ENVIRONMENTAL ASSESSMENT FOR

ICESAT: NASA GODDARD SPACE FLIGHT CENTER

GREENBELT, MARYLAND

March 2002

Prepared for and in cooperation with:

National Aeronautics and Space Administration
Earth Science Enterprise Earth Observing System
Goddard Space Flight Center
Greenbelt, MD 20771

Environmental Assessment

for

Ice, Cloud, and Land Elevation Satellite (ICESat)

Lead Agency:

National Aeronautics and Space Administration (NASA)
Goddard Space Flight Center (GSFC)
Greenbelt, Maryland 20771

Proposed Action:

NASA's Earth Science Enterprise (ESE) Earth Observing System (EOS) program objective is the study of the atmosphere, oceans, biosphere, land surface, and solid Earth systems to understand the effects of natural and human-related changes on the global environment. To meet this goal, the program proposes to design, fabricate, test and operate on-orbit the Ice, Cloud, and Land Elevation Satellite (ICESat) which would retrieve global distributed altimeter data to measure the long term changes in the mass of the ice sheets and to assess their impact on global sea level.

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March 2002

EXECUTIVE SUMMARY

The National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center (GSFC) has determined that an Environmental Assessment (EA) should be prepared in accordance with the National Environmental Policy Act (NEPA) to evaluate the environmental consequences of implementing the Ice, Cloud and Land Elevation Satellite (ICESat) mission. This EA discusses the objectives of the ICESat mission and its potential environmental impacts. ICESat is the benchmark Earth Observing System (EOS) mission to achieve the requirements for measuring the ice sheet mass balance, cloud and aerosol heights, optical densities, vegetation and land topography. The EOS ICESat mission would provide cloud property information not otherwise available from passive sensors, especially the high ice clouds common over polar areas. It would provide a land-topography data set by processing the altimeter data throughout its orbit, in addition to the polar coverage over ice sheets.

Both the ICESat mission and the No-Action Alternative were examined in this EA. The No-Action Alternative would result in not obtaining consistent, accurate, and simultaneous data information on long-term changes in the volume and mass of the ice sheets and how they may impact the global sea level. Scientists need accurate, simultaneous, world-wide, and continuous measurements of ice sheet and sea level changes to assess the interrelationship of these factors with other factors involved in or affected by global climate change. Currently, these types of data are collected in limited areas using a variety of ground and ocean survey techniques, creating uncertainty in their relationship. This would delay our assessment of factors involved in or affected by global climate change.

Air and water quality impacts, effects on biotic resources, local land contamination, health and safety issues, socioeconomic impacts, and effects on historic sites were considered in this EA. All of the activities involved in the development, fabrication, assembly, testing and integration of the ICESat mission are within the normal scope and level of activities conducted at the various sites involved. The activities involved in the ICESat mission would produce no substantial adverse effects on the environment.

The ICESat on-orbit laser operation was evaluated for its potential to affect flying aircraft, satellites, Space Shuttle and the International Space Station, as well as, humans, animals, and plants on Earth. The laser safety analysis determined that there would be no adverse effects to humans (both on the Earth's surface and in aircraft), flora, or fauna. The laser energy is far less that that received from the sun and, therefore, the impact is expected to be less than that associated with solar exposure. The Cheyenne Mountain Operations Center Laser Clearinghouse found that the ICESat laser does not exceed the reference damage threshold to space systems, such as satellites, Space Shuttle, and the International Space Station, and granted the ICESat mission an unconditional waiver.

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ABBREVIATIONS AND ACRONYMS

AGS	Alaska Ground Station
ANSI	American National Standards Institute
BATC	Ball Aerospace Technology Corporation
CAA	Clean Air Act
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite
CFC	Chlorofluorocarbon
CU/LASP	University of Colorado's Laboratory for Atmospheric and Space Physics
EA	Environmental Assessment
EDOS	EOS Data and Operations System
EOS	Earth Observing System
EPA	Environmental Protection Agency
EPDS	Electrical Power and Distribution Subsystem
EPGS	EOS Polar Ground Stations
ESE	Earth Science Enterprise
ESSB	Earth System Science Building
FONSI	Finding of No Significant Impact
GEM	Graphite Epoxy Solid Rocket Motor
GFDS	Goddard Flight Dynamics System
GLAS	Geoscience Laser Altimeter System
GLRS	Geoscience Laser Ranging System
GPS	Global Positioning Satellite
GSFC	Goddard Space Flight Center
HFC	Hydro fluorocarbon

ABBREVIATIONS AND ACRONYMS (Cont'd)

ICESat	Ice, Cloud, and Land Elevation Satellite
IPCC	Intergovernmental Panel on Climate Change
ISF	Instrument Support Facility
KSC	Kennedy Space Center
LAM	Laser Altimetry Mission
LaRC	Langley Research Center
LEO	Low Earth Orbit
LIDAR	Light Detection and Ranging
LITE	LIDAR In-space Technology Experiment
MOC	Missions Operations Center
MPE	Maximal Permissible Exposure
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOHD	Nominal Ocular Hazard Distance
NPD	NASA Policy Directive
NRC	National Research Council
NRHP	National Register of Historic Places
OSHA	Occupational Safety and Health Administration
PPF	Payload Processing Facility
RE	Radiant Exposure
SBCAPCD	Santa Barbara County Air Pollution Control District

ABBREVIATIONS AND ACRONYMS (Cont'd)

SCF	Science Computing Facility
SGS	Svalbard Ground Station
SHPO	State Historic Preservation Officer
SLC	Space Launch Complex
TSDF	Treatment, Storage, and Disposal Facility
USFWS	U.S. Fish and Wildlife Service
VAFB	Vandenberg Air Force Base
WFF	Wallops Flight Facility

1.0 PURPOSE AND NEED FOR ACTION

1.1 PROJECT BACKGROUND

This past century has experienced considerable changes in the composition of the global atmosphere, and models now predict rising concentrations of atmospheric greenhouse gases to cause significant global warming. The Intergovernmental Panel on Climate Change (IPCC) has identified the effect of polar ice sheets on global sea level change as a major category of scientific uncertainty, and baseline information on ice sheet mass balance is needed before significant greenhouse warming occurs. The Ice, Cloud, and Land Elevation Satellite (ICESat) mission would provide data that contributes to our knowledge and understanding of the Earth's cryosphere, atmosphere, and land processes and provides a better tool for the assessment of factors involved in or affected by global climate change. Specifically, the ICESat mission would measure changes of < 1 centimeter (cm)/year (< 0.39 inches (in)/year) average ice thickness on the Greenland and Antarctic ice sheets and show whether these ice sheets are growing or shrinking. These measurements would demonstrate whether global warming induced changes in ice sheet mass balance is positive or negative. Measurement of ice sheet elevation changes would provide early warning of the instability of the west Antarctic ice sheet and allow for assessments of the ice sheet's impact on the global sea level (NASA 1999).

Additional objectives of the ICESat mission include (1) measurement of cloud heights, vertical structure of clouds and aerosols in the atmosphere, and atmospheric transition layer heights, and (2) mapping land surface topography to measure roughness, reflectivity, vegetation heights, snow-cover, and sea-ice surface characteristics.

The ICESat mission was initiated in 1988 as part of research in the Earth Science Enterprise (ESE) Earth Observing System (EOS) Program. The primary objective of the original mission, the Geoscience Laser Ranging System (GLRS), was surface laser ranging, with surface laser altimetry as a secondary objective. The surface ranging objective was subsequently discontinued as a result of the ESE-EOS programmatic restructure exercise (1991) and re-scope exercise (1992) and the altimetry component became the primary objective. Laser Altimetry Mission (LAM) replaced GLRS as the mission name, and the science instrument involved was renamed Geoscience Laser Altimeter System (GLAS). Conflicts in orbit requirements relieved LAM (polar ice science) from sharing the same observatory with the Radar Altimetry Mission (physical ocean science) during a 1994 ESE-EOS programmatic re-baseline exercise. The mission name was changed from LAM to ICESat following the April 1997 ESE-EOS Biennial Review (NASA 1999).

The ICESat mission would use a LIDAR (Light Detection And Ranging) system to provide the critical cloud and atmospheric science measurements. LIDAR systems have been used for nearly 40 years to study atmospheric conditions from the ground and aircraft, as many studies have definitively shown the potential benefits of performing LIDAR investigations of the Earth's atmosphere from space. The advantage of space borne LIDAR systems over present passive monitoring instruments for global observations is their

ability to make very high-resolution vertical and horizontal measurements and operate continuously. Passive instruments rely on available energy (visible or infrared light from the sun or moon) and consequentially their sensing capabilities are limited to areas of the atmosphere, which are penetrated by the available energy. LIDAR systems, which use pulsed laser energy to penetrate the atmosphere, have no such limitation and can provide global coverage of the atmosphere.

In 1994, NASA's Langley Research Center (LaRC) conducted a LIDAR In-space Technology Experiment (LITE) on the Space Shuttle during the nine day STS-64 mission. This mission provided experience in operating a LIDAR system in a space environment and an evaluation of performing scientific measurements on clouds and aerosols. The mission was a complete success and demonstrated the value of space borne LIDAR systems for atmospheric studies.

