4.0 ENVIRONMENTAL CONSEQUENCES

This section of the EA evaluates the environmental effects of the license applicant's proposed action and each of the alternatives identified for further analysis in Section 2.6. Section 4.1 evaluates the environmental effects of the license applicant's proposed action. Section 4.2 evaluates the environmental effects of the alternative with avoidance of the Oceanic Islands. Section 4.3 evaluates the environmental effects of the alternative with avoidance of the Galapagos Islands. Section 4.4 evaluates the environmental effects of the No Action alternative.

4.1 ENVIRONMENTAL EFFECTS OF LICENSE APPLICANT'S PROPOSED ACTION

This section of the EA evaluates the environmental effects of the license applicant's proposed action. To frame this discussion, SLLP operations are broadly grouped into five phases - Home Port, pre-launch, launch, successful flight (separated into Stages I, II, and Upper Stage), and post-launch. Possible failed mission scenarios at the LP, and during flight of Stages I and II and the Upper Stage are discussed. SLLP payloads (i.e., commercial satellites), which would be loaded with propellants and sealed at Home Port, are not addressed because they become operational only when in orbit at an altitude over 35,000 km (21,700 mi). Environmental effects of payloads are discussed only with regard to possible failed mission scenarios.

As detailed in Section 2.2 of this EA, the license applicant's proposed action is for the FAA to issue an LOL for up to eight launches per year for a period of five years up to a maximum of 40 launches. These launches would be conducted over a range of azimuths (82.6^{o} to 97.4^{o}, inclusive) using a specified launch vehicle at a specified launch location for specific payload types. In general, the reader is referred to the February 11, 1999 EA, Section 4.3 for a discussion of the primary environmental impacts of the proposed project during operations at Home Port, pre-launch, launch and post-launch operations, and failure scenarios.

Impacts attributable to the range of azimuths, which affect both successful flight and the possible failure scenarios, are discussed below in Sections 4.1.1 and 4.1.2. Possible cumulative impacts attributable to the license applicant's proposed action are discussed in Section 4.1.3. The discussion of cumulative effects also considers, as a worst-case situation, the possible failure of successive launches that affect the same geographic area. Section 4.1.4 addresses other environmental concerns, such as socioeconomic considerations.

4.1.1 Environmental Effects of Successful Flight

4.1.1.1 Home Port

Under the license applicant's proposed action the environmental effects associated with the preparation of the ACS, LP, and ILV for transit to the launch site are equivalent to those described in Section 4.5.3 and Appendix A of the February 11, 1999 EA. Section 4.1.3 of this EA addresses cumulative environmental impacts associated with the license applicant's proposed action at Home Port.

The use of UDMH during operations at SLLP Home Port will require SLLP to modify Federal, state, and local regulatory documentation prior to the use of UDMH. The following documents needed to be modified:

1. Hazardous Material Inventory, (EPCRA) Long Beach Department of Health (CUPA)
2. Business Emergency Plan, Long Beach Fire Department

3. Operations Manual for the Transfer of Hazardous Material in Bulk, (USCG)
4. Integrated Contingency Plan, (EPA), (OSHA), California OSHA,
5. California Offshore Emergency Service (COES), (USCG)

The following document which will be published in 2002, will reflect emission changes occurring in 2001:

1. Annual Emissions Inventory (Year 2001), (SCAQMD)

The following document will not require changes because regulated thresholds would not be exceeded:

1. Risk Management Plan, Long Beach Department of Health, (CUPA)

Scrubbers are the components of scrubber filters specifically designed and constructed to capture and neutralize UDMH vapors. These filters have been installed at the Home Port facility.

4.1.1.2 Pre-launch, Launch, and Stage I and II Flight Over Open Ocean

Propellant loading would occur after arrival at the launch location. This would result, under normal operations, in an incidental loss of kerosene and LOX vapors, which would dissipate immediately in the atmosphere over the Pacific Ocean. Up to 125,000 liters (33,000 gallons) of freshwater from a tank on the LP would be sprayed into the LP's flame bucket to absorb energy during the initial fuel burn. The heat of the ILV exhaust would evaporate approximately 80 percent of this water, while the remainder would be dispersed by the force of the launch and settle on the ocean surface as spray or mist. This small volume of heated freshwater would cool to ambient ocean temperatures within minutes with no significant adverse effects on any marine life.

The ILV would be launched from the LP and Stage I and II flight would occur over open ocean areas. In this respect, the environmental effects associated with Stage I and II components and their operation during a successful launch along any azimuth in the license applicant's proposed action would be the same as those evaluated in Sections 4.3.2 and 4.5.5 of the February 11, 1999 EA. These include:

- Spent stages, fairing, and sleeve adapter (i.e., connection between Stage II and the Upper Stage) deposition in the ocean,
- Combustion emissions released to the atmosphere,
- Residual propellants released from spent stages to the atmosphere and ocean, and.
- Possibility of spent stages, fairing or sleeve adapter falling on a marine organism, ship, fishing vessel, or aircraft.

Section 3.2 of the February 11, 1999 EA categorized the affected environment in terms of geology, atmospheric processes, oceanography, biological communities (including marine, hydrothermal vent, coral reef, and threatened and endangered species), and commercial operations (including shipping, fishing, and air traffic). The following discussion categorizes the expected environmental effects in the same manner.

Geology

As shown in Figure 4-1, Stage I and fairing impact zones overlap slightly, and jointly form a rectangle of approximately 480 km (north to south) by 600 km (east to west) (300 by 375 mi). These impact zones are located between the Clipperton Fracture Zone and the Galapagos Fracture Zone in the eastern-equatorial

Pacific Ocean in water 2,000 to 4,000 m (1.2 to 2.5 mi) deep. The Stage II impact zone is approximately 1,270 km (790 mi) by 1,320 km (820 miles) located just west of the Galapagos Rift. The water depth in these areas is approximately 3,900 m (2.4 mi). Given the geologic setting, the deposition of spent stages and the fairing in these areas would be inconsequential relative to expanse of the open ocean environment and natural geologic processes in the region.

Oceanography and Atmospheric Processes

The open ocean environment within the proposed range of azimuths is largely uniform in terms of oceanic and atmospheric processes, with biological characteristics (e.g., plankton biomass) primarily varying with nutrient and mineral levels (Barber, et al., 1996). The spent stages and fairing pieces from any launch within the proposed range of azimuths would fall into undifferentiated deep, open waters of the tropical equatorial Pacific Ocean, far away from any Oceanic Islands or continental land mass (see Tables 4-1 and 4-2 and Figure 4-1).[a]

TABLE 4-1. IMPACT ZONES FOR SPENT STAGES AND FAIRING

Flight Element		Open Ocean Impact Zone		
Component	**Mass in kg (lbs)**	**Latitude**	**Longitude**	**Area in km^2 (mi^2)**
Stage I	36,500 (80,300)	2ºS to 2ºN	147.7ºW to 145.5ºW	107,000 (41,800)
Fairing halves*	2,400 (both) (5,280)	2.2ºS to 2.2ºN	146.6ºW to 142.2ºW	240,000 (93,800)
Stage II and sleeve adapter	11,515 (25,333)	6ºS to 6ºN	116.6ºW to 105.1ºW	1,680,000 (660,000)

* Data shown are for the potential 5-m (16.5 ft) fairing

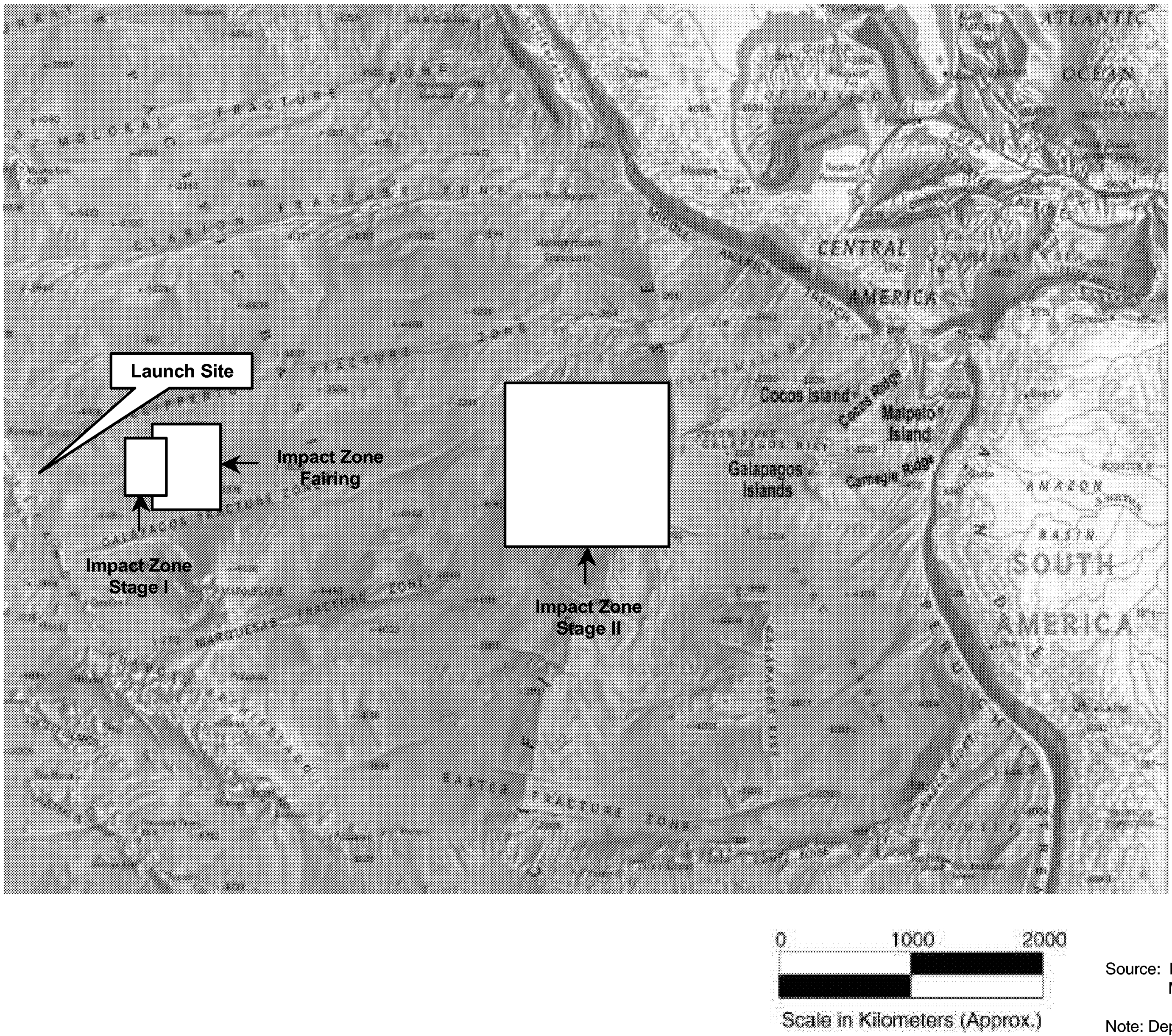
[a] The fairing and Stage I and Stage II impact zones are outside the area of the Convention for the Protection of the Natural Resources and Environment of the South Pacific Region (1986) ("Convention"). Article 2 of the Convention defines the "Convention Area" as:

