desert Blister Beetle. The Mojave desert blister beetle may occur, although uncommonly, in any habitat type in the Mojave desert. Adults consume tender tissues and pollen of asteraceous (sunflower) and brassicaceous (mustard) plants, and larvae prey upon eggs and larvae of orthopterous (grasshopper-like) insects, among others. This species is in USFWS Category 2.

Desert Tortoise. The desert tortoise is a terrestrial desert turtle found in the creosote bush scrub habitat of the Mojave desert. It is active in April and May and aestivates during the cold winter months. It is listed as a candidate species, Category 2, by the USFWS, and is under review by the California Department of Fish and Game (DFG) for listing as a threatened species.

Mojave Ground Squirrel. The Mojave ground squirrel is a small, brownish-gray ground squirrel found only in the western Mojave Desert (Tomich 1982). It is strongly associated with the mixed Joshua tree woodland and creosote bush scrub habitats at elevations of 1,800 to 5,000 ft. This ground squirrel is a solitary animal active only during the spring and early summer months, emerging from hibernation between med-January and late February and returning underground between July and mid-September. It is listed as a candidate species, Category 2, by the USFWS and as threatened by the California DFG.

B.2 BIOTA OF THE PEGASUS FLIGHT CORRIDOR

Lower elevations of eastern slopes of the principle mountain ranges such s the Tehachapi Mountains and the coastal ranges support a chaparral shrub formation dominated by chamise (*Adenostoma fasciculatum*), manzanita (*Arctostaphylos* spp.), and California lilac (*Ceanothus* spp.). Understory growth is usually lacking, but may include such species as sage (*Salvia* spp.) and buckwheat (*Eriogonum* spp.). Other species, such as ash (*Fraxunus dipetala*), oak (*Quercus* spp.), and sumac (*Rhus* spp.), may be locally dominant.

The coastal sagebrush community occurs along the lower elevations of the coastal ranges of central and southern California. This community is a moderately dense assemblage of drought-deciduous shrubs seldom over 1.5-m (4.9-ft) in height. California sagebrush (*Artemisia californica*), California buckwheat (*Eriogonum faciculatum*), white sage (*Salvia apiana*), and black sage (*Salvia mellifera*) are the dominant shrubs. Goldenweed (*Haplopappus* spp.), gumweed (*Grindelia hirsutula*), and horkelia (*Horkelia cuneata*) are common forbs, though numerous others occur in this community.

Two components of the broad-leaved forest formation, the mixed hardwood forest and the blue oak-digger pine forest, are found on the upper western slopes of the Tehachapi Mountains and on the upper eastern slopes of the coastal ranges. The mixed hardwood forest is composed of low to medium tall broad-leaved evergreen species, primarily madrone (*Arbutus menzeisii*) and oaks. Canyon oak (Q. chrysolepis) dominates at higher elevations and coast live oak (*Q. agrifolia*) at lower elevations. Needle-leaved evergreen trees, primarily pines, such as Coulter pine (*Pinus coulteri*) and ponderosa pine (*P. ponderosa*), and big-cone Douglas fir (*Pseudotsuga macrocarpa*), are often present. Chaparral broom (*Baccharis pilularis*) and buckthorn (*Rhamnus californica*) are common components of this community. The blue-oak-digger pine forest is a medium height, mixed forest of deciduous and evergreen trees, mainly digger pine (*Pinus sabiniana*) and blue oak (*Quercus douglasii*). This community intergrades with the California prairie and chaparral communities.

The western exposure of the coastal mountains support the southern oak forest community which is dominated by coast live oak (*Quercus agrifolia*). Rather low in stature, this evergreen forest is relatively open, with some shrubs present.

The savanna formation is represented by the valley oak savanna and the juniper savanna, occurring in some valleys of the coastal ranges and the Tehachapi Mountains or in higher areas of the California prairie. The valley oak savanna community is characterized by tall, widely spaced valley oaks (*Quercus lobata*) with an understory comprised mainly of needle-and-thread grass (*Stipa comata*). Shrubs are nearly absent. The juniper savanna is a somewhat open tall bunchgrass community with extensive forb cover. The community is characterized by the presence of California juniper. (*Juniperus californica*), needle-grass (*Stipa cernua*), and speargrass (*S. pulchra*).

The broad expanse of the California prairie is found along the upper elevations of the San Joaquin Valley. This community is dominated by needlegrass (*Stipa cernua*) and speargrass (*Stipa pulchra*), though numerous other bunchgrasses are also present. Many forbs occur in this community, including owl-clover (*Orthocarpus* spp.), lupine (*Lupinus* spp.), clover (*Trifolium* spp.), sisyrinchium (*Sisyrinchium* spp.), gilia (*Gilia* spp.), rusty popcorn flower (*Plagiobothrys nothofulvus*), and California poppy (*Eschschozia californica*).