1.2 NEED FOR ACTION

The effect of polar ice sheets on global sea level change has been classified by the National Research Council (NRC), Intergovernmental Panel on Climate Change (IPCC) as a key category of scientific uncertainty. Present or currently planned space missions do not have the capability to obtain information to reduce this uncertainty.

1.3 PURPOSE OF PROPOSED ACTION

The ICESat mission, as part of the EOS multi-mission program, would collect data needed for the long-term study and understanding of Earth's global processes. The ICESat mission seeks to provide information on long-term changes in the volume and mass of the Greenland and Antarctic ice sheets with appreciable accuracy to assess the impact of ice sheets on global sea level and to determine and explain trends in seasonal and inter-annual variability of the surface elevation of ice sheets and sea level. Such information is required to assess the impact of ice sheets on sea level change. The ICESat mission is to launch and operate a laser altimeter satellite with a 3-year lifetime and a 5-year goal to collect scientific information that would improve our understanding of Earth's global processes and improve climate change models. Specific goals of the mission are:

- To determine the change in mass balance of the polar ice sheets and their contributions to global sea level change.
- To measure cloud heights and the vertical structure of clouds and aerosols in the atmosphere to understand their impact on global climate.
- To map the topography of land surfaces.

1.4 SCOPE OF ENVIRONMENTAL ASSESSMENT

This Environmental Assessment (EA) addresses the environmental issues related to the development, fabrication, test, launch, and on-orbit operation of the ICESat mission.

An EA was prepared for the EOS Program in 1997 (NASA 1997). The impacts associated with launch vehicles were addressed in detail in the EOS Programmatic EA and will be summarized in this document. Copies of the EOS Programmatic EA can be obtained from the ICESat Project Office (telephone: (310) 286-5102).

2.0 DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES

2.1 PROPOSED ACTION

The proposed ICESat mission is a cooperative effort between various organizations to ultimately retrieve globally distributed ice, cloud and land elevation data with a high degree of accuracy and detail. The major organizations are the NASA Goddard Space Flight Center (GSFC), Greenbelt, Maryland; NASA Kennedy Space Center (KSC), Florida; the Ball Aerospace and Technology Corporation (BATC) in Boulder, Colorado; the University of Colorado Laboratory for Atmospheric and Space Physics (CU/LASP) in Boulder, Colorado; and the Center for Space Research, University of Texas, Austin, Texas.

2.1.1 ICESat Mission Development, Fabrication, Assembly, Test and Integration

NASA GSFC has the responsibility for overall mission management for:

- Providing the laser instrument;
- Capturing, processing and distributing mission data;
- Developing and validating science algorithms; and
- Processing and analysis of science data.

BATC is responsible for developing the spacecraft bus, integrating and testing the spacecraft, and delivering the spacecraft after on-orbit commissioning to NASA. The existing, off-the-shelf spacecraft bus provides the power, orbit maintenance, pointing, data storage, command and telemetry link with the ground stations. The propulsion subsystem contains 79 kilograms (kg) (174 pounds (lbs)) of hydrazine, a rocket propellant used in more than 90 percent of satellites orbiting the Earth, and would provide enough energy for proper orbit insertion, and for orbit adjustment due to atmospheric drag. The bus would be fabricated and tested at the existing facility at BATC. Following delivery of the laser instrument to BATC, it would be mounted to the spacecraft bus and the entire spacecraft would be subjected to acceptance testing at existing test and integration facilities at BATC.

ICESat spacecraft features are shown below:

Table 2-1. ICESat Spacecraft Features	
Spacecraft Size	2m x 2m x 3.1m (6.6 ft x 6.6 ft x 10 ft)
Spacecraft Power	640W
Spacecraft Mass	970 kg (2,138 lbs)
GLAS Instrument Mass	300 kg (661 lbs)
GLAS Instrument Power	330W

2.1.2 Geoscience Laser Altimeter System (GLAS)

The Geoscience Laser Altimeter System (GLAS) is an integral part of the NASA Earth Science Enterprise. The GLAS is designed, fabricated and tested by the GSFC Earth Science Directorate, Laser Remote Sensing Branch, Code 924 at GSFC with support from industry and academia. The GLAS is a facility class instrument designed to measure ice-sheet topography and associated temporal changes as well as cloud and atmospheric properties. In addition, its operation over land and water would provide along–track topography.

The GLAS has two principal components: a laser transmitter and a telescope receiver (Figure 2-1). The GLAS would measure the time required for the laser pulse to travel round trip from the instrument to the reflecting surface and back again to the instrument. This time interval would then be converted into a distance. These short pulses (5 nanoseconds (nsec)) of near infrared light (1064 nanometers (nm)) are used for the measurement of surface topography while backscattered light in the visible-green light (532 nm) is used for measurement of aerosols and other atmospheric characteristics. Using the on-board star tracker camera system and Global Positioning System, the spacecraft orbit and the laser direction and position in space are known very accurately.

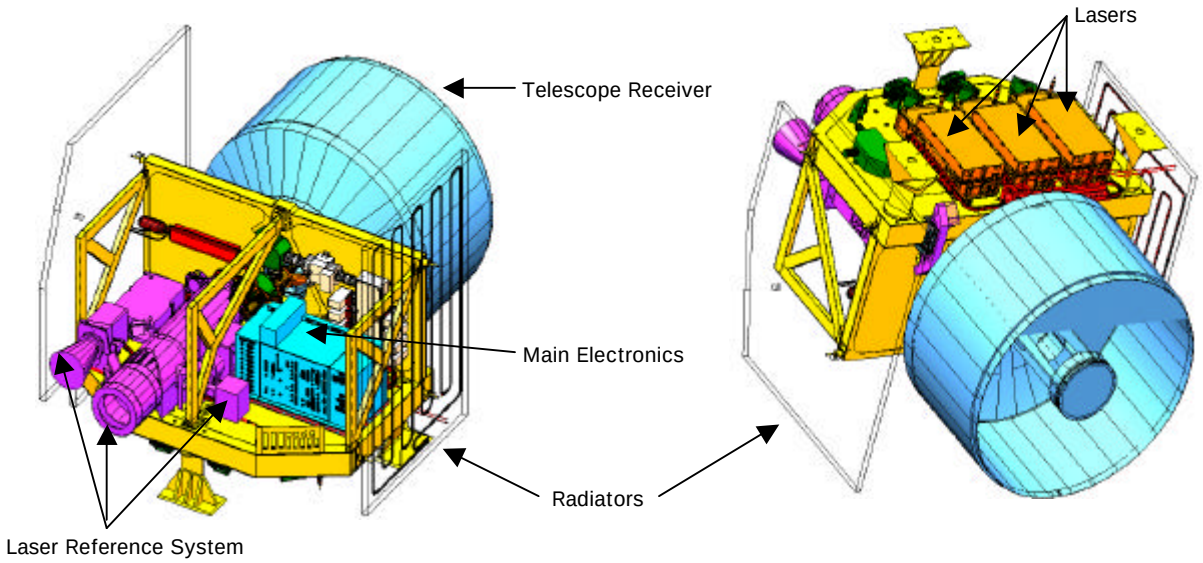

Figure 2-1. Geoscience Laser Altimeter System (GLAS)

The GLAS contains three identical diode-pumped Q-switched Neodymium-doped:Yttrium-Aluminum-Garnet (Nd:YAG) lasers. Only one laser operates continuously throughout the duration of the mission. Changeover from one laser to the next occurs only if the performance of the operating laser degrades below a useful level. When in use, each laser produces 75 millijoules (mJ) at 1064 nm and 35 mJ at 532 nm, and thus emits 27.5 megawatts (MW) of power during each 5 nsec pulse. Additional characteristics of the laser transmitter are shown in Table 2-2.

The laser emits pulses 40 times per second and would illuminate a 70-meter (230 ft) diameter footprint at the Earth's surface. Footprints are typically spaced at 175 meters (574 ft) center-to-center along the Earth's surface (NASA 2000b). A series of these recordings provides a profile of the Earth's surface, and examination of the time sequence of laser footprints allows for the resolution of temporal changes in topography (NASA 1999).

The atmosphere absorbs much of the laser energy, but some energy is reflected back toward the telescope receiver. Photons reflected back (backscattered) to GLAS from either the Earth's surface or the clouds and aerosols are collected in the 1-meter (3.3 ft) diameter receiver telescope. The characteristics of the clouds and aerosols determine the amount of energy absorbed, reflected, or reaching the Earth's surface (NASA 1993).

Table 2-2. GLAS laser transmitter output beam characteristics

LIDAR Type	Nd:YAG, diode pumped		
Wavelength	nm	532	1064
Repetition Rate	Hz	40	40
Color		green	infra-red
Output energy	mJ/pulse	35	75
Pulse width	ns	5	5
Beam divergence	μrad	110	110
Exit beam diameter	cm	4.3	4.3
Far-field beam pattern		Near gaussian	Near gaussian

The Gaussian beam pattern is used to approximate the distribution of energy in a fiber core. Most people would recognize the pattern as a bell curve.

2.1.3 ICESat Launch

NASA GSFC proposes to launch ICESat in late 2002 from Vandenberg Air Force Base (VAFB), California, Space Launch Complex 2 (SLC-2) using a Delta II 7320-10 launch vehicle built by Boeing Company (Figure 2-2). The Delta II launch vehicle, which is procured by the NASA KSC, is used for many NASA missions. The Boeing Company would also provide launch site operation support. The environmental impacts of the launch vehicle have been addressed in a separate NEPA documentation (NASA 1997) and are summarized in section 4.1.3.