(i) the 200 nautical mile zones established in accordance with international law off:
American Samoa; Australia (East coast and Islands to eastward including Macquarie Island); Cook Islands; Federated States of Micronesia; French Polynesia; Guam
Kiribati; Marshall Islands; Nauru; New Caledonia and Dependencies; New Zealand; Niue
Northern Mariana Islands; Palau; Papua New Guinea; Pitcairn Islands; Solomon Islands; Tokelau; Tonga; Tuvalu; Vanuatu; Wallis and Futuna; Western Samoa
(ii) those areas of high seas which are enclosed from all sides by the 200 nautical miles zones referred to in sub-paragraph (i).
(iii) areas of the Pacific Ocean which have been included in the Convention Area pursuant to Article 3.

Article 3 allows any Party to add to the Convention Area those areas under its jurisdiction which fall within certain specified coordinates in the Pacific region as long as no other Party objects. These specified coordinates include the area in the "Pacific Ocean between the Tropic of Cancer and 60 degrees South Latitude and between 130 degrees East longitude and 120 degrees West longitude . . . ." (Convention, Article 3). No areas have been added to the Convention Area under this Article 3.

NOTE: No areas were identified within the fairing and Stage I and Stage II impact zones over which any Party to Convention could have jurisdiction – a prerequisite for adding an area to the Convention Area under Article 3.

Figure 4-1
Impact Zones for Stage I, Stage II, and Fairing



Source: National Geographic Society
Mercator Projection,

Note: Depths are in meters.

TABLE 4-2. SHORTEST EXPECTED DISTANCES BETWEEN LAND MASSES AND ILV STAGE IMPACT ZONES

Land Mass (Country)	Distance Between Land Mass and Stage I Impact Zone (km (miles))	Distance Between Land Mass and Fairing Impact Zone (km (miles))	Distance Between Land Mass and Stage II Impact Zone (km (miles))
Kiritimati Island (Kiribati)	1,073 (667)	1,196 (743)	4,526 (2,813)
Malden Island (Kiribati)	841 (523)	954 (593)	4,255 (2,644)
Hatutu Island (France)	1,027 (638)	660 (410)	2,651 (1,648)
Clipperton Island (France)	4,108 (2,553)	3,748 (2,329)	476 (296)
Cocos Island (Costa Rica)	6,487 (4,032)	6,120 (3,804)	1,994 (1,239)
Galapagos Islands (Ecuador)	5,971 (3,711)	5,605 (3,483)	1,483 (922)
Malpelo (Colombia)	7,091 (4,407)	6,724 (4,179)	2,649 (1,646)

The maximum impact areas[b] of spent Stage I, fairing (assuming the larger 5-m fairing), and Stage II components (including the sleeve adapter) would be 404 m^2 (4,400 ft^2), 177 m^2 (1,930 ft^2) and 127 m^2 (1,380 ft^2), respectively, for any launch. In the context of the expanse of ocean area in each impact zone, the environmental effect of this deposition would be minimal. The 3-sigma impact zones for Stage I, for the fairing, and for Stage II are 1.18×10^9 m^2 (1.28×10^{10} ft^2), 4.71×10^9 m^2 (5.13×10^{10} ft^2), and 1.26×10^{10} m^2 (1.37×10^{11} ft^2), respectively. These areas are where, with 99.67 percent certainty, the components are predicted to fall.[c] Therefore, for any individual launch, only 0.00003 percent, 0.000003 percent, and 0.000001 percent of the ocean area within the impact zone area would be affected by Stage I, fairing, and Stage II debris, respectively. The deposited fairing material from successful launches would initially float and gradually sink as it becomes waterlogged, while stage material would sink and slowly dissolve and be buried in the ocean bottom. These materials are primarily composed of aluminum, steel, or graphite composite, some with small quantities of plastic, ceramic, and rubber products. On the bottom, the debris would become part of the ocean floor habitat much as materials such as old ships, drilling rigs, and tires submerged in coastal waters become substrate and shelter for marine organisms and attract new communities (Chou, et al., 1991).

Over this area of the equatorial Pacific Ocean, residual propellants would be released as spent ILV components fall into the ocean. Table 4-3 shows the quantity of residual kerosene and LOX associated with stage deposition during a successful flight. Residual LOX would dissipate immediately upon release. Residual kerosene would be dispersed into a mist during descent, and all but the largest droplets of kerosene would evaporate within a few minutes. Kerosene that reached the ocean surface would quickly spread on the surface from the effects of gravity, wind, and waves. A circular area with a radius of approximately 130 m (430 ft) would eventually be covered by a visible sheen from approximately 2,750 kg (or 6,050 lbs) of residual kerosene in Stage I (Doerffer, 1992). This estimate assumes that the entire residual amount of Stage I kerosene reaches the ocean surface, and that it would not evaporate.

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[b] The maximum impact area is defined as the largest amount of the sea floor that would be covered by the flattened surface areas of stage or fairing debris.

[c] This impact area is based on a probability estimate that accounts for each component's momentum as well as wind dispersion. For Stage I, the 3-sigma area is estimated to be an ellipse 50 km long and 30 km wide (31 by 18.8 mi; for the fairing, 120 km long and 50 km wide (75 by 31 mi); and for Stage II/Upper Stage sleeve adapter, 200 km long and 80 km wide (125 by 50 mi). For the purposes of this EA, the 5-m fairing is being evaluated as the worst case.

With these assumptions, the kerosene thickness in the center of the circle, after a few days, would be approximately one millimeter (0.05 in) (Patin, 1999; Ramade, 1978; and Lee, 2001). This theoretical approach, however, greatly overstates the area affected. Over 95 percent of this residual kerosene would evaporate within a few hours, while the remainder would disperse in the water column and degrade, such that the ocean environment would return to its initial condition within a few days (Doerffer, 1992; National Research Council, 1985; Rubin, 1989; ITOPF, 2001; and EPA, 1999). The area affected by Stage II kerosene would be proportionately less given the smaller volume of residual kerosene.

Although product-specific data are not available on alternative kerosene supplies presently being considered by SLLP, i.e., Boktan from Russia or kerosene from suppliers in the U.S., it is believed that either alternative would have physical and chemical characteristics and environmental effects comparable to the kerosene addressed in this EA. Should SLLP decide to use alternative kerosene supplies at some point in the future, proper environmental analysis will be conducted as appropriate. SLLP will continue to try to improve and optimize the use of the amount of propellants loaded on the ILV. This will serve to further reduce residual quantities of propellants remaining in tanks after engine burn.

TABLE 4-3. PRIMARY PROPELLANTS ASSOCIATED WITH STAGE I AND II FLIGHT AND DEPOSITION

Associated Component	Initial Kerosene (kg (lbs))	Initial LOX (kg (lbs))	Residual Kerosene (kg (lbs))	Residual LOX (kg (lbs))
Stage I	89,773 (197,500)	235,331 (517,728)	2,750 (6,050)	7,250 (15,950)
Fairing halves	N/A	N/A	N/A	N/A
Stage II	22,950 (50,490)	58,703 (129,147)	700 (1,540)	1,800 (3,960)

Recovery Time

The environment would recover from the effects of the residual hazardous material from each launch relatively quickly, and return to its natural condition within a few days. In terms of this recovery time, there would be no indication that a launch had taken place when the next launch occurred (approximately 45 days later under the license applicant's proposed action (Doerffer, 1992; National Research Council, 1985; Rubin, 1989; ITOPF, 2001; and EPA, 1999). No other hazardous materials would be released to the environment during this phase of a successful launch; Stages I and II, which consist of metal and small amounts of ceramic, rubber and plastic materials, would sink to the ocean floor and remain in an inert state.

The ILV would consume approximately 414,000 kg (911,000 lbs) of propellant during ascent, and produce carbon monoxide (CO), carbon dioxide (CO_2), hydrogen (H_2), and water vapor (H_2O) emissions, see Table 4-4. In addition to these main emission products, relatively small quantities of soot and sulfate particles (i.e., fine particulate matter produced in combustion) may be released to the atmosphere (Newman et al., 2001; Fahey et al., 1995). Also, as the ILV plume, which is rich in water vapor, transits the lower layer of High Altitude Tropical cirrus clouds, ice crystals form in the water vapor of the plume and mix with existing ice crystals. This higher concentration of ice crystals makes the contrail visible.

TABLE 4-4. TOTAL EMISSIONS PER LAUNCH

Atmospheric Layer	Altitude* Range (km (mi))	Propellant Consumed (kg (lbs))	Emission Products per Launch in kg (lbs)				
			CO	CO_2	H_2	H_2O	N_2
Lower Troposphere	0.0-2.0 (0.0-1.2)	61,714 (135,771)	17,033 (37,473)	26,907 (59,195)	432 (950)	17,342 (38,152)	0
Free Troposphere	2.0-10.0 (1.2-6.2)	69,100 (152,020)	19,072 (41,958)	30,128 (66,282)	484 (1,065)	19,417 (42,717)	0
Stratosphere	10.0-51.0 (6.2-32)	158,831 (349,428)	43,837 (96,441)	69,250 (152,350)	1,112 (2,446)	44,632 (98,190)	0
Mesosphere and Thermosphere	51.0-292 (32-182)	124,697 (274,333)	33,987 (74,771)	55,508 (25,231)	991 (2,180)	34,226 (75,297)	36 (80)
	Total	414,342 (911,552)	113,929 (250,643)	181,793 (303,058)	3,019 (6,641)	115,617 (254,356)	36 (80)

These emission products are thought to contribute to several types of atmospheric environmental impacts, including global warming, acid rain, and ozone layer destruction. Although CO_2 is a probable contributor to global warming, the amount released by SLLP during a year of operation is much less than the amount of CO_2 normally cycled at the ocean surface (see Section 4.1.3.4; Takahasi, et al., 1997). Launch vehicle operations in general have a negligible effect on acid rain, with effects attributable to the combination of sulfur dioxide, nitrogen oxides, and aluminum with water vapor in the atmosphere. Many studies have been done on the cumulative environmental effects of launches worldwide. The American Institute for Aeronautics and Astronautics convened a workshop to identify and quantify the key environmental issues that relate to the effects on the atmosphere of launches. The conclusion of the workshop, based on evaluation of scientific studies performed in the U.S., Europe, and Russia, was that the effects of launch vehicle propulsion exhaust emissions on stratospheric ozone depletion, acid rain, toxicity, air quality, and global warming were extremely small compared to other anthropogenic impacts. SLLP propellants would not generate significant amounts of these substances therefore these launches would have negligible effects on acid rain formation.