The highest elevations of the coastal mountains and the Tehachapi Range contain the four plant communities belonging to the evergreen needle-leaved formation. The southern Jeffrey pine forest is found on the traverse and peninsular ranges at elevations of 2,100 to 2,600 m (6,900 to

8,500 ft). This relatively open community is dominated by Jeffrey pine (*Pinus jeffreyi*), though silver fir (*Abies concolor*) may predominate in higher, more mesic areas. Rabbitbrush (*Chrysothamnus* spp.) and juniper (*Juniperus occidentalis*) occur in colder, dryer regions, especially on north- and east-facing slopes. Numerous other evergreen shrubs can be found in the community, with graminoids and forbs abundant in open spaces.

The southern montane subalpine forest occurs in the highest elevations mainly in the San Gabriel, San Bernardino, and San Jacinto Mountains above 2,400 m (7,800 ft). Silver fir, sugar pine (*Pinus lambertiana*), and lodgepole pine (*P. contorta*) occur in low to medium tall stands. Lodgepole stands may be locally dense, with sugar pine stands occurring in more open habitat. Other species of pines, junipers, oaks, mountain mahogany (*Cercocarpus ledifolius*), and incense cedar (*Calocedrus decurrens*) may be found in this community. Numerous small forbs may be present, such as several species of buckwheat (*Eriogonum* spp.) and wild onion (*Allium monticola*). Other shrub species include service berry (*Amelanchier pallida*), currant (*Ribes* spp.), buckbrush (*Ceanothus* spp.), prickly phlox (*Leptodactylon pungens*), and chinoquapin (*Cgrysolepis sepervirens*).

The juniper-pinyon woodland occurs at intermediate elevations primarily on the northern slopes of the traverse and peninsular ranges. This community is composed of evergreen trees [California juniper and singleleaf piñyon pine (*Pinus monophylla*)] rarely over 10 m (33 ft) tall. Vegetative cover is sparse, seldom exceeding 50% except in the most mesic areas. Occasional dense groups of evergreen to deciduous shrubs [e.g., big sagebrush, rabbitbrush, and bitterbrush (*Purshia tridentate*)] may be found locally. Low herbaceous plants [e.g., prickly phlox, penstemon (*Penstemon* spp.), and phacelia (*Phacelia* spp.)] are present in most areas , but remain inconspicuous. Grasses are dominated by needlegrasses (*Stipa coronaria and speciosa*). Mojave yucca (*Yucca schidigera*) is common in many parts of the community, at least in the corridor.

The fourth community in the evergreen forest formation is the coastal cypress and pine forest community, which occurs in a narrow, interrupted belt along the coast. This is a fairly dense forest comprised of several species of cypress (*Cupressus* spp.), California wax-myrtle (*Myrica californica*), and pine. Other Species characteristic of this community include salal (*Gaultheria shallon*), black twin-berry (*Lonicera involucrate*), blackberry (*Rubus ursinus*), evergreen blueberry (*Vaccinium ovatum*), and bracken (*Pteridium aquilinum*).

The final vegetative community found in the Pegasus corridor is the southern seashore community, a complex vegetation type compromise of beach and dune scrub habitats. The beach habitat is dominated by evergreen perennials, primarily sand verbena (*Abronia mairitima*). Graminoids are rare to absent. Plant coverage varies from less than 20% on the upper beaches to 80% on the foredunes. Most forbs are succulents. Up to 70% of dunes are covered by a dune scrub habitat characterized by dense, broad-leaved evergreen shrubs roughly 50 cm (20 in.) tall, with a lower layer of succulent, perennial forbs. Dominant species include Mormon tea (*Ephedra californica*), goldenweed (*Haplopappus ericoides*), and boxthorn (*Lycium brevipes*).

A listing of selected wildlife likely found in the flight corridor can be found in Table B.1.

B.2.1 Threatened and Endangered Species

Salt Marsh Bird's-Beak. Colonies of this annual plant are found in scattered salt marsh habitats along coastal southern California and northern Baja California, Mexico. A population from the Morrow Bay estuary has recently been reported. This plant's existence is threatened by the extensive alteration of salt marshes along he California coast and is classified by the USFWS as Endangered.

Blunt-Nosed Leopard Lizard. The blunt-nosed leopard lizard is a large, robust lizard is a large, robust lizard ranging in length form 0.08 to 0.13 m (3 to 5 in.). This species was historically distributed throughout the California prairie, chaparral, and scrub formations. This species is classified as Endangered by the USFWS and the State of California.

San Joaquin Kit Fox. The San Joaquin kit fox is a small fox approximately 0.5 m (20 in.) in total length, with a 2.3 kg (5-lb) adult weight. Kit foxes are primarily nocturnal in habit. Dens are usually constructed on gentle slopes or levels areas. Historically, the kit fox occupied the California prairie, chaparral, and scrub formations in the San Joaquin Valley south to Bakersfield. The fox is currently limited to areas along the eastern slope of the coastal mountain ranges and the northern slope of the transverse ranges. It is classified as Endangered by the USFWS and Threatened by the State of California.