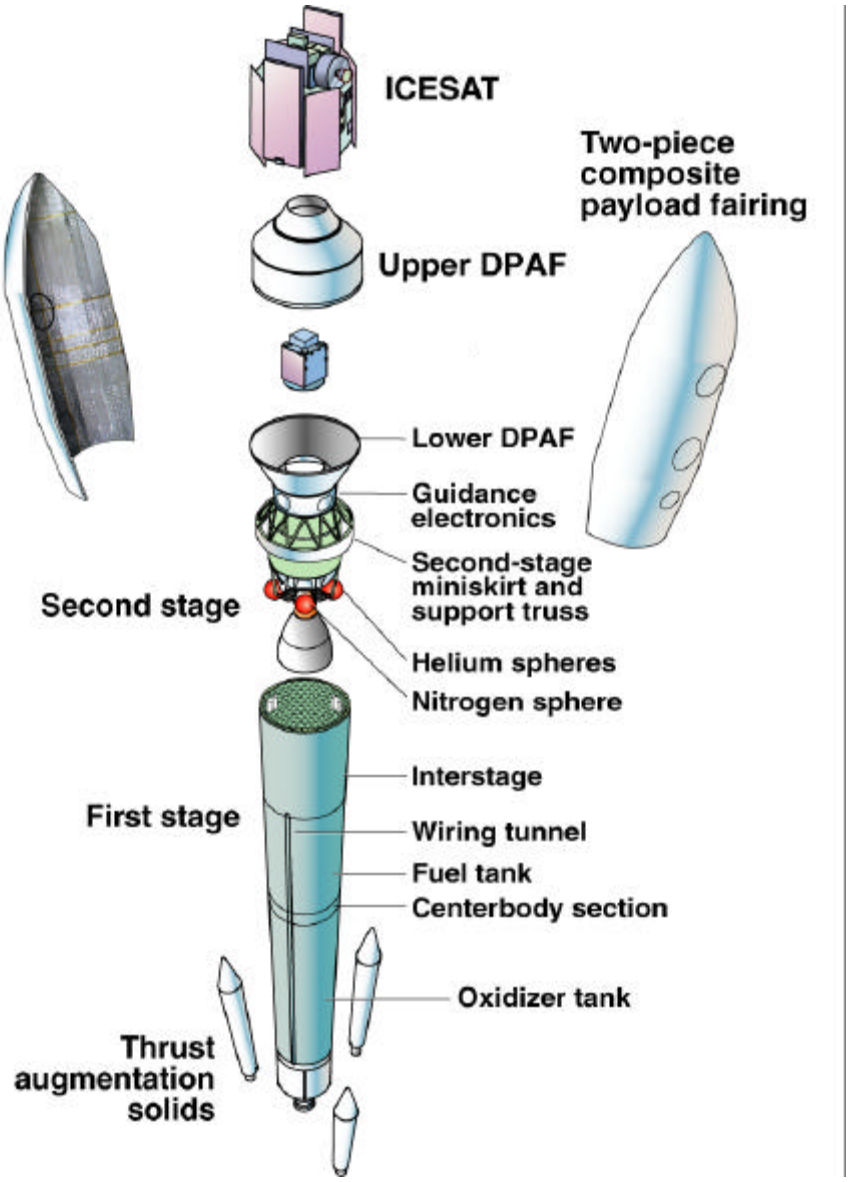

Figure 2-2. Diagram of a Delta II space launch vehicle

2.1.4 ICESat On-Orbit Mission Operations

ICESat would be launched into a 600 km (373 miles (mi)) near polar circular Low Earth Orbit (LEO) at a 94-degrees inclination in a 183-day repeat orbit cycle (Figure 2-3). This orbit would provide co-incidence of measurements with the EOS Terra and Aqua spacecraft and specific ground control points at various times during the life of ICESat. The satellite is designed for a 3-year, lifetime with a 5-year goal.

The ICESat on-orbit operations involve several mission elements: 1) the ground stations, 2) the mission operations center, 3) ground data and operations system, and 4) the science and instrument support facilities. Each is discussed below.

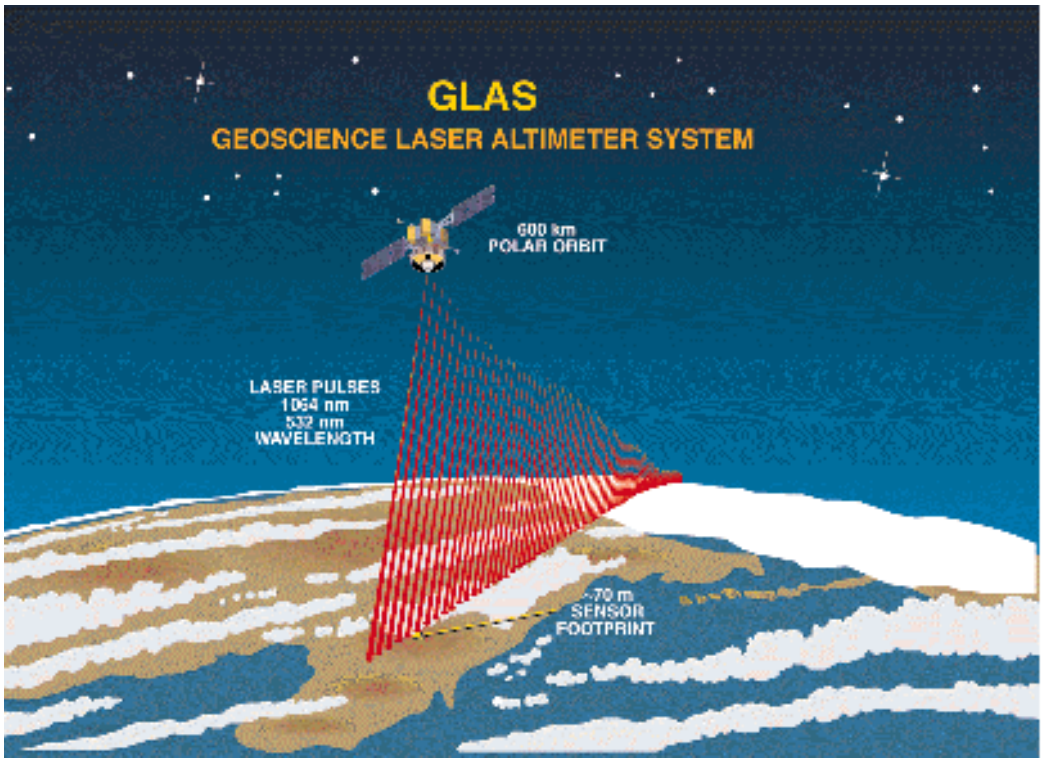

Figure 2-3. Diagram of ICESat orbiting above the Earth

The GSFC EOS polar ground stations, Alaska Ground Station (AGS) at the Poker Flat Research Range, Alaska, and Svalbard Ground Station (SGS) at Spitzbergen Island, Norway, would provide S band telemetry and command and X band communications with the spacecraft. GSFC Wallops Flight Facility at Wallops, Virginia, will receive only the S band housekeeping telemetry data and would be used chiefly for launch support and spacecraft commissioning.

The Missions Operations Center (MOC) is the main operations facility for the ICESat mission. The MOC is located at CU/LASP. The MOC would provide for the real-time monitoring and control of the spacecraft and the processing and archival of housekeeping telemetry data. The same operations team is currently operating the QuikSCAT spacecraft, and much of the ICESat operations system has been derived from the system used for QuikSCAT.

The GSFC EOS Data and Operations System (EDOS) would receive high-rate telemetry data, perform Level Zero processing of data, and distribute telemetry data sets to mission operation center and the data archive facilities.

The ICESat Science Computing Facility (SCF), which would collect and process science data, is composed of several home institutions, including the GSFC Cryospheric, Atmospheric and Land Surface Laboratories, the University of Texas, Ohio State

University, the University of Wisconsin, Massachusetts Institute of Technology, and the University of California San Diego.

The GSFC Instrument Support Facility (ISF) would oversee the daily operation of the GLAS instrument. The National Snow and Ice Data Center, located at the University of Colorado in Boulder, is the ultimate archive for ICESat science data.

2.1.5 Spacecraft Decommissioning at the End-of-Mission

ICESat would have a mission lifetime of three years, with a goal of extending the mission to five years, total. Therefore, ICESat would have sufficient spacecraft expendables to support a five-year mission goal. ICESat would be disposed of by atmospheric reentry within 25 years. Calculations of time to atmospheric reentry and an assessment of hazards associated with debris that would come through the atmosphere and either burn during reentry or fall to earth were performed in accordance with NASA requirements. The Delta II solid rocket motors, first stage and two fairing halves do not achieve orbit and are planned disposals after launch into the Pacific Ocean. The ICESat and the Delta II launch vehicle second stage would be disposed of at end of mission by an uncontrolled atmospheric reentry, breakup, and disintegration of most pieces.