Biological Communities and Commercial Activities

The potential effects of successful launches and Stage I and II flight on biological communities and commercial activities are limited to the noise effects associated with the launch; and spent stages and fairing falling on a marine organism, ship, fishing vessel, or aircraft.

Noise Effects on Biological Communities

In terms of noise, steady noise from pre- and post-launch operations (e.g., from ship engines) may reach approximately 70 dB. Research indicates that this level of noise would not have a detrimental affect on any animal that would linger in the area (Shulhof, 1994; Richardson, et al., 1997). In fact, wind speeds of approximately 60 km/hr (37 mi/hr), which occur in the eastern portion of the Pacific Ocean, generate similar levels of noise (i.e., approximately 70 dB) on the open ocean (NIMA, 1998; Cato, 1994).

No significant noise impacts would be expected from the launch because of the relatively short duration of launch noise and the unlikely presence of the higher trophic level organisms near the launch site. Section 4.3.2.1 of the February 11, 1999 EA identified noise from a single launch to be 150 dB at 378 m

(1240 ft), with the equivalent sound intensity in the water at this distance being 75 dB. This reflects the fact that noise generated above the ocean is significantly attenuated by the air-water interface, which protects fish and marine mammals from most above-water noise impacts (Bowles, 1995). Navy research indicates that noise levels of 130 dB in the water are needed before changes in behavior patterns of certain whale species (Sperm and Humpback) are observed (Office of Naval Research, 2000). Other research found that noise of 130 dB might cause humpback whales to move away from the noise source and increase their dive duration. This level of noise did not result in any observed mass strandings or desertion of young (Ocean Studies Board, 1995). This study also found that elephant seal behavior near the sound source was apparently unaffected (Ocean Studies Board, 1995). Some environmental groups assert that noise levels of 140 dB cause whales to change their course and abandon their calves (ENS, 2000a). The Navy is currently preparing an EIS that evaluates the effect of its Surveillance Towed Array Sonar System (STASS) on marine mammals. The STASS generates noise levels of 160 to 180 dB; noise levels that could cause behavioral changes and/or injury to marine mammals, according to the U.S Marine Mammal Commission (ENS, 2000a). The Navy's Draft EIS concluded that the STASS is not likely to adversely affect listed species under the National Marine Fisheries Services (NMFS) jurisdiction, which include marine mammals. On 5 May 2000, NMFS informed the Navy that NMFS was not able to concur with their determination (ENS, 2000b). The Navy's Final EIS has not been released. The noise generated from SLLP's ILV would be diffuse compared to that generated by STASS.

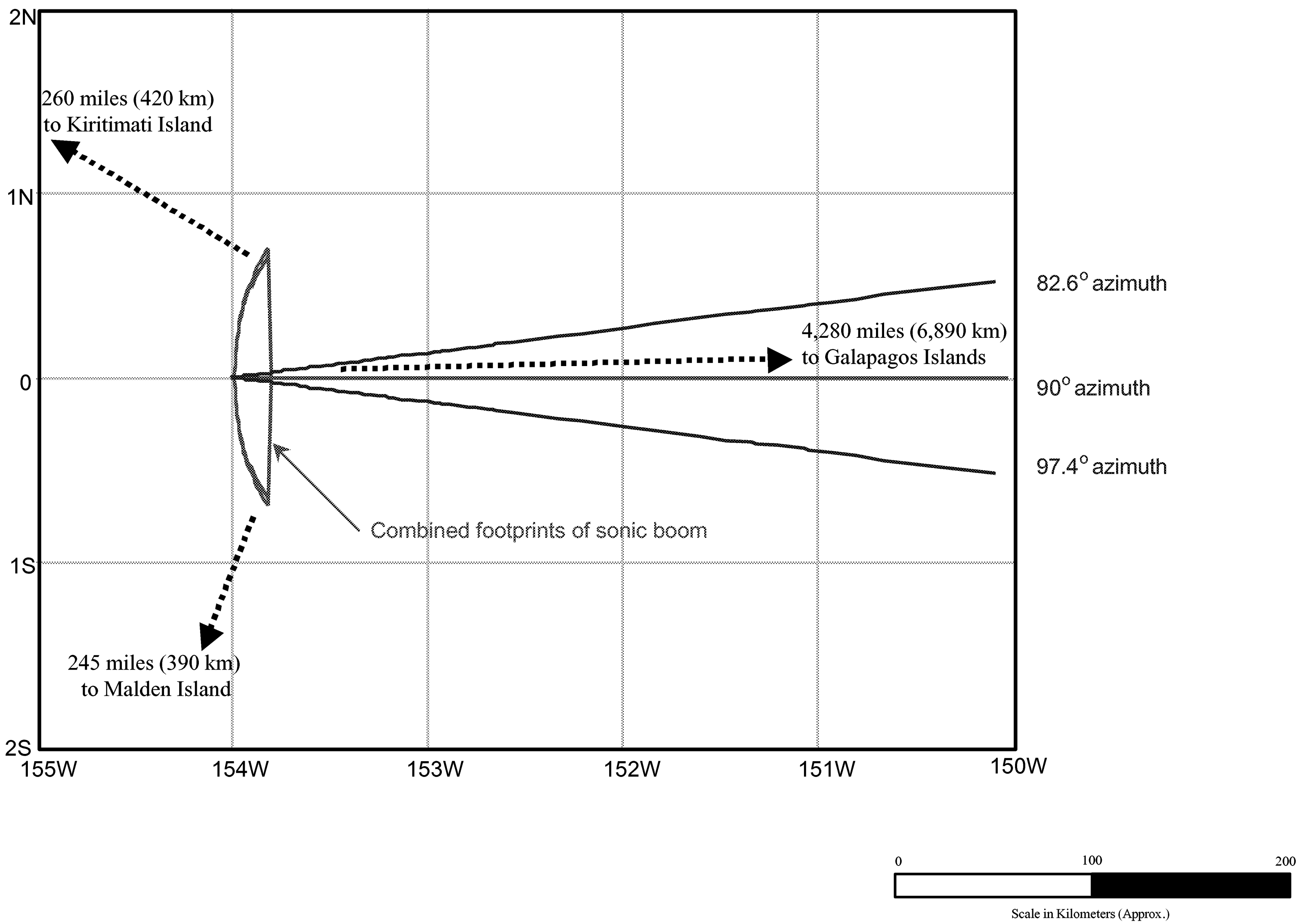
Data suggest that fish and marine mammals will move to avoid chronic high level noise and noise that may increase slowly in magnitude (Office of Naval Research, 2000; ENS, 2000). Fish and marine mammals, however, are not likely to be able to move quickly enough to avoid sudden acute high level noise. The velocity of sound in seawater is approximately 1,500 m/s (4,950 ft/s), or about 4.5 times faster than in air (Taley, 1990).

The decibel scale used to measure acoustic energy or sound is logarithmic (i.e., an increase from 60 dB to 120 dB represents a million times greater level of acoustic energy). The available data indicate that noise levels impacting the ocean environment would need to be much higher than the 75 dB generated by an SLLP Zenit-3SL launch to adversely affect marine life. Further, noise generated by the launch would last less than a minute (i.e., in less than 60 seconds the ILV would be over 10 km (6 mi) in altitude). Finally, as a condition of the launch license, an individual launch would be postponed if a whale or turtle were spotted within 100 m (330 ft) of the LP by visual observers up to 60 minutes prior to launch, at which time automatic launch processes are activated. In the seven launches to date, only one species of concern has been sighted during the entire launch countdown. An endangered species of Hawaiian Petrel was observed as part of the environmental monitoring for Mission 4. A bird was observed on the day before the launch and one-hour after the launch by observers on the ACS. Environmental monitors noted the sighting and submitted the information as part of the launch monitoring report. (See Environmental Monitoring Program Plan (EMPP), found in Appendix G.)

Sonic Booms

A sonic boom would occur when the ILV reaches supersonic velocity during Stage I flight. A sonic boom is caused when an object moving faster than sound (i.e., 1,200 km/hr (750 mi/hr) at sea level) compresses the air in its path. The sound heard at the Earth's surface as a "sonic boom" is the sudden onset and release of pressure after the buildup by the shock wave or "peak overpressure." The change in pressure caused by a sonic boom is only a few kilograms per square meter (pounds per square foot). The footprint of the sonic boom extending from the ILV during supersonic flight is provided in Figure 4-2, which encompasses the sonic boom footprint for all launch azimuths under the license applicant's proposed action. In other words, the effects of a sonic boom for flight on any azimuth within the license applicant's proposed action would be contained within the limits depicted in the footprint in Figure 4-2

Figure 4-2
Sonic Boom Footprint and Distances to Selected Land Masses



The maximum pressures experienced from a sonic boom would be directly under the launch vehicle flight path, and is primarily a function of velocity and altitude. As Figure 4-2 indicates, the sonic boom would occur over the open ocean far from any of the Oceanic Islands. The distance between the sonic boom footprint and the closest landmass (i.e., Kiritimati Island) is 420 km (260 mi). The effects of the sonic boom would be rapidly attenuated by the air-water interface (i.e., the acoustic energy associated with the sonic boom will be partially absorbed as it goes from the air into the water surface, lessening the effect) (Bowles, 1995). Thus, it would not have any significant adverse effects on marine organisms that happen to be in the area other than a startle reaction. A startle reaction may cause an adverse effect in a threatened and endangered species; however, little information on the physiological impacts of the startle effect is available for marine organisms in the open ocean. No physical harm to animals or ships at sea level would occur because of the altitude of the launch vehicle and its vertical acceleration (USAF, 1996).