Giant Kangaroo Rat. This species is found in fine sandy loam soils covered with sparse vegetation, typical of the California prairie. Its current distribution is limited to the western reaches of the California prairie in the Panoche Hills, Cuyama Valley, and Carrizo and Elkhorn Plains. This species is listed by both the USFWS and State of California as Endangered.

Tipton Kangaroo Rat. The Tipton kangaroo rat was historically limited to the Tulare Basin portion of the San Joaquin Valley, occupying portions of the San Joaquin saltbush and California prairie communities. Current distribution is limited to widely dispersed alkaline sink habitats within areas of intensive agricultural production. This species is proposed as Endangered by the USFWS.

Morro Bay Kangaroo Rat. The Morro Bay kangaroo rat is a highly restricted, geographically isolated subspecies of the Heermanns kangaroo rat. Historically, this species occupied a range of less than 10,356,000 m2 (4 mi^2) in and around the community of Los Osos, San Luis Obispo County. Considerable urban development in this area has reduced the range to six small disjunct populations occupying a total of 1,295,000 m2 (0.5 mi^2) in the remaining coastal dune scrub habitat. This species is listed by both the USFWS and the State of California as Endangered.

California Least Tern. Least terns are the smallest tern measuring 0.23 m (9 in.) from beak to tail with a 0.50 m (20 in.) wingspread. Least terns nest in open expanses of light-colored sand, dirt, or dried mud close to a lagoon or estuary. Increased human activity has made many of these sites unsuitable for nesting. This migratory bird arrives on its summer breeding areas the last week of April and departs in August. The historical breeding range is from Monterey County to southern Baja California in Mexico. Currently, however, the only known regularly used breeding locations between Santa Barbara City and Monterey Bay are within 16,100 m (10 mi) of the mouths of the Santa Ynez and Santa Maria Rivers in Santa Barbara County. Both the USFWS and the State of California list this species as Endangered.

California Brown Pelican. The breeding distribution of this subspecies ranges from the Channel Islands of southern California southward to Isla Isabela and Isla Ixtapa off the Mexico coast. Intermittent breeding occurs as far north as Point Lobos near Monterey, California. Their winter range extends from British Columbia to Colima, Mexico. This species is classified as Endangered by the USFWS.

Peregrine Falcon. Peregrines inhabit open country near cliffs and often near seabird colonies. Historically, they nested throughout North America. Remnant breeding populations currently occur in California, Arizona, New Mexico, Utah, Texas, and Alaska. They occur in the flight corridor area in all habitats during the winter. Summer breeding range is limited to the coastal sections of the corridor, although no critical habitat occurs in the area. This species is classified as Endangered by the USFWS.

Bald Eagle. Although currently only occasional winter residents of the flight corridor area bald eagles formerly nested in the needle-leaved evergreen communities of the corridor. Nesting habitat in California is currently restricted to the far north, predominantly in Shasta County. This restriction in nesting range is the result of persecution, habitat destruction, and DDT contamination, which resulted in reproductive failure. During the winter, eagles in the flight corridor area are primarily associated with open water in the coastal mountain ranges and the Tehachapi Mountains. This species is classified as Endangered by the USFWS.

California Condor. The California condor is among the largest flying birds in the world. Condors historically occurred in the foothills and mountains surrounding the southern San Joaquin Valley. Nesting habitat is found in the mountains of northern Los Angeles and Ventura Counties, central Santa Barbara County, and eastern Tulare County on U.S. Forest Service lands. Typical foraging sites were in the California prairie and savannah communities. Currently, the only condors in existence are held in captivity and are being bred for reintroduction to the wild. This bird is classified as Endangered by the USFWS and the State of California. Critical habitat has been identified by the USFWS in two locations along the flight corridor: Tejon Ranch and Mt. Pinos Condor Areas in southern Kern County and the Hi Mountain-Beartrap Condor Areas east of San Luis Obispo in the Los Padres National Forest.

B.3 PROTECTED MARINE VERTEBRATE SPECIES FROM THE WTR

Green Turtle. This pelagic turtle has a worldwide distribution, primarily confined to warm ocean waters. It uses rocky shores as basing areas and lays its eggs in breeding rookeries on sandy beaches. It is an occasional visitor to the southern California coast, although it formerly used the San Diego Bay. This species is classified as threatened by the USFWS.

Leatherback Turtle. The leatherback is the largest living turtle. A pelagic species, females lay eggs on tropical and subtropical sandy beaches. This turtle is generally confined to warm seas, but occasionally enters colder waters, recorded as far north as Sedgwick Bay, Queen Charlotte Islands. This species is classified as endangered by the USFWS.