2.2 ALTERNATIVES

2.2.1 Alternative Technologies

Under a separate mission to ICESat, NASA proposes to fly the Cloud-Aerosol Lidar and Infrared Pathfinder (CALIPSO) mission. The CALIPSO mission is designed to examine the role of clouds and aerosols and their impact on the Earth's radiation budget. Although ICESat is designed to collect information on clouds and aerosols, the primary mission of ICESat is to measure the polar ice sheets and their impact on global sea level change. Therefore, while CALIPSO is an alternative technology mission, it would not accomplish the ICESat mission's primary science goals. This alternative would delay scientific progress and development of technology that can aid in prediction of global climate change.

2.2.2 Alternative Launch Vehicles

The Delta II launch vehicle is proposed for the launch because of its capacity for carrying multiple satellites, cost-effectiveness and reliability for launching medium size satellites such as ICESat. Alternative launch vehicles include the space shuttle and other larger or smaller vehicles. These alternative launch vehicles were not considered reasonsable because they either greatly exceed or do not meet launch system requirements for the spacecraft size, weight, or orbit placement.

2.2.3 Alternative Launch Sites

Vandenberg Air Force Base (VAFB) in California is proposed as the launch site, because the ICESat mission science requires a high inclination orbit to map the ice sheets and VAFB is primarily designed for launching payloads into this orbit. VAFB possesses near-ideal conditions for the launch with the entire flight path of the rocket over water. In addition, NASA has utilized this launch site on numerous occasions. Cape Canaveral Air Force Station, Florida would not be a suitable launch site because the launch inclination required for a polar launch has the potential for oveflight of populated areas and would create unacceptable safety concerns.

2.2.4 No-Action Alternative

The No-Action Alternative would mean not flying the ICESat mission. This alternative would result in not obtaining consistent, accurate, and simultaneous data information on long-term changes in the volume and mass changes of the ice sheets and how they may impact the global sea level. This would delay more accurate scientific analysis of global warming and other climate processes.

3.0 AFFECTED ENVIRONMENT

Elements of the environment affected by the ICESat mission, as presented in Chapter 2, are described below:

3.1 MANAGEMENT, DEVELOPMENT, FABRICATION, ASSEMBLY, TEST, INTEGRATION AND OPERATIONS

The mission development, management, communications infracture, science data capture, processing, distribution and archival, science algorithm development and instrument support activities would be performed at the main GSFC campus and other support facilities as described in Chapter 2. The NASA GSFC organization and its support elements have the existing office, research, laboratory, ground stations, and manufacturing and test facilities needed to implement the mission.

The spacecraft to ground communications stations exist at the GSFC polar ground stations, the Poker Flat Research Range, Alaska, and Svalbard Ground Station at Spitzbergen Island, Norway.

The National Snow and Ice Data Center, the ultimate archive for ICESat science data, is located at the University of Colorado in Boulder.

The Missions Operations Center, the main operations facility for the ICESat mission, is located at CU/LASP in Boulder, Colorado.

Spacecraft bus, GLAS and the launch vehicle would be developed, fabricated, assembled and tested at NASA GSFC in Greenbelt, Maryland, the Ball Aerospace facility in Boulder Colorado, and the Boeing plants in Huntington Beach, California, and Pueblo, Colorado. These facilities are equipped and permitted to do such work. Following delivery to BATC, the GLAS would be mounted to the spacecraft bus and the entire spacecraft would be subjected to acceptance testing at existing test and integration facilities at BATC.

No new facilities or changes in facilities or the operations would be required to support the mission.

3.2 LAUNCH SITE

NASA proposes to launch the ICESat mission from the Delta II Space Launch Complex (SLC) 2 West at VAFB in California. VAFB is the headquarters of the 30th Space Wing, Air Force Space Command. The primary objective at VAFB is to perform launch operations, with more than 1,700 launches occurring since 1958. The discussion presented below of the existing environment is limited to those resources or related resources that could be affected by the proposed ICESat launch from SLC-2. The description of these resources is summarized from the EOS EA (NASA 1997).

3.2.1 Geographical Location

VAFB occupies approximately 400 square km (150 square mi) of land in Santa Barbara County on the coast of south central California and is bordered by 56 km (35 mi) of Pacific Ocean coastline to its west. Santa Maria, located 10 km (6.2 mi) northeast, and Lompoc immediately to the east, are the nearest cities to the base. The base is administratively divided into North Vandenberg, which contains SLC-2, and South Vandenberg, which contains SLC-4 and SLC-6.

3.2.2 Land Use

Approximately 6 percent of Santa Barbara County is occupied by VAFB. Sixty percent of the base is reserved for recreation and open space, 30 percent for grazing and agriculture, and 10 percent for facilities and operations associated with U.S. Air Force activities.

3.2.3 Meteorology

VAFB's location on the southwest coast of California results in a Mediterranean climate, which brings warm, dry weather from May to November, and cool, wet weather from December to April. The average annual temperature is 12.8°C (55°F) and the mean annual relative humidity is 77 percent at VAFB. The average annual precipitation is 32.3 centimeters (12.7 in), and more than 90 percent of this precipitation falls between November and April. Mornings at VAFB frequently bring coastal fog and low clouds. These conditions are particularly common in summer months when inversion conditions intensify.

Two sites on VAFB are responsible for meteorological monitoring. The first site is on Watt Road, near the VAFB Airfield and SLC-2, and the second station is located next to the SLC-6 power plant, about 1.6 km (1.0 mi) north of the Spaceport. Wind at VAFB blows predominantly out of the north-northwest, and the average monthly wind speed ranges from a low of approximately 9.36 km/hr (5.8 mi/hr) in August to a high of 4 m/sec (9 mi per hour) in March.

Mixing heights are determined by the location in the atmosphere of the first layer of air that is warmer than the air below. The mixing height of the atmosphere represents the upper limit of the atmospheric region where pollutants and emissions generally remain. Higher mixing heights (inversion layers) facilitate dispersion of any trapped air pollutants. The average maximum mixing height at VAFB ranges from a low of approximately 900 m (2,950 ft) above mean sea level in July to a high of 1,350 meters (4,430 ft) above mean sea level in November (NASA 1997).

3.2.4 Air Quality

Santa Barbara County is located within the South Central Coast Air Basin. VAFB monitors five criteria pollutants defined by the Clean Air Act (CAA): ozone (O_3), carbon

monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulate matter under 10 microns in diameter (PM_{10}). The National Ambient Air Quality Standards (NAAQS) are not met in many sections of Santa Barbara County. For all monitoring stations, the State ozone standard is violated between 30 and 45 days per year and the national standard is violated between two and eight days per year in Santa Barbara County. Thus, Santa Barbara County is classified as a serious ozone non-attainment area.

Santa Barbara County manages an air quality program in which both the Air Force and the Santa Barbara County Air Pollution Control District (SBCAPCD) have agreed to cooperate. According to this program, VAFB must coordinate with the SBCAPCD and obtain its permission before making any changes in base activities. Any new emissions on VAFB from regulated sources must be considered within the context of this agreement.

3.2.5 Water Quality

3.2.5.1 Surface Water

Three major stream drainage areas or watersheds characterize surface water resources near VAFB:

1. Jalama Creek and its tributaries border VAFB to the south.

2. The Santa Ynez River bisects North and South VAFB and makes up the core of the Santa Ynez drainage system.

3. The San Antonio drainage system, is located on North VAFB and is drained by San Antonio Creek.

Space Launch Complex 2 (SLC-2) is furthest removed from local drainages. San Antonio Creek and the Santa Ynez River are about 4.8 and 6.4 km (3 and 4 mi) from SLC-2, respectively. Surface flows have been sampled near SLC-2 and other space launch complexes on both North and South VAFB. Dissolved oxygen values of not less than 5.0 milligram/liter (mg/l) and pH values of 6.5 – 8.5 pH units are within the U.S. Environmental Protection Agency's (EPA) criteria limits for aquatic life. Surface waters do have high levels of total dissolved solids, chloride, lead, and zinc, resulting in the water quality being classified as of poor to medium quality.

3.2.5.2 Ground Water

The Monterey shale underlying the region supports a minimal amount of ground water in fracture zones, with the lower member of this formation containing greater amounts of water than the upper member. The depths to the water table vary from 42 m (138 ft) to 40 m (131 ft).

Ground water in the vicinity of VAFB is present in four ground water basins: the Lompoc Upland Basin, the Lompoc Plain Basin, the Lompoc Terrace Basin, and the San

Antonio Creek Valley Basin. Ground water is the sole potable water source on VAFB; ten wells are used to draw water from the first three basins for domestic and operational use. The adjacent U.S. Penitentiary and Federal Correctional Institute also consumes ground water pumped by VAFB. Increased withdrawals from the area's ground water basins have caused an overdraft condition that is affecting the overall water availability and quality in these basins.

Regional water quality meets all national Interim Primary Drinking Water Regulation standards. The use of water for irrigation has caused a slight decrease in water quality. As irrigation water flows through the soil and back into the basin, it leaches salt from the soil, which increases the salinity of the ground water.

3.2.6 Biotic Resources

VAFB is recognized as a biologically important area, occupying a transitional zone between the cool, moist conditions of northern California and the semi-desert conditions of southern California. Therefore, many plant species and communities reach their northern or southern limits in the area. Plant communities of particular interest include tanbark oak forest, bishop pine forest, Burton Mesa Chaparral, coastal dune scrub, and a variety of wetland types.