Limiting Potential Impacts from Falling Stages and Fairing

The likelihood of spent stages and fairing striking a marine organism, ship, fishing vessel, or aircraft and preventative measures taken to avoid such an event are described in Sections 4.3.2.1 and 4.5.5, respectively, of the February 11, 1999 EA. (See Appendix A.) Coordination efforts to reduce this possibility are further detailed in the EMPP (Revision 1, August 21, 1999), which is attached to this document as Appendix G. In summary, for each launch, SLLP gives advance notice to the FAA (Central Altitude Reservation Function), the USCG (14th District), NIMA, and the U.S. Space Command (USSC). To coordinate air, marine, and space traffic, these organizations routinely issue necessary information through well-established communication channels. For vessels without receiving equipment, standard notices are delivered by fax to Kiribati government authorities and regional fishing fleet and tour operators for distribution and posting. Notices are broadcast using U.S. Government protocols via INMARSAT-C, Pacific Ocean Region satellite on Safety Net channel at 10:00-10:30 and 22:00-22:30 GMT each day starting 5 days prior to each launch. The notice is also broadcast on frequencies in the high frequency (HF) band by USCG, Honolulu. The notice is distributed to Christmas Island local authorities and tour boat operators for posting and distribution; the Ministry of Information, Communication, and Transport for posting; and the operators of regional fleets at their headquarters, e.g., national and industry operators. In addition, the launch criteria prescribe that no launches would be conducted unless all vessels are clear of the predetermined safety zones surrounding the LP (visual observations would be taken up to 30 minutes prior to launch). Visual and radar sensors would be used to verify the absence of vessels in this zone. Therefore, the chance of spent stages or fairing striking a marine organism, ship, fishing vessel, or aircraft is very remote.

4.1.1.3 Upper Stage Flight Over the Oceanic Islands and South America

Upper Stage and payload flight would progressively transit over open ocean waters, the Oceanic Islands, and the northern part of South America. Upper Stage flight during a successful mission would have no effect on the ocean or land environments or the lower atmosphere because its operation occurs at very high altitudes.

Atmospheric Processes

The only environmental effect associated with Upper Stage flight of a successful mission is the combustion or venting of relatively small quantities of Upper Stage and payload propellants at high altitudes that are well above the range for potential atmospheric impact. The Upper Stage would achieve a low Earth orbit at an approximate altitude of 180 km (112 mi), at which point motors would be fired as needed to position the payload in the specified orbital parameters.

Future launches may use alternatives to the Russian kerosene (RP-1) presently used on the Upper Stage of the Zenit-3SL. Specifically, a petroleum hydrocarbon product called "Boktan" that is manufactured in Russia may be used to enhance ILV performance by increasing thrust and lift capacity. Kerosene from suppliers in the United States may be used to lower operating costs. The analyses presented in this EA, therefore, anticipate the possible substitution of Russian RP-1 kerosene with either of these alternatives. The U.S. kerosene is chemically equivalent to the RP-1 kerosene presently used by SLLP. The Boktan product, however, is a different chemical that needs to be considered further. See Appendix E for a comparison of chemical and physical characteristics of these propellants. Should SLLP decide to use either U.S. kerosene or Boktan at some point in the future, proper environmental analysis will be conducted as appropriate.

While Boktan requires somewhat greater personnel safety precautions (e.g., gloves and protective clothing) during handling than kerosene (based on their respective toxicity classes), its fate and effect during use or in the event of a spill are expected to be similar to kerosene or other low molecular weight hydrocarbon products. Specifically, Boktan would be used in equivalent quantities as an engine fuel and it would have the same emission products (e.g., CO, CO_2, H_2 and H_2O) as kerosene when burned. Boktan's rates of dispersion and evaporation in the open ocean environment if spilled or released would be somewhat greater given that its boiling, melting, and flash points are all somewhat lower than kerosene (i.e., resulting vapor pressure would be somewhat greater). Therefore, it is likely that the fate (i.e., ultimate break down and chemical form in the environment) and effect of Boktan in the environment would be very similar to those of the currently used Russian kerosene. Should SLLP decide to use Boktan at some point in the future, proper environmental analysis and review will be conducted as appropriate.

The February 11, 1999 EA (Section 4.3.2.1) solely considered the use of MMH as an Upper Stage propellant, which is the propellant used in six SLLP launches to date (the seventh mission used UDMH and N_2O_4). It is conceivable that UDMH (both U.S. and Russian produced) would be used in future launches proposed in this action. The properties of UDMH are summarized in Appendix E. Although it has a different molecular structure in the hydrazine family of chemical compounds, UDMH is equivalent to MMH in terms of its use in the Upper Stage. UDMH quantity, behavior, fate, and effect relative to the environment during a successful launch would also be equivalent as it is expended at very high altitudes beyond the range of potential atmospheric impact.

Once in the target orbit, the Upper Stage would be separated from the satellite payload, its gases and propellants would be vented or depleted into space, and it would be put into a final disposal orbit where it would remain for decades or longer.

4.1.1.4 Post-Launch Operations

Debris remaining on the LP would be collected, identified as to source (for compliance with U.S. Department of State Technology Transfer requirements), and disposed of in accordance with the International Convention for the Prevention of Pollution (in compliance with MARPOL 73/78) or brought back to Home Port for proper disposal. As part of post-launch cleaning, particulate residues (i.e., scorched deck paint) would be swept and washed off the deck with freshwater, and the deck would be repainted while at sea. The quantity of such wash water is expected to be a few kilograms/pounds.

4.1.2 Environmental Impacts of Possible Failed Mission Scenarios

A possible failed mission can occur at the LP, during Stage I or Stage II flight, or during Upper Stage flight. In most cases, a failure would result from a detected deviation between the programmed flight path parameter (e.g., pitch, yaw, roll) and the actual flight parameters as monitored by ILV sensors. If flight deviations exceed established limits, the thrust termination system would terminate the flight. Failure of the onboard computer systems could also result in thrust termination and loss of the mission. SLLP has projected launch reliabilities of 0.982 for Stage I flight, 0.956 for Stage II flight, and 0.974 for Upper Stage flight (SLLP, 2001). For the purposes of conducting debris risk analyses the FAA specifies that for launch vehicles "with fewer than 15 flights, a launch operator shall use an overall launch vehicle failure probability of 0.31." 14 CFR § 417.227(b)(6)(i) For launch vehicles "with at least 15 flights, but fewer than 30 flights, a launch operator shall use an overall launch vehicle failure probability of 0.10 or the empirical failure probability, whichever is greater." 14 CFR § 417.227 (b)(6)(ii) For launch vehicles "with 30 or more flights, a launch operator shall use the empirical failure probability determined from the actual flight history." 14 CFR § 417.227 (b)(6)(iii)

4.1.2.1 Possible Failure at the Launch Platform

Section 4.3.4.1 of the February 11, 1999 EA considered an explosion on the LP as representing a worst-case occurrence of Stage I and II failure. A possible failure at the LP would likely result in a cascading explosion of all ILV propellants. The explosions would scatter pieces of the ILV, and perhaps pieces of the LP, as far as three kilometers (two miles) away (the LP is designed to survive an explosion of the fully fueled launch vehicle). A smoke plume would rise and drift downwind some distance before dissipating. In the course of about one minute, the entire matter and energy of the ILV would be dispersed in the environment in a relatively concentrated area of the ocean. Environmental effects would include intense heat generated at the ocean surface; debris and noise released during the explosion; emissions released to the atmosphere; and the subsequent cleanup needed on the LP. Despite this intense, short-term, and localized disruption, there would be no discernible long-term impact to the environment. The fuels not consumed in the explosion would evaporate or become entrained in the water column and would eventually be degraded by microbial activity and oxidation (Doerffer, 1992; National Research Council, 1985; Rubin, 1989; ITOPF, 2001; and EPA, 1999). The areas of plankton lost due to heat or toxic effect would be re-colonized as currents redistribute the surface waters (Grigg and Hey, 1992). Section 4.3.4.1 of the February 11, 1999 EA concluded that the environmental effects of a failure at the LP would be short-term and localized relative to the scale and character of the ocean environment. For the license applicant's proposed action, the environmental effects of a failure at the LP would be the same as described in the February 11, 1999 EA.

Launch Abort Scenarios

There is also the potential for a launch abort at the LP (i.e., when a countdown is interrupted or no launch occurs, which is technically not a failure). In general, a launch would be aborted if equipment malfunctions or unresolved deviations of ILV parameters occur just before launch. Due to the inherent complexity of the ILV, a deviation in any number of factors could trigger an abort, and the extent to which propellants need to be safeguarded would vary based on the time prior to launch that the abort occurs. In all cases, however, the resulting contingency measures initiated by SLLP would follow established routines to stabilize the ILV on the LP. A worst-case abort, which would occur three seconds prior to launch, involves the largest quantities of propellant and the most detailed contingency measures. An abort scenario would involve draining small quantities of propellant into the flame bucket where it would evaporate due to wind effects. In addition, the pyrophoric fluid that initiates kerosene ignition would be burned according to SLLP's operating procedures. The ILV would be returned to a horizontal position in the LP hanger, and the propellant reservoirs from the Stage I engine would be drained into containers for later disposal at the Home Port as a hazardous waste.

An abort at three seconds prior to launch occurred during the SLLP Mission 6 launch planned for January 8, 2001. Visual observations by safety personnel during that event reported that, when drained, the pyrophoric fluid combusted instantly upon exposure to air in a sporadic stream approximately 4 m (13 ft) long, over several minutes. The draining of kerosene in engine propellant lines occurred as described in Section 4.3.1 the February 11, 1999 EA. Specifically, approximately 70 kg (150 lbs) of kerosene from the Stage I engine splashed onto the exhaust deflector, a large steel structure positioned under the ILV, and evaporated over the course of several hours from the effects of a steady breeze. No hazardous material was observed contacting the ocean surface. The emissions from the propellants that burned or evaporated during this process were dispersed into the atmosphere. These emissions would pose less environmental risk than those from a successful launch because much less of the propellant would be combusted during an abort event.