Light-Footed Clapper Rail. Clapper rails inhabit coastal salt marshes of California and Baja California. They feed primarily on marsh invertebrates, small fishes, and amphibians. Salt marshes in the southern California area have been subject to heavy development for their real estate potential, which has resulted in the loss of much of this important wildlife habitat. This species is classified as endangered by the USFWS.

Black Rail. Black rails inhabit brackish and salt marshes. Real estate development along the California coast has caused the loss of much of this species' habitat. This species is classified as threatened by the USFWS.

Belding's Savanna Sparrow. Belding's savanna sparrows occur in coastal marshes of southern California and Baja California. Their range is currently heavily restricted because of coastal real estate development and consequent loss of salt marsh habitat in the California Bight to San Diego region. Populations occur in isolated relict marshes. This species is classified as endangered by the California DFG.

Sperm Whale. Sperm whales are the largest of the toothed whales, males growing to 18 m (60 ft) in length. They have a global distribution in open oceans. Mains food sources for this species are thought to be giant squids of the deep ocean. Females and young remain year-round in warmer waters, while males migrate to colder waters in the summer. This species is classified as threatened by the USFWS.

Finback Whales. Finback whales include the humpback, finback, blue, and Sei whales. These are the largest of the whales and the largest animals known to have occurred on the earth. Finbacks have a world-wide distribution, although their feeding grounds are primarily in the colder waters of continental shelves. There they feed upon small zooplankton, such as krill. Finbacks are classified as threatened by the USFWS.

Gray Whale. The gray whale is a well-known migrant along the Pacific Coast. Breeding grounds are in the warm waters of Baja California, Mexico. Calving and breeding occur in these waters from February to April. Gray whales migrate northward along the coast to feeding areas in the colder north Pacific waters. Southward migration runs from late December to early February. They are distinguished from the finback whales by the lack of a dorsal fin, and from right whales by their gray color and smaller head-to-body ratio.

Right Whale. Right whales occur throughout the Pacific and Atlantic, primarily in coastal waters. They are classified as threatened by the USFWS.

Guadalupe Fur Seal. This eared seal occurs primarily on and around the islands offshore of the southern California and Mexican coasts. The majority of the population currently may be found in Mexico. Breeding occurs in rookeries on rocky shores. Young are born in the rookeries in June or July. Guadalupe fur seals are classified as threatened by the USFWS.

Northern Elephant Seal. Elephant seals generally inhabit warmer waters, feeding on small sharks, squid, and rays. Young are born on land on sandy beaches. Current range extends from southern British Columbia south into Mexico. This species is classified as endangered by the California DFG.

TABLE B.1. Selected Wildlife of the Pegasus Flight Corridor (a)

Scientific Name	Common Name	Formation (b)							
		BL	NL	SH	CO	RI	GR	SA	SC
AMPHIBIANS									
Ensatina eachschozia	Enssatina	*	*	*	*	*	*		
Batrachoseps attenuatus	California slender salamander	*	*	*	*				
Aneides lugubris	Arboreal salamander	*	*	*	*				
Bufo boreas	Western toad	*	*	*	*	*	*	*	
B. punctatus	Red-spotted road			*		*	*	*	*
Hyla regilla	Pacific treefrog	*	*	*		*	*		
Rana aurora	Red-legged frog	*				*			
R. catesbeiana	Bullfrog	*				*			
REPTILES									
Gopherus agassizi	Desert tortoise			*					*
Clemmys marmorata	Western pond turtle	*				*			
Sceloporus occidentalis	Western fence lizard	*	*	*	*		*	*	*
Uta stansburiana	Side-blotched lizard			*		*	*	*	*
Eumeces skitonianus	Western skink	*	*	*			*	*	
Gerrhonotus multicarinatus	Southern alligator lizard	*	*	*	*	*	*		
Crotalus scutulatus	Mojave rattlesnake			*			*	*	*
Diadophis puntatus	Ringneck snake	*	*	*					
Coluber constrictor	Racer	*	*	*	*	*	*	*	*
Pituophis melanoleucus	Gopher snake	*	*	*	*	*	*	*	*
Thamnophis sirtalis	Common garter snake	*		*	*	*	*	*	
T. elegans	Western terrestrial garter snake	*	*	*	*	*	*	*	
MAMMALS									
Didelphis marsupialis	Common opossum	*	*	*		*	*		
Sorex ornatus	Ornate shrew	*	*		*	*			
S. trowbridgii	Trowbridge's shrew	*	*		*				
Scapanus latimanus	California mole	*	*	*			*	*	
Sylvilagus audubonii	Desert cottontail	*	*	*	*	*	*	*	*
S. bachmani	Brush rabbit	*		*	*				*
Lepus californicus	Black-tailed jackrabbit	*	*	*	*		*	*	*

TABLE B.1. (contd)