The portion of VAFB's coastline that lies within the ICESat launch's region of influence is occupied by several species of seabirds, marine mammals, and other species of interest (e.g., threatened and endangered species, NASA 1997). Harbor seals, protected under the Marine Mammal Protection Act, use the beaches south of Rocky Point as breeding areas. Southern sea otters also feed in the offshore kelp beds and occasionally come onshore. Peregrine falcons nest on the rocky cliffs. Western gulls, brown pelicans, pigeon guillemots, marine cormorants, rhinoceros auklets, black oystercatchers, and Brandt's cormorants use the rocky outcrops for roosting or nesting purposes. Three miles of VAFB's coastline are protected under agreement with the State of California as a marine ecological reserve. This area extends from Lookout Rock to Point Pedernales. VAFB has a memorandum of agreement with the California Department of Fish and Game for access to these areas for military operations and scientific research only (NASA 1997).

3.2.6.1 Terrestrial Biota

Terrestrial animal life consists of species common to coastal sage scrub, grassland, and chaparral communities. Common mammalian species occurring at VAFB include mule deer, coyote, bobcat, jackrabbit, cottontail, skunk, ground squirrel, and numerous nocturnal rodents. The larger, contiguous, relatively undisturbed tracts of native vegetation on south VAFB provide high-quality foraging habitat for wide-ranging carnivores, such as mountain lion, bobcat, black bear, badger, gray fox, and coyote, in addition to several regionally rare or declining hawks and owls. The region contains a diversity of bird species, such as red-tailed hawks, American kestrels, white-tailed kites, and numerous common land birds. Shore birds are abundant on all sandy beaches.

California brown pelicans do not breed on VAFB, but are transient visitors to the coast. The western snowy plover is considered a year-round resident of VAFB.

Due to the predominance of southerly and westerly exposures, the region's vegetation is primarily central coastal scrub or coastal sage scrub, grassland, and chaparral community types. The riparian vegetation of drainages in the area provides important habitat for wildlife.

Approximately 30 vegetative assemblages, representing more than 15 distinct plant communities have been identified within VAFB boundaries. Plant communities include coastal salt marsh, coastal sage scrub, central dune scrub, riparian woodland, a variety of chaparral types, and diverse upland woodland communities. This diversity results from variation in topography, elevation, geology, and proximity to the coast. Approximately 85 percent of VAFB supports natural vegetation; the remaining 15 percents support a ruderal, or disturbed, vegetation or is developed for human use.

The flora of VAFB comprises approximately 624 species and subspecies, approximately 21 percent of which are alien to California; the remaining 79 percent are native. Local flora includes a number of sensitive plant taxa, including several species recognized as rare, threatened, or endangered by the State or Federal government (NASA 1997).

3.2.6.2 Aquatic Biota

A variety of reptiles, amphibians, and marine mammals occur on or in the vicinity of VAFB. Several snakes, the Pacific tree frog, western toad, and the California legless lizard, among others represent reptiles and amphibians. The coastal waters encompassing south VAFB and the northern Channel Islands support diverse marine mammal assemblages. The sea otter, six species of pinniped (seals), and more than 25 species of cetacean (whales) inhabit the regions either as residents or transients. The Marine Mammal Protection Act of 1972 protects all marine mammals inhabiting the study region. The Santa Barbara County Local Coastal Plan identifies marine mammal haul out and pupping grounds as environmentally sensitive habitat and delineates policies designed to help protect these areas.

A harbor seal population haul out site occurs at Purisima Point, which is identified in the National Marine Fisheries Service census as a breeding rookery in their annual harbor seal census. Sea otters have been the focus of recent reintroduction efforts in the southern Channel Islands and are sighted frequently at various rocky areas along the VAFB coastline. The California sea lion and the northern elephant seal use the northern Channel Islands as haul out, mating, and pupping grounds (breeding activities). The Guadalupe fur seal is a rare visitor to the VAFB coast, and Stellar sea lions have not been spotted in the area since 1985.

The National Marine Fisheries Service has granted the U.S. Air Force an incidental-take permit (i.e., for disturbance of pinniped populations in coastal waters near VAFB) effective for up to 20 launches per year at VAFB for the 5-year period starting March 1,

1999 through December 31, 2003 (NASA 2000a). This permit applies to launches of Delta II, Atlas, Taurus, Titan IV, and Lockheed Martin launch vehicles.

3.2.6.3 Threatened and Endangered Species

No threatened or endangered amphibians, reptiles, or land mammals known to occur in the vicinity of SLC-2. Two Federally endangered bird species, one Federally threatened bird, one Federally threatened mammal, and two State threatened plant species, however, do occur on or in the vicinity of VAFB SLC-2. The Federally endangered bird species include the California brown pelican and California least tern. The California brown pelican is a transient species and does not nest or breed on VAFB. The California least tern nests in sand dune areas on North VAFB from mid-April to August and uses the waters off South VAFB for foraging and migration (NASA 2000a). The Federally threatened western snowy plover has been reported near SLC-2 and nests from March to September at VAFB beaches from Purisima Point (about 900 m) (3,000 feet) west of SLC-2 northward. One Federally threatened mammal, the southern sea otter, is occasionally found feeding offshore. Two State threatened plant species (the surf thistle and spectacle pod) have been reported or are expected to occur near SLC-2. Another plant, the Lompoc yerba santa, has been proposed for Federal listing as endangered and may also occur in the area surrounding SLC-2. Although no known sightings of the federally listed arroyo toad have been recorded at VAFB, its range does overlap the base, its habitat types are found on base, and it has the potential to occur at VAFB.

3.2.7 Socioeconomics

Agriculture is the region's primary industry, particularly in the Santa Maria area. Surface mining for diatomaceous earth is also a major regional industry. The largest employers in the area of Santa Barbara County surrounding VAFB are services, retail trade, government, and manufacturing.

Currently, the number of persons employed at VAFB is approximately 7,400. This includes government civilian employees, military employees, and contractors. Of these, approximately 52 percent are civilian employees. The base generates about 3,400 jobs for the local economy and has an overall monetary impact of more than $900 million on the surrounding region. The majority of services contracted out are from the local communities of Lompoc and Santa Maria (Klock 2001).

Based on the 2000 Census of Population and Housing, Santa Barbara County had a population of 399,347. This was an increase of 8.0 percent from the 1990 population of 369,608 persons. Of the 2000 total population, 109,022 persons (27.3 percent) were minority and 58,305 persons (14.6 percent) were low-income as defined by the U.S. Census Bureau criteria.

3.2.8 Noise, Sonic Boom, and Vibration

Noise levels at most of the region surrounding VAFB are normally low. Higher levels appear in industrial areas and along transportation corridors. The rural areas near Lompoc and Santa Maria are expected to have low overall community noise equivalent levels (NASA 1997).

EPA or Occupational Safety and Health Administration (OSHA) requirements and recommendations would not be exceeded by peak launch noises (the Delta II has a maximum noise level of 110 dbA; NASA 1997) that are experienced for a very brief time. Comparatively, peak noise levels created by industrial and construction activities (mechanical equipment such as diesel locomotives, cranes, and rail cars) could range from about 90 to 111 dBA. Vehicular traffic noise ranges from about 85 dBA for a passenger auto to about 100 dBA for a motorcycle (NASA 1997).

3.2.9 Cultural/Historical/Archaeological Resources

Cultural resources are present within and adjacent to SLC-2. The State Historic Preservation Officer (SHPO) has recommended specific elements of SLC-2 as eligible for listing in the National Register of Historic Places (NRHP) (NASA 1997). If any modifications to the SLC-2 are proposed, VAFB and NASA would consult with the SHPO; however no modifications are proposed for the ICESat mission.

3.3 ICESAT ON-ORBIT MISSION OPERATION

The on-orbit laser operations would potentially contact the Earth's surface at many geographical locations. The Earth's surface is highly varied and is described in numerous, commonly available reference books and atlases. These surface types can be described as biomes (i.e., large geographical areas of distinctive plant and animal groups which are adapted to that particular environment). Major biomes include coniferous forests, temperate deciduous forests, deserts, grasslands, rainforests, shrublands, tundras and several types of aquatic environments.

4.0 ENVIRONMENTAL CONSEQUENCES OF PROPOSED ACTION AND ALTERNATIVES

The environmental consequences of the proposed action are analyzed in this section. The activities involved in the mission management, development, fabrication, assembly, test, integration and operations would be performed at existing facilities, which are designed and permitted to conduct these activities. The activities are within the normal scope of work for the facilities. No new facilities or change in facilities or operations would be required to accomplish this work. No adverse impacts are expected from these activities. The discussion below will focus on the environment consequences of the launch and the on-orbit laser operations.

4.1.1 Mission Launch Site

NASA proposes to launch the ICESat mission using a Delta II 7320-10 class launch vehicle built by Boeing. The Delta II 7320-10 launch vehicle has three strap-on graphite epoxy solid rocket motors (GEMs). The impacts associated with a normal launch of the Delta II 7925, a more powerful launch vehicle with nine strap-on GEMs, is being used to estimate the impacts from the launch of ICESat. The Earth Observing System (EOS) EA (NASA 1997) contains an assessment of potential impacts from the Delta II 7925 launch vehicle. The anticipated environmental effects from a Delta 7320 launch vehicle with three GEMs are not expected to exceed the impacts from a Delta 7925 with nine GEMs. The potential environmental impacts of the launch are summarized in the following sections.