This is considered the worst-case abort scenario since before this point in the countdown, fewer hazardous materials would be involved, while after this point, the starting fluid would have initiated ILV ignition and flight. After this point, the event would take the form of either failure on the LP (see above) or during flight (Sections 4.1.2.2 and 4.1.2.3 below). As this observed event represents the worst-case abort scenario and did not result in significant environmental impacts, this or similar potential launch aborts would not be expected to significantly affect the environment.

The environmental impacts of failed missions that occur during Stage I or II flight or during Upper Stage flight, however, are evaluated below as such failures would affect a broader geographic area due to the proposed range of azimuths. The effect of successive launch failures is also considered in Section 4.1.3.6.

4.1.2.2 Potential Failure During Stage I and II Flight Over Open Ocean

An ILV failure moments after the ILV leaves the deck of the LP could also be considered a worst-case scenario since the propellant quantities involved would still be near a maximum at the onset of flight, and the failure would occur over the ocean rather than on the LP. A possible failure at this stage of flight would put all unexpended propellants, other hazardous materials, and ILV hardware into the environment in a more concentrated area than would occur during a successful flight. The quantity of hazardous material and debris reaching the ocean surface would depend on when in the flight the failure occurred (i.e., the longer the flight before failure, the less propellant would be onboard the ILV and available to potentially reach the ocean surface).

Possible failure at this point of the launch could occur in two ways: explosive failures and thrust termination failures. The mass and character of hazardous material (including the various propellants) and debris that would reach the ocean would depend on the type and time of failure during a launch.

Explosive versus Thrust Termination Failures

Potential explosive failures (marked by the sudden destruction of propellants and the ILV during flight) would result in the scattering of ILV parts and the immediate consumption by burning of most if not all of the hazardous materials incorporated by or contained in those parts. In contrast, possible thrust termination failures (i.e., one in which a deviation in flight triggers engine cutoff) would result in the ILV losing upward and forward momentum and falling toward Earth. In this case, an ILV early in Stage I flight would likely fall intact and rupture on the ocean surface, while later in Stage I flight and during all of Stage II flight, the ILV would begin to tumble within seconds and break up due to stresses on the structure. Explosions may also occur during thrust termination if, as the ILV breaks up, flammable materials become exposed to hot engine parts and ignite. If an explosion does not occur, the extent to which ILV materials would reach the Earth's surface would depend on the altitude and speed of the ILV at the time of thrust termination.

Possible Failure Near the Launch Platform

The worst-case scenario during initial ILV flight would be a thrust termination failure within 20 seconds of the ILV leaving the LP and the ILV falling intact and rupturing on the ocean surface. Regardless of when within the first 20 seconds the failure occurs, the ILV flight would continue until the twentieth second at which time the thrust termination system would automatically end the flight. This delayed termination has been automated to ensure that this type of failure does not damage the LP and to ensure that the ILV falls safely away from the ACS, which is positioned approximately five km (three mi) from the LP. At this point in flight, most of the propellant is unburned and virtually all of the ILV mass of propellants (see Table 4-3), other hazardous material, and components would be released into the environment in a concentrated area.

A possible failure near the launch platform would be worse than either an explosive failure or a thrust termination failure in which the ILV explodes later in the flight. In the case of a failure involving an explosion, most of the ILV would be consumed, destroyed, and scattered in a series of cascading explosions, and the propellants and other flammable materials would be burned before reaching the ocean surface. A thrust termination or explosive failure later in the launch may have less environmental impact (depending on the impact location). During such a failure later in flight more of the debris and virtually all of the propellants would be incinerated or evaporated and not reach the ocean surface, while those debris or propellants that would reach the ocean surface would be more dispersed. In general, larger and more concentrated amounts of ILV material and debris released during a failure would have a proportionately greater impact and take more time to dissipate and break down in the environment.

Effects of a Possible Failure During Stage I or II Flight

For the license applicant's proposed action, the scenario of possible Stage I or II failure, and especially the worst-case scenario of possible thrust termination failure during the first 20 seconds of flight, would occur over the east-central Pacific Ocean, well away from the Oceanic Islands and South America. Even if a failure caused a deviation from the intended flight plan, the deviation prior to thrust termination would not be so great as to have any environmental effects significantly closer to the Oceanic Islands than the normal debris deposition areas of a successful flight (see Table 4-2). Therefore, the debris from the ILV would fall into the deep waters of the open ocean far from any Oceanic Islands. The debris, which includes metal and composite components that incorporate small amounts of rubber, plastics, and ceramics, is largely inert and would settle to the ocean bottom as described in Section 4.1.2.1 and become an inert part of the seafloor ecology (Chou, 1991).

A possible failure during Stage I or II flight would result in the release of propellants and other hazardous materials (see Section B.3 and Table B.3-1 of the February 11, 1999 EA). In addition to the main propellants, kerosene (or Boktan) and LOX, small quantities of the propellants MMH (or UDMH) and N_2O_4 would be released, as would even smaller amounts of explosive compounds and metals present in release mechanisms and batteries.

The primary effects of a failure during Stage I or II flight are threefold:

- Release of emissions to the atmosphere.
- Release of propellants and other hazardous material to the ocean.
- Likelihood of Stage I or II debris falling on marine organisms, marine vessels, or aircraft.

Each of these effects is evaluated below for the worst-case scenario.

Release of Hazardous Materials, Including Emissions, to the Atmosphere

Vapors and aerosols (from evaporating propellants including LOX, kerosene (or Boktan), MMH (or UDMH), and N_2O_4) and combustion reaction products (primarily O_2, CO, CO_2, H_2, H_2O, nitrogen oxides (NO_x), including potentially small quantities of soot and sulfate particles) would disperse with the prevailing winds. Vapors would react with solar energy, break down to form smog and dissipate into the environment. Aerosols and liquid drops large enough to fall to the ocean surface would disperse with surface currents and break down under the influence of solar energy and microbial action (primarily to CO_2 and H_2O). As combustion during a failure is uncontrolled and inefficient, not all propellant mass would be converted to energy and some particulate residues would travel with the wind, settle on the ocean surface some distance from the point of failure, and break down into the same more basic compounds.

Release of Hazardous Materials to the Ocean

Potential impacts from the release of hazardous materials to the open ocean as a result of a possible failure during Stage I or II flight would be the same as those discussed in Section 4.1.1.2, "Oceanography and Atmospheric Processes."

Kerosene can be toxic to marine organisms, and it would likely affect plankton on the ocean surface. Overall plankton mortality, however, would be minimal because the affected area would be small relative to the scale of the ocean, and plankton population densities are naturally discontinuous and concentrated below the surface (Murray, 1994). Plankton re-colonization of the affected area would occur within a few days to a week in even the most directly affected area as surface waters move and mix under the effect of currents and winds (Grigg and Hey, 1992). Accordingly, the surface and ocean environment would return to pre-launch conditions within a week or so, even considering the most significant aspect of this worst-case failure. As such, there would be no indication of a failure by the time the next launch would occur. As discussed in Section 4.1.4.6 of this EA, this duration would be four to 12 months, considering the mandatory investigation that would follow any failure.

Comparable physical and chemical processes would be expected if the present kerosene product is replaced by Boktan or another kerosene. This determination is based on product data presented in Appendix E. Should SLLP decide to use either U.S. kerosene or Boktan at some point in the future, proper environmental analysis will be conducted as appropriate.

The hazardous materials in the Upper Stage and payload (primarily MMH (or UDMH) and N_2O_4) that would be released to the environment during a failure, would have slightly greater initial toxic effect than released kerosene because they are more volatile and reactive (see Appendix E and discussions in this section above). UDMH and MMH are both hydrazine fuels (a type of launch vehicle and spacecraft fuel used in hypergolic propellant systems) that have different chemical and physical parameters (e.g., boiling point, specific gravity, vapor pressure, flash point). The two fuels, however, are similar in terms of their reactivity, products of combustion (based on using N_2O_4 as an oxidizer), exposure limits and United Nations and United States Department of Transportation hazard classification. The overall impact from these materials would be considerably less than the impacts from kerosene because smaller quantities would be used.

Compared with the worst-case failure scenario (i.e., thrust termination failure within 20 seconds of flight), the return to pre-launch conditions for Stage I or Stage II failure would be somewhat faster (i.e., hours and days rather than days to a week) given the decreasing mass of propellants and other hazardous material onboard the ILV as the flight progresses (Doerffer, 1992; National Research Council, 1985; Rubin, 1989; ITOPF, 2001; and EPA, 1999).

Risk of Debris Falling on Marine Organisms, Vessels, or Aircraft

There is likely to be more debris reaching the Earth surface from a failure than from a successful mission. Also, and as indicated above, a thrust termination failure without an explosion would result in the most debris (i.e., potentially the entire ILV), while a failure late in Stage II flight would introduce less debris as some of the ILV would vaporize or burn before reaching the Earth's surface. In general, therefore, increasing altitude and speed would result in more debris being burned up during descent, and debris that does reach the ocean surface from a high-altitude Stage II failure would be inert after being subjected to the intense heat generated while re-entering the upper atmosphere. The surviving debris, which would cool during the descent through the lower atmosphere, would still initially be hot to warm. The debris would cool to ambient ocean water temperature within minutes of contact, and would have a negligible effect on any marine life.

The risk of ILV debris falling on marine organisms is remote given the launch criterion that a launch would not occur if whales or sea turtles are observed in the area surrounding the LP prior to launch. As with Stage I or II deposition during a successful flight, however, there is a chance that the debris and/or hazardous material from a failure later in flight may fall on a marine organism at the ocean surface. Because of the relatively low population densities of marine organisms (especially marine mammals) in this region, and low probability of an organism being present at the ocean surface (e.g., during breaching) (Kasamatsu, et al., 1995), such an impact would be very unlikely. The probability of debris falling on a marine vessel or aircraft during Stage I or II failure is discussed in Section 4.1.2.3 of this document, and is calculated to be between 0.6×10^{-8} to 1.1×10^{-13}.[d]

4.1.2.3 Potential Failure During Upper Stage Flight Over the Ocean, Oceanic Islands, or South America

Possible failure during flight of the Upper Stage could conceivably occur at any point as the Upper Stage progressively transits over the open ocean, the Oceanic Islands, and the northern part of South America. Given the speed and altitude of the Upper Stage during this period, a failure during any point in Upper Stage flight would result in most of the material components and all of the propellants being heated in the atmosphere and vaporized or burned from frictional effects before reaching the Earth's surface. Approximately 42 components from the Upper Stage and payload could survive reentry friction and reach the Earth's surface. These objects range from 0.04 m (0.13 ft) to 1.2 m (3.9 ft in size, and 0.3 kg (0.7 lbs)) to 90 kg (205 lbs) in mass (see Table 4-5). The actual amount of debris that survives depends on the time of failure during the flight (i.e., more debris would survive a failure that occurs earlier during the flight).