Scientific Name	Common Name	Formation (b)							
		BL	NL	SH	CO	RI	GR	SA	SC
Spermophilus beecheyi	California ground squirrel	*	*	*	*	*	*	*	*
Spermophilus mohavensis	Mojave ground squirrel			*					*
Sciurus griseus	Western gray squirrel	*	*					*	
Thomomys bottae	Valley pocket gopher	*	*	*			*	*	
Perognathus californicus	California pocket mouse	*		*	*	*		*	
P. penicullatus	Desert pocket mouse			*					*
Dipodomys agilis	Pacific kangaroo rat	*	*	*	*	*	*		*
Reithrodontomys megalotis	Western harvest mouse	*	*	*	*		*	*	*
Permyscus californicus	California mouse	*		*	*	*		*	*
P. manuculatus	Deer mouse	*	*	*	*	*	*	*	*
P. boylii	Brush mouse	*	*	*					*
P. truei	Pinon mouse	*	*	*					*
Neotoma fuscipes	Dusckey-footed woodrat	*	*	*		*			
Microtus californicus	California vole	*	*	*	*	*	*		
Castor Canadensis	Beaver	*				*			
Canis latrans	Coyote	*	*	*	*	*	*	*	*
Vulpes marotis	Kit fox			*					*
Urocyon cinereoargenteus	Gray fox	*		*	*	*		*	
Procyon lotor	Raccoon	*	*		*	*			
Mustela frenata	Long-tailed wessel	*	*	*	*	*	*	*	
Taxidea taxus	Badger	*		*	*		*	*	*
Mephitis mephitis	Striped skunk	*		*	*	*	*	*	*
Lynx rufus	Bobcat	*	*	*	*	*	*	*	
Sus scrofa	Feral pig	*			*	*			
Odocoileus hemionus	Mule deer	*	*	*	*	*	*	*	*
BIRDS									
Podiceps caspicus	Eared grebe				*	*			
Podilymbus podiseps	Pied-billed grebe				*	*			
Puffinis griseus	Sooty shearwater				*				
Pelecanus occidentallis	Brown pelican				*				
Phalacrocorax penicillatus	Brandt’s cormorant				*				
Ardea herodias	Great blue heron				*				

		Formation (b)							
Scientific Name	Common Name	BL	NL	SH	CO	RI	GR	SA	SC
Eyretta thula	Snowy egret				*				
Melanitta perspicillita	Surf scoter				*				
Anas platyrhynchos	Mallard				*	*			
A. cyanoptera	Cinnamon teal				*	*			
Oxyura jamaicensis	Ruddy duck				*	*			
Athene cuniculoria	Burrowing owl			*			*	*	*
Otus flammeolus	Flammulated owl	*	*						
Asio otus	Long-eared owl	*	*						
Buteo regalis	Ferruginous hawk			*			*	*	*
B. jamaicensis	Red-tailed hawk	*	*	*	*		*	*	*
Falco sparverius	American kestrel			*			*	*	*
F. columbarius	Merlin	*		*				*	
Fulica americana	American coot				*	*			
Haematopus bachmani	Black oystercatcher				*				
Charadrius montanus	Mountain plover			*		*	*	*	*
C. vociferous	Killdeer	*			*	*	*	*	
Arenaria melanocephala	Black turnstone				*				
Numenius phaeopus	Whimbrel				*				
Catoptrophorus semipalmatus	Willet				*				
Caldris alba	Sanderling				*				
C. mauri	Western sandpiper				*	*			
C. minutilla	Least sandpiper				*	*			
Lobipes lobatus	Northern phalorope				*	*			
Larus heermanni	Heermann’s gull				*				
L. delawarensis	Ring-billed gull				*				
L. occidentalis	Western gull				*				
Sterna albifrons	Least tern				*				
Callipepla californicus	California quail	*	*	*			*	*	*
Oreortyx pictus	Mountain quail	*	*	*					
Zenaida macroura	Mourning dove	*	*	*			*	*	*
Phalaenoptilus nuttallii	Common poorwill			*				*	*
Ceryle alcyon	Belted kingfisher				*	*			
Colaptes auratus	Northern flicker		*	*			*	*	