Potential impacts of a Delta II launch from VAFB would occur from hazardous materials use, storage, and disposal, air pollutant emission, exhaust plumes, rocket motor noise, and sonic boom.

4.1.1.1 Environmental Impacts of ICESat Launch Preparation

Hazardous materials are typically involved in a number of industrial activities required for launch vehicle and payload processing at VAFB. Hazardous, solid, and liquid wastes and air emissions would be handled in compliance with Federal, State, and local regulations and in accordance with relevant VAFB hazardous materials and waste management plans. No new environmental licenses or permits would be required for the ICESat mission. No significant impact would occur.

4.1.1.2 Environmental Impacts of a Normal Launch

4.1.1.2.1 Land Use

Land use of areas on and around SLC-2 at VAFB would be consistent with the uses designated for the launch complex.

4.1.1.2.2 Air Quality

Rocket motor emissions form a cloud at the launch pad during the first few seconds after ignition and liftoff of a normal launch. The high-temperature cloud rises quickly and stabilizes at an altitude of a few hundred meters near the launch area before mixing with the atmosphere and dissipating. The launch poses the greatest source of uncontrollable emissions to the atmosphere. Primary constituents of exhaust from solid-fueled rocket motors are hydrogen chloride (HCl), carbon dioxide (CO2), carbon monoxide (CO), and aluminum oxide (Al_2O_3). Total emissions from a Delta II 7925 launch vehicle are summarized in Table 4-1. Emissions from the Delta II 7320 are expected to be less than those from the Delta II 7925.

Table 4-1. Total Emissions From Typical Delta II 7925 Launch Vehicle (First Stage and GEMs)

Constituents	Kg	Tons
Carbon monoxide (CO)	64,660	71.2
Aluminum oxide (Al_2O_3)	38,237	42.1
Water (H_2O)	33,333	36.7
Carbon dioxide (CO_2)	31,062	34.2
Hydrogen chloride (HCl)	22,525	24.8
Nitrogen (N_2)	8,810	9.7
Hydrogen (H_2)	3,815	4.2
NO_x	8,719	9.6

Source: adapted from NASA 1997

Launches are generally directed in a southerly direction, and predominant winds are from the north, so no impacts on populated areas of western Santa Barbara County are expected. Further, exhaust products are expected to dissipate before reaching sensitive human, flora, or fauna receptors (NASA 1997). Predicted peak impacts on VAFB property due to launch-related activity emissions are below adverse health limits. West Ocean Avenue is the closest public access location to SLC-2. Peak impacts at this location would be even less than those on VAFB, which are below permitted levels, and these impacts would be of short duration. In addition, launch activities would be controlled to limit impacts. The ambient air quality impacts due to launch-related activities are expected to be insignificant. Emissions from the Delta II launch vehicle fall well within acceptable levels when compared with standards for human exposures.

The Air Force has extrapolated Delta II 7925 exhaust plume diffusion data from models developed for the Titan launch vehicle program due to the similarity of propellant types used by the Delta II and the Titan launch vehicles. These data estimates peak ground level concentrations of ground cloud pollutants. The size of the Delta II ground cloud should be significantly smaller than that of the Titan because the Delta II uses less propellant, produces less vapor, and accelerates off the launch pad quicker than the Titan.

From these estimates, HCl concentrations in a Delta II ground cloud should not exceed 5 ppm beyond about 4.3 km (3 mi) downwind. The closest public area is approximately three miles away. Therefore, while there is no National Ambient Air Quality Standards (NAAQS) for HCl to compare expected concentrations with, other risk-based limits indicate that short-duration concentrations of 5 ppm HCL or less should not be harmful to the general public. The USEPA EPA Health Effects Notebook for Hazardous Air Pollutants-Draft (EPA-452/D-95-00, PB95-503579, December 1994) indicates that there is no limit for acute inhalation exposure, and that long-term effects are non-carcinogenic. The Occupational Safety and Health Administration's permissible exposure limit, which is the concentration of a substance to which most workers can be exposed without adverse effect averaged over a normal 8-h workday is 7 mg/m^3 or 4.69 ppm.

Concentrations of CO are not expected to exceed the National Ambient Air Quality Standards (NAAQS) of 35 ppm (1-hour average) beyond the immediate vicinity of the launch complex and are expected to rapidly oxidize to carbon dioxide in the atmosphere. CO concentrations for Titan launches are expected to be less than 9 ppm except during a brief period during liftoff. Delta II emissions should be even lower. Peak concentrations of aluminum oxide (particles smaller than 10 microns) should not exceed 11 ppm at a distance of approximately 4.8 km (3 mi) from the launch site (NASA 1997).

No releases of fluorocarbons to the atmosphere are anticipated (NASA 1997). Ozone-depleting chlorofluorocarbons (CFCs) and hydro fluorocarbons (HFCs) are commonly used for both cooling and fire suppression systems. All ozone-depleting chemicals would be properly contained, reused, or disposed of in accordance with applicable federal, state and local laws, regulations, rules, and the VAFB Hazardous Waste Management Plan.

Permits allow for the launch of two rockets per year from SLC-2. The EOS is considering launching two Delta IIs per year and expects no considerable impacts beyond the scope of current permits (NASA 1997).

The total direct and indirect emissions from the Proposed Action do not exceed the Federal de minimis conformity threshold for the criteria non-attainment pollutants (ozone precursors). Total emissions for each non-attainment pollutant are less than 10 percent of SBCAPCD’s 1990 Base Year Annual Emission Inventory. Therefore, the Proposed Action is considered not regionally significant (NASA 1997).

4.1.1.2.3 Noise

Peak launch noises for the Delta II launch vehicle last for a very brief time (approximately 5 seconds) and are not expected to exceed EPA or OSHA requirements. Noise levels at one mile from the Delta II launch would reach approximately 110 dBA (NASA 1997); however, the general public would not be present within one mile of the launch site. The closest public area is approximately three miles away. Workers and visitors at VAFB would be required to wear protective hearing equipment during launches. Therefore, human populations would not be adversely affected.

Sonic booms would occur in offshore areas at VAFB. Marine mammals may be startled by sonic booms, and a further discussion of potential impacts to marine resources is presented in Section 4.1.3.2.9. Ships and recreational boaters would be warned of launches in advance and no adverse impacts are expected.

4.1.1.2.4 Geology and Soils

The geology and soils at VAFB are not expected to be adversely affected by the ICESat launch. Al_2O_3 particulates and HCl gas are the primary exhaust products from the launch. They would be dispersed over VAFB dependent upon particle size and wind conditions. VAFB soils are capable of buffering these exhaust products.

4.1.1.2.5 Water Quality

Possible impacts to local water resources during a normal launch would be associated with disposal of the spent deluge water and launch pad wash down water. Deposition of launch exhaust products can occur in local bodies of surface water. However, these sources are not expected to cause significant adverse impacts on water quality. In the event that rainwater absorbs chemicals associated with exhaust products, the natural buffering capacity of the streams would result in negligible or no chance in water quality (NASA 1997). No impacts would be expected from discharge of spent deluge water or launch pad wash down water because such wastes are discharged to the base treatment plant or hazardous waste facility.

4.1.1.2.6 Groundwater

No launch related impacts are expected to ground water because no ground water withdrawals would be made. In addition, SLC-2 is equipped with a retention basin to retain all deluge water and contaminants from the launch. Deluge water is tested before disposal.

4.1.1.2.7 Surface Water

No adverse affects on surface water are expected because the nearest surface water bodies are outside of the range of expected impacts.

4.1.1.2.8 Offshore Environment

The first stage and the GEMs would land in the ocean during a normal launch. Slow corrosion rates of metals and the large quantity of water available for dilution would likely prevent toxic metal concentrations in the deep ocean environment (NASA 1997). Residual propellants in the GEM casings would slowly leach out and should not reach toxic concentrations outside of the immediate vicinity of the casings. Sensitive habitats are not expected to be encountered by the GEM casings in the deep ocean; therefore potential impacts of toxic substances leaching from the casings would be minimal. Substantial impacts are not expected from the reentry and ocean impact of spent stages because of small amounts of residual propellants and the large amount of water for dilution.

4.1.1.2.9 Biological Resources

Noise levels generated by the launch of a Delta II would probably disturb both terrestrial and aquatic biota near the launch site but are not expected to result in long-term adverse affects (NASA 2000a). The U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) have previously reviewed NEPA documentation for proposed launch vehicles at VAFB and have specified required launch restrictions and other monitoring and mitigation measures. Marine mammals harassment permits and a biological opinion are in place to accommodate the launch of Delta IIs from VAFB. Other potential minor, short-term impacts associated with launch may include singeing associated with the launch, but there are no anticipated impacts to wetlands, floodplains, or threatened or endangered species.

4.1.1.2.10 Socioeconomics

The ICESat launch from VAFB would be part of the ongoing Delta launch program. No increase in existing personnel and no demographic or infrastructure changes in the vicinity are expected.

4.1.1.2.11 Cultural and Historic Resources

The ICESat processing and launch from SLC-2 would not affect any property listed or eligible for listing in the National Register of Historic Places. Since no modifications to the SLC-2 area are expected, including surface or subsurface disturbances, no impacts to cultural or historic resources would occur.