As is the case for possible Stage I and II failures discussed above, a possible Upper Stage failure could occur as an explosion (where propellants in the Upper Stage suddenly combust) or a thrust termination (where acceleration ceases and the remaining ILV components begin to fall). In both types of failure scenarios, the hazardous materials associated with the Upper Stage, the satellite payload, and their connecting components would be rapidly consumed (in an explosion) or released and dispersed (as the ILV components tumble and break up in the fall to Earth). In this manner, only the ILV components that would survive the fall to Earth (Table 4-5) would affect the environment.

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[d] *Draft: Standard Geosynchronous Transfer Orbit Missions, Launch Operator License Application*, Document D688-10739-1, SLLP, October 2000.

TABLE 4-5. DEBRIS EXPECTED FROM UPPER STAGE AND PAYLOAD REENTRY

DM-SL Debris Surviving Re-entry			
Components	**Size** **m (ft)**	**Mass** **Kg (lb)**	**Area** **m^2 (sq. ft)**
Uncooled nozzle	1.2x1.0 (3.9x3.3)	12 (26)	1.2 (13)
Engine frame	0.4x1x1 (1.3x3.3x3.3)	14 (31)	0.4 (14)
Combustion chamber	0.14x0.25 (0.46x0.82)	13 (29)	0.035 (0.38)
Cooled nozzle	1x0.6 (3.3x2.0)	40 (88)	0.6 (6.6)
Turbo pump	0.75x0.25 (2.46x0.82)	31.5 (70)	0.188 (2.02)
Tank valves (2)	0.12x0.2 (0.39x0.66)	9 (20)	0.024 (2.6)
Submerged bottle	0.48 dia. (1.57)	16 (35)	0.18
Oxidizer supply unit	0.75x0.3 (2.46x1.0)	35.5 (78)	0.22 (2.46)
Gas generator	0.6x0.1 (1.97x0.3)	19 (42)	0.06 (0.59)
Batteries (6)	0.5x0.5 (1.6x1.6)	90 (205)	0.25 (0.59)
Fuel supply unit	0.4x0.2 (1.3x1.7)	25.5 (56)	0.08 (2)
Multiple start unit	0.365 dia. (1.197)	18 (40)	0.10
Bolts – titanium	0.04x0.014 (0.13x0.045)	1.5 (3.3)	0.0006 (0.006)
L-brackets – titanium	0.13x0.25 (0.42x0.82)	0.30 (0.7)	0.033 (0.34)
Payload Debris Surviving Reentry			
Liquid apogee motor	0.56x0.028 (1.84x0.09)	3.8 (8.4)	0.02 (0.2)
5-lbThrusters (12)	0.3x0.08 (1.0x0.26)	2.4 (5.3)	0.02 (0.3)
Battery (4)	0.52x0.5 (1.71x1.6)	73 (161)	0.26 (2.7)
Fuel tanks (4)	0.90 dia. (3.0)	60 (132)	0.63 (6.9)
Propulsion/ACS assembly (equip)	0.90 dia. (3.0)	58 (128)	0.63 (6.9)

Effects of Debris, Including Hazardous Materials, in Open Ocean

An Upper Stage failure has the potential to affect the open ocean, with the impacts being less than those described in Section 4.1.2.2 because most of the material components and all of the propellant would vaporize or burn. Only inert materials, such as durable metals in engine components and batteries, would reach the Earth's surface.

Several types of batteries (i.e., nickel-cadmium, nickel-hydrogen, and silver-zinc), are used in the Upper Stage payload unit, and they would fall to Earth during Stage I, Stage II, and Upper Stage failures. These types of batteries are widely used (e.g., consumer electronics) and are not unique to the space industry. The batteries contain relatively small volumes of potentially toxic chemicals, which would be released into the environment under the various failure scenarios. Specifically, batteries would either fall into the ocean if the batteries do not rupture during Stage I or II failure, or partially disperse in the atmosphere when ILV structures containing batteries rupture during Stage II or Upper Stage flight. In the latter situation, some portion of the battery material would fall to the Earth's surface.

Nickel-cadmium and silver-zinc batteries use potassium hydroxide as an electrolyte between the two metal plates in each battery. Potassium hydroxide is a very corrosive chemical (pH of 13.5). Once in contact with the ocean, an acid-base reaction would quickly occur that would form a potassium based salt, which is not toxic to the environment (Pankow, 1991). Any remaining potassium hydroxide would dissipate in the ocean since it is soluble in water. Nickel, zinc, and cadmium are naturally occurring metals found in trace amounts in ocean water (Eisler, 1998; Eisler, 1985). Silver is most commonly found deposited as a mineral ore, but as a result of various anthropogenic sources (e.g., smelting operations) is now commonly found in trace amounts in the open ocean (Eisler, 1996). The small amount of these metals present in the batteries would gradually disperse.

In the event of a failure during Stage II or Upper Stage flight, the batteries would rupture either from the explosion or from the frictional forces encountered in their descent. Although the battery casings would be expected to survive the reentry, the potassium hydroxide would likely vaporize and react with water vapor present in the atmosphere, again forming a non-toxic salt.

The overall effect on the open ocean from batteries and other surviving debris would be minor, as the hot to warm debris would immediately cool, sink, and come to rest on the ocean floor. An Upper Stage failure, however, also has the potential to impact Oceanic Islands (i.e., the Galapagos Island group, Malpelo Island, or Cocos Island) and the portions of South or Central America that are located within the ILL overlay area (see Figure 3-1). In the unlikely event of an Upper Stage failure, the potential impacts would be small but could include effects from debris falling on:

- Marine organisms,
- Coral reef communities,
- Terrestrial communities on oceanic islands,
- South American habitats, and
- Vessels, aircraft, or humans.

Each of these potential environmental effects is evaluated below.

Debris Impacting Marine Organisms

There is a very slight chance that Upper Stage debris may strike marine organisms. The effects associated with an Upper Stage failure would be less than that for a Stage I or II failure, because most of the components and all of the propellants would burn up or be vaporized before reaching the ocean surface; consequently, there would be less material available to fall on or affect marine organisms. In general, the population density of most marine organisms is low throughout much of the area of concern. The lack of microhabitats and decreased solar energy inputs at necessary water depths limits the diversity and density of marine organisms in the deep ocean (Rex, 1981). Seasonal migrations of Southern minke whales and sharks are relatively dispersed in the eastern Pacific Ocean while right, humpback, and gray whales migrate along the shore, congregate in nearshore breeding areas, and are rarely found in the open ocean (Kasamatsu, et al., 1995). There are, however, particular areas (such as near or on the Oceanic Islands and upwelling boundaries) where population densities would be more variable and potentially higher due to localized increased primary productivity attributable to nutrient and mineral levels (Barber, 1996). On the whole, however, the impact of debris alone falling on individual organisms would be negligible at the population level.

There is a remote possibility that debris may fall on a marine animal (e.g., whale, seal, or turtle) that is listed as a threatened or endangered species by the IUCN or USFWS (see Table 3-2). For the vast majority of the open ocean that constitutes the affected environment of the license applicant's proposed action, however, population densities of these species are very low; the probability of debris falling on one of these species is remote. Although their populations are generally higher near the oceanic islands and where upwelling occurs, they occupy a very small percentage of the surface area of the equatorial Pacific Ocean based on estimates of population sizes and survey data (Hill, et al., 1990). In addition, these species are highly mobile and occupy the ocean at varying depths. An individual would need to be at or near the ocean surface and within the impact zone (e.g., while breaching) to risk injury from falling debris.

Debris Impacting Coral Reef Communities

As described in Section 3.2.1.4, coral growths and reefs are relatively small, poorly developed, and of discontinuous distribution in the eastern equatorial Pacific Ocean. This is generally attributed to low water temperatures, low salinity, high nutrient loads, natural bioerosion, and storm disturbances. Nearshore steep slopes also limit the amount of area suitable for underwater coral platforms (Cortes, 1997). Cocos Island has the only relatively well-developed coral reef in the area affected by the license applicant's proposed action and it is, therefore, considered here in terms of possible impacts to coral.

The Cocos Island reef system would only be susceptible to damage in the Upper Stage failure scenario because Stage I and II failures would occur far to the west of Cocos Island. If an Upper Stage failure occurs during an overflight of Cocos Island, the probability of debris falling on the coral reef at Cocos Island is estimated to be 1.4×10^{-8}, based on a reef area of approximately 15 km^2 (5.8 mi^2) (see Figure 3-8). This calculation overestimates the true probability in that it assumes that the entire reef system area is densely filled with coral growths when it is actually discontinuous (Bakus, 1975). Further, corals near the Oceanic Islands of the eastern Pacific Ocean and off the western shore of Central America have undergone a dramatic decline in recent years, with large areas of coral dying or becoming diseased (Camoin and Davies, 1998).

Corals at Cocos Island are found from just below the water surface to depths of approximately 30 m (99 ft) (Bakus, 1975). Debris from a possible Upper Stage failure could strike an area of healthy coral and damage or dislodge the coral. Because the debris would quickly decelerate during its initial transit through the water, deeper coral areas would sustain less damage. Some inferences may be drawn on the potential effects of Upper Stage debris striking coral from studies in which coral were intentionally damaged by hammer strikes (Syms, 2000) or surficial scrapes (Hall, 1997). These corals showed relatively rapid commencement of recovery within a year or so, as did the associated reef communities. If the foundation platform is undamaged new growth would replace the dislodged coral within decades (Pearson, 1981; and Jaap, 1984). Bioerosion, which is naturally prevalent from time to time, would further jeopardize coral growth and reef recovery in such situations (Reaka-Kudla, 1996). In any event, the probability of debris striking coral reefs is remote.

Recovery from a possible failure that affects coral would require at least several years or more. Because of the discontinuous nature of the coral and the size of the predicted surviving debris is relatively small (see Table 4-5), damage from this failure scenario would be extremely unlikely, would remain very localized and would not threaten the reef system itself.