Scientific Name	Common Name	Formation (b)							
		BL	NL	SH	CO	RI	GR	SA	SC
Melanerpes formicivorus	Acorn woodpecker	*				*		*	
Picoides pubescens	Downy woodpecker	*							
P. villosus	Hairy woodpecker		*						
P. nuttallii	Nuttall’s woodpecker	*		*		*		*	
Hirundo pyrrhonota	Cliff swallow	*		*	*	*		*	*
Aphelocoma coerulescens	California scrub jay	*	*	*			*	*	*
Corvus brachyrhynchos	American crow	*		*			*	*	*
Geococcyx californianus	Roadrunner			*					*
Parus inornatus	Plain titmouse	*		*	*			*	
Eremophila alpestris	Horned lark			*	*	*		*	*
Psaltriparus minimus	Bushtit	*	*	*				*	
Chamaea fasciata	Werntit		*	*			*		
Campylorhynchus brunneicapillus	Cactus wren			*					*
Thyomanes bewickii	Bewick’s wren	*	*	*		*	*	*	
Cistothorus palustris	Long-billed marsh wren				*	*			
Toxostoma lecontei	LeConte’s thrasher			*					*
T. redivivum	California thrasher	*		*			*	*	
Oreoscoptes montanus	Sage thrasher			*					*
Lanius ludovicianus	Loggerhead shrike	*		*			*	*	
Sturnus vulgaris	Starling			*			*	*	*
Sturnella neglecta	Western meadowlark			*			*	*	*
Pheucticus melanacephalus	Black-headed grosbeak	*	*			*		*	
Agelaius phoeniceus	Red-winged blackbird					*	*	*	
Carpodacus Mexicans	House finch	*		*	*		*	*	
Pipilo erythrophthalmus	Rufous-sided towhee	*	*	*				*	
P. fuscus	Brown towhee	*		*		*		*	
Passerculus sandwichensis	Savannah sparrow				*	*		*	
Junco hyemalis	Dark-eyed junco	*	*	*					

TABLE B.1. (contd)

Scientific Name	Common Name	Formation (b)							
		BL	NL	SH	CO	RI	GR	SA	SC
Zonotrichia leucophrys	White-crowned sparrow	*	*	*	*		*	*	
Melospiza melodia	Song sparrow	*		*	*	*			

(a) From American Ornithologist Union (1973); Metcalf (1972); NASA (1978); National Geographic Society (1983); and Stebbins (1966).
(b) BL = broad-leaved forest formation, GR = graminoid formation, NL = needle-leaved forest formation, SA = savannah formation, SH = shrub formation, SC = scrub formation, CO = coast formation, RI = riparian, * = expected in habitat,

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APPENDIX C

PROPELLANT COMPOSITION

APPENDIX C

PROPELLANT COMPOSITION

A summary table has been produced for ease of accident scenario comparison (Table C.1).

C. 1 COMBUSTION PRODUCTS – ATMOSPHERIC BURN

Propellant, burning at atmospheric pressure, will likely have combustion temperatures well below the nominal 2000°C (3600°F), or about 1200°C (2200°F). This temperature difference should have a marked influence on reaction rates and combustion products. Also, the low temperatures would permit entrainment of unburned or partially combusted organic particles; this is normally visualized by the more sooty appearance of smoke plumes and could represent 20 to 30% of the total organic matter.

The major products determined for atmospheric pressure burning on the propellant are provided in Table C.2. The major Al- containing combustion species include crystallins (C) and liquid (L) Al_2O_3, which account for 160 g of each lb of fuel burned. By calculation, combustion of 35,000 lb fuel should yield 12,300 lb of Al species. The major gaseous components include CO (7,380 lb), CO_2 (890 lb), HCl (7,440 lb), H_2 (740 lb), H_2O (2,870 lb), and N_2 (2,880 lb). Only traces (<10 lb) of Bi salts, HNO_3, NO_X and H_3PO_4 will be formed.

Additionally, in the atmospheric burn scenario, the drop from altitude scenario (explosive over land) and the destruct in-flight scenario (over water), a substantial quantity of propellant will be thrown free of the combustion center(s), particularly in the latter scenario. Some of this propellant will likely impact in the unburned state; some will be ignited, but because of the course grain of the ammonium perchlorate, will likely burn at a substantially lower temperature [<1200C (2200°F)], if combustion can be sustained.

TABLE C.1. Accident Scenario Comparison

Location	Area of Fire m^2 (ft^2)	Length of Burn, min	Plume Rise, m (ft)	HCl Release, g (lb)	Uniform Mixing	HCl Concentration In Initial Cloud, ppm
Rail crossing, burn of fist stage	1,000 (10,800)	4	200 (656)	2.6×10^6 (5,730)	Y	400
Ordnance detonation of Pegasus within VAB, burn of all stages	100 (1,080)	4	200 (656)	3.4×10^6 (7,590)	N	---
Motor ignition outside VAB, burn of all stages	1,000 (10,800)	4	200 (656)	3.4×10^6 (7,490)	Y	500
Drop of Pegasus after takeoff, burn of third stage	100 (1,080)	2	150 (492)	1.7×10^5 (374)	Y	200
Drop of Pegasus after takeoff, burn of all stages	100 (1,080)	4	300 (984)	3.4×10^6 (7,490)	N	---

TABLE C.2. Atmospheric Burn Components for Unconfined Propellant, 14 psi (Hercules Aerospace Company)