4.1.1.2.12 Waste Generation, Treatment, Transportation, Disposal, and Storage

VAFB operates as a generator of hazardous waste and as a Treatment, Storage, and Disposal Facility (TSDF). Hazardous and solid waste management would comply with all existing Federal, applicable State and local base environmental regulations. Launches from SLC-2 are not expected to cause substantial environmental impacts with respect to hazardous wastes.

4.1.1.2.13 Environmental Justice

The ICESat launch would be a routine launch at VAFB and would be one of a number of similar launches at VAFB in 2002. If ICESat is not launched, another mission is likely to use a similar Delta launch configuration and trajectory from VAFB. Based on the 2000 Census of Population and Housing, Santa Barbara County had a population of 399,347. Of the total population, 109,022 persons (27.3 percent) were minority and 58,305 persons (14.6 percent) were low-income as defined by the U.S. Census Bureau criteria. The ICESat launch would not have disproportionate health or safety effects on low income or minority populations near the launch sites.

4.1.1.2.14 Hazards

The ICESat presents routine hazards, which are discussed below. Hazardous materials present on the spacecraft are listed in Table 4-2.

The batteries consist of 11 nickel-hydrogen (NiH_2) common pressure vessels. Each vessel contains two cells, each containing a 31 percent solution of potassium hydroxide (KOH) as the electrolyte. The electrolyte is absorbed into the internal plates and separator material such that there is no free or spillable KOH. The cells are vacuum filled. The KOH electrolyte is a caustic material, which can cause severe burns. If the electrolyte gets onto the skin or eyes, the area must be flushed with copious amounts of water. Medical assistance must be obtained. KOH is incompatible with water, acids, flammable liquids, organic halogens, and some metals. When not installed on the spacecraft, the batteries would be stored in a battery box and moved/handled using approved procedures, minimizing any contact with these materials. The battery cell casings exceed safety requirements. The cells have a Maximum Expected Operating Pressures (MEOP) of 61.2 atmospheres (atm) (900 pounds per square inch (PSI)), with a burst pressure safety factor > 3:1. Leakage of the electrolyte during normal ground operations is not probable. The nickel-hydrogen battery would be installed in the spacecraft bus. The battery would be shipped in a discharged condition. Upon arrival at VAFB, the spacecraft would be thoroughly inspected for damage and functional testing would augment visual inspection.

Table 4-2. ICESat hazardous chemicals/materials

Substance	Quantity	Use	MSDS	Hazard
Potassium Hydroxide (KOH)	N/A	Battery electrolyte	Yes	Corrosive
Gallium Arsenide (GaAs)	N/A	Solar cells	N/A	Arsenic is a poison
Ceria	N/A	Borosilicate glass solar cell covers	N/A	Low degree of hazards in a powdered state. Mild eye irritant, chronic inhalation exposure is bronchitis.
Hydrazine (N_2H_4)	76 kg	Spacecraft fuel	Yes	Flammable/combustible carcinogenic, toxic, corrosive
Ammonia (NH_3)	670 g	Heat pipe gas	Yes	Irritant/toxic health hazard
Propylene (C_3H_6)	940 cc	Heat pipe fluid	Yes	Flammable
Beryllium (Be)	79 kg	Telescope mirror	Yes	Toxic as fine powder. Inhalation hazard.

The propulsion system tank would be loaded with 59.7 kg (128 lbs) of hydrazine at VAFB. Fueling would be performed by BATC personnel with a Ball-supplied fueling cart. The fuel would be supplied, stored and sampled by VAFB. Personnel would wear propellant handlers ensemble during the fueling operation. All materials used in the

propulsion subsystem have demonstrated long-term stability and compatibility with the propellant agent hydrazine.

The solar cells contain arsenic. The total amount of arsenic contained in the gallium arsenide compound in the arrays is ~4 grams (0.14 oz). The density of arsenic in the arrays is the same as that in the majority of spacecraft now launched. The cells are covered with a cover glass and are not accessible by personnel.

GLAS contains seven unique axial grooved ammonia-charged heat pipes and two propylene-charged closed loop heat pipes. These heat pipes and loop heat pipes could reach high pressures. If any of these pipes were to rupture, the working fluid would be a hazard. This is because ammonia is toxic, and propylene is flammable. The maximum non-operating pressure that the ammonia heat pipes could reach is 11.6 atm (170 psia). Each ammonia heat pipe contains approximately 95 grams (3.4 oz) of ammonia. Ammonia can damage human respiratory systems. The two propylene loop heat pipes contain about 470 cc (15.9 oz) of propylene each. The maximum non-operating pressure that the propylene heat pipe could reach is 12.9 atm (190 psia). All heat pipes are designed to meet an ultimate factor of safety greater than 4.0x MEOP and are proof tested to at least 2.0x MEOP.

The beryllium is not hazardous in the configuration found on GLAS and no oxidation or machining is planned. The beryllium components are coated with a scratch resistant plating.

Safe hardware and support equipment would be used to ensure safety for both personnel and equipment during all phases of testing and operation. A Missile System Pre-launch Safety Package (MSPSP) has been prepared in accordance with NASA GSFC, NASA KSC and the Air Force Western Range Safety Office requirements. The MSPSP documents compliance with the requirements established by the Eastern and Western Range Regulation, EWR 127-1, dated 31 October 1997. This document also serves to demonstrate that requirements and procedures are met to obtain flight and ground payload safety approval.

Cleaning materials and other processing materials would be used in Building 1610 in a well-ventilated area. Application of some of the processing materials is for contingency use only. This would include the solar array repair kit chemicals and solothane. These potential hazards are enumerated in the MSPSP. All hazardous wastes generated at VAFB are managed according to the VAFB Hazardous Waste Management Plan. Hazardous wastes produced during processing and launching operations would be collected and stored in hazardous waste accumulation areas before being transferred to a hazardous storage area. These wastes would eventually be transported to an off-station licensed hazardous waste treatment/disposal facility.

While potential health and environmental hazards connected to the ICESat mission exist, a number of safety mechanisms are in place to minimize risks. All potentially hazardous activities at GSFC and VAFB have been documented and hazard reduction practices have been addressed and implemented. The procedures are within the scope of

normal activities at both GSFC and VAFB and meet all NASA safety requirements. No significant environmental consequences are associated with these activities.

4.1.1.2.15 Pollution Prevention

Executive Order 12856, "Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements," requires the Federal government to prevent pollution at the source and comply with the Emergency Planning and Community Right to Know Act (EPCRA) and Pollution Prevention Act (PPA).

NASA, as an agency, is complying with Executive Order 12856. NASA has achieved a 50 percent reduction in releases of toxic chemicals to the environment and off-site transfers for treatment and disposal. NASA Centers have established chemical inventory databases for use in management and reporting of the chemicals. Each center performs Toxic Release Inventory (TRI) reporting and emergency planning and notification reporting to the local authorities. Each center also submits annual Pollution Prevention Progress. The NASA centers work to identify and implement pollution prevention opportunities through source and waste reduction and new technologies.

In implementing the ICESat mission, NASA would comply with TRI reporting requirements, Emergency Planning and Community Right-to-Know responsibilities, and State and local Right-to-Know and pollution prevention requirements. NASA would support the Local Emergency Planning Committee as requested and would make available all pollution prevention and Community Right-to-Know information upon request. The ICESat mission would be managed in compliance with NASA requirements and objectives for pollution prevention.

The ICESat mission, during spacecraft processing, would not use, generate, accumulate, or store any significant amounts of toxic, corrosive, flammable, reactive, or irritant hazardous material waste requiring special collection/disposal methods. Reactive solvents, thinners, and reducers have been eliminated from ICESat processing. The cleaning at instrument and spacecraft level uses only deionized water and isopropyl alcohol.

4.1.1.3 Environmental Impacts of Potential Accidents

Potential environmental impacts associated with Delta II accidents have been discussed in previous U.S. Air Force and NASA NEPA documentation and are summarized below.

A variety of accidents could occur during preparations for and launch of a Delta II expendable launch vehicle. Only two types of accidents would potentially have off-site consequences: a liquid propellant spill during fueling operations and a launch failure. The potential consequences of these accidents are presented below.

4.1.1.3.1 Liquid Propellant Spill

A liquid propellant spill would be managed in accordance with the VAFB Spill Prevention, Control and Countermeasure Plan and approved hazardous waste management plans, which are in place. Therefore, no substantial adverse impacts are expected.

4.1.1.3.2 Accident Scenario During Processing at the VAFB Payload Processing Facility (PPF)

An accident during transfer operations and moving the fueled spacecraft pose potential risk from hydrazine and nitrogen tetroxide (NASA 1997). The PPF is designed to contain and minimize effects from accidents. The effects would be limited to the PPF and the workers in the building. Emergency procedures are in place to minimize risks and injuries to workers. The most likely outcome of an accident is a spill that is contained with no damage to life or property.

4.1.1.3.3 Launch Failure

Accidents on the launch pads or within a few seconds of launch present the greatest threat to people. Range safety and operational requirements require that all personnel to be sufficiently far away from the launch site so that debris and other direct impacts of such accidents do not affect them. Hazardous concentrations of propellants dispersed into the air would not occur, except in the immediate vicinity of the launch complex.