As discussed in Section 3.2.1.4, Malpelo Island and the Galapagos Islands have even more discontinuous, solitary coral growths with little reef development. Therefore, the risk of falling debris striking living coral reefs at these islands would be commensurately less than at Cocos Island. If coral at Malpelo Island or the Galapagos Islands were affected, the impacts to and recovery of individual coral would be comparable to those described here for Cocos Island.

Debris Impacting Terrestrial Communities on Oceanic Islands

There is also the potential for debris from a possible Upper Stage failure to land on an Oceanic Island (i.e., Malpelo, Cocos, or one of the Galapagos Islands) (see Table 4-6). The debris would be inert after being subject to the intense heat generated while re-entering the upper atmosphere. The surviving debris, which would cool during the descent through the lower atmosphere, is highly unlikely to be hot enough to pose a risk of fire. Of the islands involved, the Galapagos and Cocos Islands in particular have notable diversities in terrestrial plant and wildlife species, while Malpelo Island is steep and rocky with relatively less diversity or abundance in terrestrial plant or wildlife species.

As indicated in Table 4-5, approximately 42 components totaling less than 10 m^2 are predicted to survive reentry. The combined size of these components represent less than 0.0000001 percent of the land area of the Galapagos Islands, 0.0005 percent of Cocos Island, and 0.0006 percent of Malpelo Island. The chance of the debris striking a plant or animal is remote. If debris struck a terrestrial organism, however, it could be injured or killed. There is a remote chance that a threatened or endangered species could be hit by falling debris. In such an unlikely event, replacement in terms of population dynamics would depend on the species' abundance, reproduction characteristics, and recruitment success.[e]

The probability of debris landing on the Oceanic Islands would be very low (see Table 4-6), the risk of damage to an island habitat or harm to any individual member of a resident species would also be very remote, and any possible impact would be limited in extent. Taking Cocos Island as an example from Table 4-6, most azimuths within the range in the license applicant's proposed action would present virtually no risk of debris landing on Cocos Island. In fact, azimuths of 83.00° to 83.28° and 84.50° to 97.00° are far enough away from the island that their ILLs would not overlay it at all. Only with azimuths of 83.29° to 84.49° would the Upper Stage overfly or the ILL overlay Cocos Island, thus presenting a probability that should a failure of the Upper Stage occur, some debris might survive and fall on the island.

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[e] In this instance, recruitment success refers to the ability of one member of a species to convince another individual to behave in a desired manner.

TABLE 4-6. PROBABILITY OF UPPER STAGE DEBRIS FALLING ON AN OCEANIC ISLAND DURING A SINGLE LAUNCH

Oceanic Island	**Azimuth Associated With**			**Dwell Time[a] (sec)**	**Probability of Debris Falling on an Island**
	ILLs do not overlay island(s)	ILLs overlay island(s) but less than maximum dwell time	Island(s) directly overflown with maximum dwell time		
Galapagos Islands (as a group) [b]	82.6° to 87.47° and 92.22° to 97.4°			0	0.0[c]
		87.48° to 90.84° and 90.86° to 92.21°		Between 0 and 10.61	Less than 0.00067
			90.85°	10.61	0.00067
Cocos Island	82.6° to 83.28° and 84.50° to 97.4°			0	0.0
		83.29° to 83.89° and 83.91° to 84.49°		Between 0 and 0.15	Less than 0.0000094
			83.90°	0.15	0.0000094
Malpelo Island	82.6° to 85.07° and 86.36° to 97.4°			0	0.0
		85.08° to 86.04° and 86.06° to 86.35°		Between 0 and 0.03	Less than 0.0000019
			86.05°	0.03	0.0000019

[a] Dwell time can be considered the amount of time when the Upper Stage is over the island. More technically, it is the amount of flight time when the Instantaneous Impact Point (IIP) (based on a speed of 33,000m/s and a failure probability of 6.28×10^{-5}/sec) traverses the island.
[b] For Galapagos Islands (as a group), assumes debris would land on an island rather than in inter-island water.
[c] As a statistical concept, the probability cannot be zero.

In applying these data to the Galapagos Islands, which possess the greatest variety of habitat types and species among the islands considered in this EA, some general observations can be made. Extensive parts of the islands are very arid and devoid of vegetation or much soil; this is especially true of the steep flanks and young lava flows that usually extend to the sea from the numerous volcanic peaks and ranges. Also dominant on the islands are extensive areas that, while very arid, are more moderate or level in slope, which allows established soils to support desert vegetation including cactus, brush, and grasses. Also present, but less common, are relatively moist areas marked by lush grasses and trees. Most fauna are concentrated near the sea or in the moist habitats due to their reliance on associated nutrients.

Debris could directly fall on resident reptiles, birds, or mammals, or damage habitat due to the initial force of contact. Such debris impacts could damage vegetation, cause cracks and depressions in harder material (e.g., volcanic rock), or lodge into softer material (e.g., soil) on a semi-permanent basis. No scientific studies were found specific to this scenario relative to the Galapagos Islands; however, recovery following severe events (e.g., hurricanes, logging, and poor farming practices) in tropical regimes were studied in other parts of the world. These reports indicate that vegetation in moist to arid regimes would recover from these more severe conditions over a few years to decades, respectively (Mack, 1998; Kuerpick, 1997; Boucher, 1997; Living Earth, 2001; and Donfack, 1995). In light of habitat recoveries in these extreme situations, and given the significantly smaller impact that could possibly occur during a failure of the Upper Stage, it may be inferred that any damage to the islands' habitats would be minor and short-term.

When a launch vehicle uses the 83.90° azimuth it directly overflies Cocos Island with the greatest dwell time (which is described as the amount of time the Upper Stage flies over the island). For this azimuth the potential for damage from surviving debris reaching Cocos Island is the greatest, however there is a probability of only 0.0000094 that damage would occur from a failed launch.

For Malpelo Island, there is a similar effect from the possibility of debris impacting the island environment. Azimuths of 82.6º to 85.07º and 86.36º to 97.4º are far enough away that ILLs for these flightpaths would not overlay the island. The 86.05º azimuth corresponds to the flight path with the greatest dwell time directly over Malpelo Island (i.e., 0.03 sec), and that corresponds to a probability of 0.0000019 that some debris might survive and fall on the island should there be a failure during Upper Stage flight.

For the Galapagos Islands—taken as a group—azimuths of 82.6º to 97.47º and 92.22º to 97.4º are far enough away so that ILLs for these flight paths would not overlay the islands or the 40-mile marine sanctuary surrounding the islands. The 90.85º azimuth corresponds to the flight path with the greatest dwell time (i.e., 10.61 sec) over several islands as well as inter-island water. This azimuth corresponds to a probability of 0.00067 that some debris might survive and fall on one of the Galapagos Islands or in the surrounding inter-island waters, should there be a failure during Upper Stage flight.

To provide some context to the remoteness of the probabilities being discussed above, the following probabilities have been reported (for U.S. citizens on an annual basis):

- the probability of a coal miner or farmer dying on the job is 0.0004,
- the probability of drowning is 0.00002,
- the probability of dying from a bicycle accident is 0.0000077, and
- the probability of being killed by lightning 0.0000005 (Laudan, 1994).

Debris Impacting South American Habitats

The probability of Upper Stage debris falling on South America (as well as a small portion of Panama) is very low. As indicated above, during a possible Upper Stage failure, approximately 42 components representing a combined surface area of 10 m^2 could survive reentry. Most debris would burn or vaporize in the atmosphere as it falls from an altitude of approximately 180 km (110 mi), and would, therefore, not affect either Central or South America. The surviving debris would be subjected to the intense heat generated while re-entering the upper atmosphere and would cool during the descent through the lower atmosphere. As such, it is highly unlikely that surviving debris could present a fire hazard.

The probability of debris falling on Central or South America is related to the amount of time the Upper Stage is over the area, which varies with the azimuth of the launch, but ranges between 25 and 44 seconds[f] (see Table 4-7).

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[f] These dwell times are associated with the heaviest anticipated payload (i.e., 6,100 kg or 13,420 lbs). Lighter payloads would result in shorter dwell times.

TABLE 4-7. UPPER STAGE AZIMUTHS OVER SOUTH AMERICA AND POPULATION CENTERS

Launch Azimuth (degrees)	Dwell Time for Continental overflight (sec)]	High Population[a] Density (per km^2)	Low Population Density (per km^2)	Cities Overflown (Populations Over 50,000)
083	25	207.22	0	Bucaramanga, Georgetown
084	27	207.22	0	Medellin, Puerto Ayacucho, Paramaribo
085	29	422.22	0	Pereira, Bogota, Cayenne
086	30	178.56	0	Buenaventura
087	30	44.30	0	Neiva, Boa Vista
088	32	44.30	0	Tumaco, Florencia
089	34	95.38	0	Esmeraldas, Ipiales, Mitú
090	37	131.16	0	Quito, Macapá
091	39	131.16	0	Manta, Portoveijo
092	40	211.47	0	Guayaquil, São Luís
093	39	874.36	0	Manaus, Fortaleza
094	43	88.14	0	Loja, Iquitos
095	44	117.55	0	Piura, Teresina, Mossoró
096	43	45.82	0	Imperatriz, Natal
097	42	289.72	0	Chiclayo, João Pessoa

[a] The data in Table 4-7 are calculated by using the 1° x 1° grid data from the *Carbon Dioxide Information Analysis Center* (CDIAC) database.

Though remote, the chance of damage to plants, animals or the habitat from falling debris would be due solely to the initial force of contact (e.g., a stricken animal or damaged vegetation). If debris falls on an animal, that animal could be injured or killed; however, the probability of such an event is estimated to be on the order of one in one million, or 1×10^{-6}. The potential for long-term harm occurring to a regional habitat from falling debris would be minimal, and the recovery of damaged areas would occur through re-colonization by neighboring species or replacement by the larger population over a period of months or years.

Over much of the affected portion of South and Central America, the predominant ecosystem is tropical rain forest (see Figure 3-10). Since Upper Stage debris would at most cause a few isolated impacts (e.g., broken limbs) to widely spaced trees or similar foliage, recovery from such damage would occur relatively rapidly (i.e., on the order of months), although it may not completely return to pre-impact conditions for a number of years (Kuerpick, 1997; Boucher, 1997; Living Earth, 2001; Mack 1998; Westy 2000; and Donfack, 1995). The majority of nutrients and natural resources in the tropical rain forest is typically found in the dense vegetation and canopy, and not in the soil. Any damage to the canopy or vegetation would affect these nutrients by temporarily removing them from the vegetative growth cycle, however these impacts are expected to be negligible. In the western lowlands and the more rocky mountainous areas of the continent, less vegetation is present to be damaged; however, recovery times would be much longer (i.e., several years or more) given the less fertile substrate and conditions for new growth. Nevertheless, any impact is expected to be negligible from this scenario on these receptors.