Chemical Species (a)	g/lb Fuel	Chemical Species (a)	g/lb Fuel
Al	4.0E-5	N	3.2E-6
AlCl	6.8E-2	NH	1.5E-6
$AlCl_2$	4.8E-2	NH_2	1.1E-5
$AlCl_3$	3.0E-2	NH_3	1.8E-4
AlH	3.0E-6	NO	5.9E-3
AlN	1.5E-10	NO_2	2.0E-8
AlO	8.9E-5	N_2 *	37.4
AlOCl	4.3E-2	O	1.4E-3
AlOH	2.2E-3	OH *	1.2E-1
AlO_2	2.8E-5	ONCl	8.6E-8
AlO_2H	8.6E-3	O_2	5.0E-4
Al_2O	3.1E-6	O_2NH	3.8E-9
Al_2O_2	1.5E-6	P	3.1E-5
Bi	3.1E-2	PCl	1.0E-5
BiH	5.0E-4	PH	1.3E-5
BiO	2.2E-4	PH_2	8.5E-6
Bi_2	4.7E-8	PO	1.1E-2
PN	3.6E-3	PO_2	6.8E-3
CH_2O	2.0E-5	P_2	3.4E-7
CH_4	9.4E-8	Al_2O_3(C)*	102
CN	6.9E-8	Al_2O_3 (L)*	58.8
CO *	95.8	H_2O *	37.3
COCl	1.4E-4	H_2 *	9.6
CO_2 *	11.5	HO_2	3.0E-7
Cl *	1.3	HOCl	1.7E-4
ClO	2.3E-5	HNO_2	4.4E-9
Cl_2	1.3E-3	HNO	1.5E-6
H	9.4E-2	HCl *	96.6
HAlO	6.4E-8	HCP	1.4E-7
HCN	6.3E-5	HCO	1.2E-4

(a) Mass balance = 451 g components/lb fuel. Major constituents (*) account for 450 g of 451 g fuel.

C.2 MOTOR HOUSING COMBUSTION PRODUCTS

The motor housings are constructed from graphite composite. The graphite fiber is basically inert, but the binders and embedments are prone to thermal damage and burning. In all accident scenarios, a portion or all of the rocket housing will be exposed to 600 to 1200C (1100 to 2200F) combustion temperatures. A portion of the resin binder will be thermally decomposed and released as volatiles, likely phenolics. The quantity of these released materials is likely minimal with respect to overall risk form other components released during accident scenarios.

APPENDIX D

GAUSSIAN PLUME DIFFUSION

APPENDIX D

GAUSSIAN PLUME DIFFUSION

This appendix lists the equations and table used in calculating surface air concentrations for routine and accidental atmospheric releases discussed in Chapter 5.0 of the main text.

D.1 GAUSSIAN PLUME DIFFUSION

The air concentration values produced in this report are based on the Gaussian equation approximation. The actual values may vary considerably from the modeled values. The values computed using this equation should be viewed as averages.

Gaussian plume diffusion was used to describe the downwind air concentrations of the effluent from an accidental burn of the Pegasus rocket. The plume spread is assumed to have a Gaussian distribution. The surface air concentration in the plume is given by the following equation:

Chi = [Q/(Ðóyózu)*exp[-(y2/2y2)]*exp[-(h^2/2óz^2)]

where:

Chi =surface air concentration,
y =perpendicular distance in meters form the plume centerline,
óy =standard deviation of the plume concentration,
óz =standard deviation of concentration in the vertical,
h =height of the plume,
u =mean wind speed, and
Q =emission rate.

Note: óy and óz are functions of distance.

Centerline plume concentrations (average maximum) for y=0 reduces to the form:

Chi = [Q/(Ðóyózu)* exp[-(h^2/2óz^2)]

D 1.1 Uniform Vertical Mixing

The assumption of uniform vertical mixing was used to describe the downwind transport of the plume for the accident scenario involving widely dispersed rocket fuel. The following equation was used to cumpoute surface air concentrations when the plume was distributed uniformly in the vertical:

Chi = [Q/((2Ð)$^{1/2}$óyLu)]*exp[-y^2/2óy^2

Where:

L = vertical mixing depth.

D 1.2 Explosion

An explosion was considered in the accident scenario involving the Pegasus drop from altitude, where surface air concentrations were of concern. The following puff equation was used:

$$Chi = [Q/(2^{1/2}\,Ð^{3/2}(óxóyóz + V)]*exp[-(x^2/2óx^2+y^2/2óy^2+h^2/2óz^2)]$$

Where

óx = diffusion parameter describing the spread along the path of the puff, and
V = initial volume of the puff.

In this case the óx, óy, óz need to be adjusted based on the initial volume of the cloud produced by the explosion.