No long-term adverse affects would be expected if large pieces of solid rocket propellant were to enter the ocean. The propellant would dissolve slowly and pose no threat to aquatic biota outside of the immediate vicinity of the GEMs. Ocean systems may be temporarily affected, but the high buffering capacity of the ocean would allow for rapid recovery and no long-term adverse impacts would be anticipated.

4.1.2 ICESat On-Orbit Operation

The ICESat on-orbit laser operations have been examined for any affect to flying aircraft, communication and military satellites, space shuttle flights and the International Space Station, when completed. The laser ranging is the primary feature of the ICESat mission that could impact the environment. As discussed in Section 2 and subsequent paragraphs, a portion of the optical energy from the laser would pass through the atmosphere and reach the Earth's surface. Consequently, a laser safety analysis was conducted, using the American National Standard Z136 series (ANSI Z136), to assure that all environmental concerns and impacts were studied and evaluated.

4.1.2.1 Normal Operation

With the exception of orbital maintenance, the spacecraft does not emit any material, chemical or effluent that could escape into the atmosphere or space under normal

operations. During periodic orbit maintenance (roughly once per week) the spacecraft hydrazine thrusters would be operated to maintain the satellite in its desired orbit. Hydrazine is nearly completely burned during these operations. Exhaust emissions would consist of small quantities of carbon dioxide and water vapor. The effect of such emission at high altitude is negligible.

ICESat does not produce operational debris during Delta II staging, separation and deployment nor does ICESat release any operational debris during normal flight operations.

4.1.2.1.1 Biological Effects of Laser Operation

Effects on Flora and Fauna

The ICESat laser would have no adverse effects on the Earth's flora and fauna because solar energy reaching the Earth far exceeds the energy from the laser. Solar radiation is typically 1,388 watts per square meter (W/m^2), and may reach as high as 1,410 W/m^2 (NASA 1993). The total power of the ICESat laser energy on the Earth's surface, assuming no atmospheric attenuation is 0.22×10^{-4} W/m^2. Because of the lack of any potential impact, no consultation under section 7 of the Endangered Species Act was necessary for this EA.

Effects on Skin and Eye Exposure for Animals and Humans

Skin and eyes of animals and humans may potentially be affected by exposure to laser energy. In order to assess the potential effects of exposure, the Radiant Exposure (RE) to which a person within a laser footprint would be exposed was calculated assuming the satellite would be at the planned height of 600 km (373 mi) above the Earth with no atmospheric attenuation. Table 4-3 compares the RE of GLAS laser to the Maximal Permissible Exposure (MPE) for skin and eyes as determined by the American National Standard for the Safe Use of Lasers (ANSI Standard Z136.1-1993). These standards typically provide for a factor of safety one or two orders of magnitude above levels of exposure known to cause injury. Safety factor is the ratio of the MPE to the RE to which a ground observer would be exposed from the GLAS laser. The safety factor for eye and skin exposure is > 700 at both operating wavelengths.

RE values shown in Table 4-3 at the two operating wavelengths are significantly lower than the MPE for both skin and eye exposure. MPE values are for exposure to a single pulse. For a stationary observer, the laser beam produces footprints 70 m (230 ft) in diameter, 175 m (574 ft) apart, and appearing along track at 7 km/s (4.3 mi/s). Therefore, an observer would be illuminated by only a single shot on a given orbit, and it is not likely that an observer would ever be exposed more than once, since an exact satellite overflight doesn't occur for weeks or months.

Table 4-3. REs and MPEs for Skin and Eye Exposure			
Wavelength (nm)	**MPE for Skin Exposure (J/cm^2)**	**MPE for Eye Exposure (J/cm^2)**	**Maximum RE (J/cm^2)**
1064	1×10^{-1}	5×10^{-6}	1.8×10^{-9}
532	2×10^{-2}	5×10^{-7}	0.63×10^{-9}

The GLAS laser safety analysis found minimal risk of skin or eye injury. The laser is expected to be visible to people on the ground, but the brightness is comparable to the planet Venus and is not expected to startle observers.

Effect of Exposure to Multiple Simultaneous Wavelengths

ANSI Z136.1-1993 indicates that the cumulative effects of laser exposure should be examined where laser systems simultaneously emit several widely separated wavelengths. The sum of the ratios of RE to MPE at the two wavelengths was calculated and found to be much less than 1. A ratio this small indicates that the exposure would not create a hazard.

Effect of ICESat Off-Nadir pointing maneuver

The ICESat spacecraft would occasionally operate in off-nadir pointing mode for science consideration for no more than 5 degrees. Operation in this mode has no additional potential effects to human eye or skin exposure.

Effects on Human Eyes when using Binoculars

The RE to observers using 50 millimeters (mm) (2.0 in) binoculars to view the laser beam was calculated to be less than the MPE. The safety factor for persons using binoculars within a footprint of the laser viewing the zenith at the exact moment the laser pulse illuminates was calculated to be >15. There is no credible danger of eye injury from viewing the laser beam through binoculars.

Effects on Human Eyes when using a Telescope

The Safety Factor for viewing the laser beam through a 15.2 centimeters (cm) (6 in) diameter telescope was calculated to be 1.5. MPEs are established at exposures that are one or two orders of magnitude lower than the level of any known hazard, so considerable safety factor still exists. Observing the laser beam with an optical telescope with a diameter greater than 15.2 cm (6 in) does not necessarily cause injury to the observer. The observer would receive radiant exposure in excess of MPE, but there is no known biological hazard to this. In addition, telescopes with large diameters are considerably less common than those with 15.2 cm (6 in) diameters or smaller which are typical of the

amateur viewer. The normal viewing mode for many large telescopes is not direct ocular viewing, but is instead accomplished electronically or photographically. Just as important here is that the laser and the telescope must also share the exact same line of sight in that brief moment of exposure. Therefore, the probability of exposure is very low.

4.1.2.1.2 Effects on Aircraft, Communications, and Space Systems

Aircraft to 60,000 feet Altitude

The effect of ICESat laser on an aircraft flying at up to 18 km (60,000 ft) is minimal and essentially the same as for surface observers, as discussed above. In addition, there is no credible risk to aircraft pilots or passengers from viewing of the laser beam. No coordination with the FAA is required because the laser does not impact navigable air space at a level which would cause a hazard.

Shuttle to 400 Km Altitude

ANSI Z136.1-1993 defines Nominal Ocular Hazard Distance (NOHD) as "the distance along the axis of the unobstructed beam from the laser to the eye beyond which the irradiance or radiant exposure during normal operation is not expected to exceed the appropriate MPE." A shuttle at maximum altitude would be separated from ICESat by a minimum of 200 km (124 mi). This is ten times the acceptable NOHD. If a shuttle crosses the ICESat orbit, an observer can see a maximum of one shot from the laser beam. This shot is only 5 nsec in duration, and it is highly unlikely that the shuttle's crew would notice this short flash of light. A review from the Cheyenne Mountain Operations Center Laser Clearinghouse found that the ICESat laser does not exceed the reference damage threshold to space systems and granted an unconditional waiver.

4.1.2.2 Satellite De-orbiting and Decommissioning at the End of the Mission

The ICESat and the Delta II 7320 launch vehicle second stage would be disposed of at end of mission by an uncontrolled atmospheric reentry, breakup, and disintegration of most pieces. The ICESat orbit lifetime is predicted to be just over fifteen years. This is in compliance with the NASA guideline of reentry within 25 years after end of mission (NASA 2001). In addition, the NASA guideline for limiting orbital debris returning to Earth is that the total "footprint" of objects impacting the Earth's surface may not exceed 8 m^2 (86 ft^2). The calculated causality area for ICESat is 3.63 m^2 (39 ft^2). Therefore, ICESat satisfies the NASA Policy Directive (NPD) 8710.3, NASA policy for Limiting Orbit Debris Generation.

Although the Delta II second stage does not meet the re-entry guidelines, it has been accepted because it is a mature system and is consistent with mission requirements and cost effectiveness. No known chemical hazards would exist due to the mission decommissioning. The ICESat debris hazard analysis (NASA 2001) identified ablation of the GLAS beryllium telescope receiver during reentry as a potential hazard. However, it is very unlikely that beryllium introduced to the atmosphere during reentry would cause impacts to human health or the environment.

4.1.2.3 Accident Scenario

The ICESat laser would not be activated until the satellite is in its intended orbit at 600 km (373 mi) altitude. Therefore, in case of launch failure, no object would be exposed to the laser energy. ICESat utilizes a hydrazine monopropellant pressurized with gaseous nitrogen to deliver thrust for orbit acquisition, orbit maintenance, and spacecraft control (Boeing 1999). There are no expected impacts associated with release of propellants, such as hydrazine, under an accident scenario.

4.2 OTHER ALTERNATIVES

Other alternatives considered included alternative technologies, alternative launch vehicles, and alternative launch sites, as discussed in Sections 2.2.1, 2.2.2, and 2.2.3. The impacts of these alternatives were not assessed as the alternatives were deemed not to be feasible for various reasons.

4.3 NO-ACTION ALTERNATIVE

The No-Action alternative entails no LIDAR testing from space, resulting in no environmental risks to the Earth and no health risks to humans. The No-Action alternative would delay scientific progress and development of technology that can aid in prediction of global climate change.

5.0 REFERENCES

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