D 2 BRIGGS PLUME RISE

In the accident scenarios where burning occurred, the height of the plume was needed to determine the surface air concentrations. Briggs (1981) provides a formulation for buoyant plume rise based on the heat flux (f0) and a stability parameter, s:

$$Zeq =(F_0)^{1/4}(s)^{-3/8}5.3-6R_0$$

Where:

Zeq =equilibrium height, and
R_0 =radius of the burn area.

D3 FUMIGATION

In the accident scenarios considered, the maximum surface air concentrations from the elevated plumes is a result of fumigation of the plume. Fumigation is caused by an inversion breakup usually a result of surface heating but sometimes a result of mechanical mixing. Turner (1969) provided equations for estimating the surface air maximum concentrations caused by an inversion break-up fumigation as follows:

$$Chi = Q/((2Ð)^{1/2}óyFhiu)*exp[-y^2/2óyF^2)]$$

Where:

óyF = óy + h/8
h = height of the plume center, and
h_i = h+ 2óz.

The h/8 is included here because of the work by Bierly and Hewson (1962), who found that the plume tended to spread out as it mixed downward.

D 4 ATMOSPHERIC DIFFUSION FACTORS

Air concentrations may be divided by emission rate to obtain an estimate of atmospheric diffusion (Chi/Q). Average values of Chi/Q are used to predict air concentration form long-term releases from a given site. In this case, a table of annual values (Table D.1) has been computed for Edwards Air Force Base with an effective release height of 5 m. Using the table requires an emission rate, an angle (compass direction) from the source point based on 360° to the north, and a distance in meters. The average air concentration at the distance and the direction can be estimated from the table using the appropriate Chi/Q value and multiplying it by the emission rate (e.g., g/sec) yielding air concentrations in g/m^3.

D.5 REFERENCES

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TABLE D.1 Annual Average Atmospheric Dispersion (X/Q) at Edwards AFB (a)

	100.m	200.m	400.m	800.m	1600.m	3200.m	6400.m	12800.m	25600.m	51200.m
S	2.95E-05	1.65E-05	9.24E-06	3.64E-06	1.22E-07	4.21E-07	1.54E-07	5.87E-08	2.31E-08	9.31E-09
SSW	4.13E-05	2.07E-05	1.04E-05	3.92E-06	1.29E-06	4.41E-07	1.60E-07	6.06E-08	2.37E-08	9.52E-09
SW	4.39E-05	1.93E-05	8.71E-06	3.16E-06	1.02E-06	3.45E-07	1.24E-07	4.46E-08	1.80E-08	7.22E-09
WSW	2.90E-05	1.21E-05	1.77E-06	1.77E-06	5.64E-07	1.88E-07	6.69E-08	2.49E-08	9.62E-09	3.84E-09
W	3.37E-05	1.38E-05	2.02E-06	2.02E-06	6.43E-07	2.15E-07	7.67E-08	2.87E-09	1.11E-08	4.44E-09
WNW	2.27E-05	8.91E-06	1.24E-06	1.24E-06	3.93E-07	1.31E-07	4.67E-08	1.75E-08	6.79E-09	2.73E-09
NW	1.97E-05	8.44E-06	1.30E-06	1.30E-06	4.17E-07	1.41E-07	5.06E-08	1.91E-08	7.43E-09	2.99E-09
NNW	1.65E-05	7.54E-06	1.24E-06	1.24E-06	4.01E-07	1.36E-07	4.92E-08	1.86E-08	7.27E-09	2.92E-09
N	3.27E-05	1.82E-05	3.57E-06	3.57E-06	1.18E-06	4.06E-07	1.48E-07	5.64E-08	2.21E-08	6.92E-09
NNE	5.78E-05	3.46E-05	6.55E-05	6.55E-08	2.16E-06	7.45E-07	2.72E-07	1.03E-08	4.04E-08	1.62E-08
NE	1.20E-04	7.06E-05	1.29E-05	1.29E-05	4.24E-06	1.46E-06	5.30E-07	2.00E-07	7.97E-08	3.10E-08
ENE	9.54E-05	5.47E-05	1.05E-05	1.05E-05	3.47E-06	1.20E-06	4.35E-07	1.64E-07	6.38E-08	2.54E-08
E	6.19E-05	4.42E-05	1.02E-05	1.02E-05	3.45E-06	1.20E-06	4.43E-07	1.69E-07	6.64E-08	2.66E-08
ESE	3.63E-05	2.97E-05	7.78E-05	7.78E-06	2.65E-06	9.31E-07	3.44E-07	1.32E-07	5.20E-08	2.09E-08
SE	2.24E-05	1.95E-05	5.36E-05	5.36E-06	1.83E-06	6.45E-07	2.39E-07	9.19E-08	3.63E-08	1.47E-08
SSE	1.35E-05	9.65E-06	2.48E-06	2.48E-06	8.43E-07	2.95E-07	1.09E-07	4.18E-08	1.65E-08	6.67E-09

(a) Based on 21 years of sector-averaged data – 5 m release height, sec/m^3.