Debris Impacting Vessels, Aircraft, or Humans

An Upper Stage failure could also pose a small risk to vessels, aircraft, and humans. As described in Section 3.2.1.6 of this EA, shipping and aircraft traffic in the affected environment is relatively low, though traffic does increase closer to the coast of South and Central America. Conversely, the probability of Upper Stage debris falling on a vessel or aircraft diminishes as the Upper Stage approaches the coast of South America because as the altitude and speed of the Upper Stage increase, the impact window becomes smaller and more debris is burned up during descent.

The probability of debris from a mission failure falling on a person in an affected portion of Central and South America is also generally low and must satisfy FAA safety standards for SLLP to receive a license.[g] Based on the population densities calculated in Table 4-7, SLLP estimates the risk of debris falling on a person in the affected portions of Central and South America to be between 1.18×10^{-6} (corresponding to an 88^{o} azimuth) and 3.26×10^{-6} (for a 93^{o} azimuth).[h] The FAA has not yet conducted its review of SLLP's estimates for licensing purposes for the LOL. Although the FAA will be conducting a more detailed review of these estimates in its safety analysis through the licensing process, as estimates, they are considered the best information currently available, are not unreasonable and can be relied upon for the purposes of analyzing potential environmental impacts.

Summary of Possible Failure Scenarios and Impacts

Table 4-8 summarizes the possible failure scenarios and their potential environmental consequences.

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[g] The FAA's standard is based on the expected casualty rate (E_c), which is a function of dwell time, population density, and impact size. FAA's standards for an acceptable E_c is 30×10^{-6} or less.

[h] 1.18×10^{-6} corresponds to a chance of one in 847,000 of debris falling on a person, this is similar to the one-year odds of drowning in a bathtub. 3.26×10^{-6} corresponds to a chance of one in 306,000 of debris falling on a person, this is similar to the one-year odds of being struck and killed by a falling object.

TABLE 4-8. SUMMARY OF FAILURE SCENARIOS AND ASSOCIATED ENVIRONMENTAL IMPACTS

Failure Scenarios	Impact Area	Failure Rate	Potential Environmental Impacts
During initial Stage I Flight	Launch region	3 x 10^{-18}/sec (one in 30 trillion)	• ILV impacts open ocean virtually intact (Thrust Termination Failure), or in pieces (Explosive Failure) • Maximum quantity of propellants (e.g., kerosene) released and dispersed in the topmost ocean layer • Inert ILV fragments settle on ocean floor • Very low probability of debris falling on vessels (fishing, shipping, or air traffic) or marine organisms
During Stage I Flight	Downrange area of 800 km (500 mi)	26.94x 10^{-5}/sec (one in 3,700)	• ILV (less most Stage I propellants) impacts open ocean after tumbling and fragmentation or explosion • Propellants (e.g., kerosene) released and dispersed in atmosphere through evaporation, residual reaching the topmost ocean layer (or combustion if Explosive Failure) • Inert ILV fragments settle on ocean floor • Very low probability of debris falling on vessels (fishing, shipping, or air traffic) or marine organisms
During Stage II Flight	Downrange area beyond 4,600 km (2,900 mi)	28.65x 10^{-5}/sec (one in 3,450)	• Fragments of the ILV (less Stage I) surviving descent, impact open ocean • Propellants (e.g., kerosene) released and dispersed in atmosphere through evaporation, no propellant expected to reach the topmost ocean layer • Inert ILV fragments settle on ocean floor • Very low probability of debris falling on vessels (fishing, shipping, or air traffic) or marine organisms
During Upper Stage Flight Over Ocean Waters	Downrange area beyond 4,600 km (2,900 mi) affecting shipping	6.28 x 10^{-5}/sec (one in 15,800)	• Fragments of the Upper Stage (ILV less Stages I and II) surviving descent, impact open ocean • Propellants (e.g., kerosene) released and dispersed in atmosphere through evaporation, no propellant expected to reach the topmost ocean layer • Inert ILV fragments settle on ocean floor • Low probability of debris falling on vessels (fishing, shipping, or air traffic) or marine organisms
During Upper Stage Fight Over an Oceanic Island	Potentially populated areas	6.28 x 10^{-5}/sec (one in 15,800)	• Fragments of the Upper Stage surviving descent, impact terrestrial ecosystems or shallow, near-island ocean • Propellants (e.g., kerosene) released and dispersed in atmosphere through evaporation, no propellant expected to reach the ocean or land • Low probability of debris falling on vessels (fishing, shipping or air traffic) or on land or marine organisms
During Upper Stage Flight in vicinity of Panama Canal shipping	Western approaches to Panama Canal affecting shipping	6.28 x 10^{-5}/sec (one in 15,800)	• Fragments of the Upper Stage surviving descent, impact terrestrial ecosystems or coastal area • Propellants (e.g., kerosene) released and dispersed in atmosphere through evaporation, no propellant expected to reach the ocean or land • Low probability of debris falling on vessels (shipping) or land or marine organisms
During Upper Stage Flight Over South America	Potentially populated areas	6.28 x 10^{-5} /sec (one in 15,800)	• Fragments of the Upper Stage surviving descent, impact terrestrial ecosystems • Propellants (e.g., kerosene) released and dispersed in atmosphere through evaporation, no propellant expected to reach land • Low probability of debris falling on plants animals or people

4.1.3 Cumulative Impacts

Cumulative impacts to the environment result from incremental effects of the license applicant's proposed action or other alternatives when considered in combination with other past, present, and reasonably foreseeable future projects in the area. Cumulative impacts can result from minor, but collectively substantial, actions undertaken by various governments and U.S. agencies (Federal, state, and local) or by individuals. NEPA[i] requires the assessment of cumulative impacts resulting from all projects that are proposed, under construction, recently completed, or expected to be implemented in the near future.

The FAA is not aware of any past, present or reasonable foreseeable future projects in the area. Therefore, this EA focuses on the cumulative impacts associated with the proposed eight SLLP launches per year for five years, or a maximum of 40 launches, over the broader range of azimuths of the license applicant's proposed action. Section 4.6 of the February 11, 1999 EA evaluated the cumulative effects associated with up to six launches per year along a single azimuth. The February 11, 1999 EA concluded that SLLP operations at the proposed launch site, during launch, at the Home Port, and other connected actions including transport to and from the Home Port, would cause only insignificant and temporary impacts to the environment.

In general, all of the potential environmental impacts of the license applicant's proposed action would occur on a regional scale. No larger global impacts are expected to occur, mainly because of the small amounts of debris, hazardous material, and atmospheric emissions produced by the ILV relative to other anthropogenic activities (e.g., power generation and the scale of natural processes in the Pacific Ocean).

The potential cumulative effects for each phase of the launch operation are discussed below.

4.1.3.1 Home Port

The license applicant's proposed action differs from the February 11, 1999 EA in that it would involve eight launches per year. Other than the increase in the number of launches requiring processing, operations at the Home Port would be the same as those evaluated in the February 11, 1999 EA. The higher rate of throughput of both payload processing and marine vessel activity would remain within the capacity and regulatory approvals of all Home Port facilities, which were designed by SLLP to handle eight launches per year. Additional launches would generate more solid and hazardous waste material requiring disposal, although this increase may be offset by more efficient use of inventories (and less material being disposed of because it has expired). Home Port is allowed to store waste up to 90 days in its Central Hazardous Waste Accumulation area.

The Navy Mole facility, where the Home Port is located, is currently underutilized as compared to past levels of operation and development. The Navy Fuel Depot and the U.S. Department of Transportation Maritime Administration currently use the Navy Mole facility as well. It is planned that, in time, the former Navy facility will become part of the Alameda corridor, which is a rail transit system which moves containers from shipyards to railroad distribution points in Los Angeles. The additional launches would not place a significant burden on the Home Port's workforce or equipment; rather, the license applicant's proposed action would be expected to have a slight beneficial cumulative effect on socioeconomic conditions in the Home Port area through increased payrolls and material expenditures. Scrubber filters were installed at the Home Port facility to prevent UDMH vapors from escaping the building. Therefore, the license applicant's proposed action would have no adverse cumulative effects on the Home Port area.

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[i] This document is being developed based on the requirements of E.O. 12114, the implementation of which is guided by NEPA.

4.1.3.2 Pre-Launch

Transit of the LP and ACS from Home Port to the launch site would be like any normal maritime shipping and would be subject to U.S., United Nations (UN), and other international rules and regulations. The vessels carry and must comply with the following certificates:

- Safety Construction Certificate (per International Convention for the Safety of Life at Sea (SOLAS), 1974, as modified by Protocol 1988),
- International Load Line Certificate (per International Convention on Load Lines, 1966 as modified by Protocol of 1988),
- International Oil Pollution Prevention Certificate (per International Convention for the Prevention of Pollution from Ships, 1973, as modified in Protocol 1978 and Resolution MEPC.39(29),
- Mobile Offshore Unit Safety Certificate (per Code for the Construction and Equipment of MODUs),
- Safety Equipment Certificate (per SOLAS 1974, as amended 1988),
- Certificate of Compliance for Prevention of Pollution by Sewage From Ships (per Annex IV of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by Protocol of 1978),
- Certificate of Compliance ILO No. 92 and 133 - Crew Accommodation (per International Labour Organization (ILO)), and
- International Tonnage Certificate (per International Convention of Tonnage Measurements, 1969).

The ships are further required to operate in compliance with the regulations of

1. The Government of The Republic of Liberia and carry the following certificates issued by Flag State:
    - Liberian Certificate of Registry
    - Liberian Ship Radio Station License
    - Liberian Minimum Safe Manning Certificate (per International Convention on Standards of Training, Certification and Watchkeeping, 1978, Resolution A.481(XII))
    - Liberian Special Purpose Ship Safety Certificate (per IMO Resolution A.534(13), Code of safety for Special Purpose Ships)
    - Liberian Self Propelled Mobile Offshore Unit Minimum Manning Scale for Marine Personnel

and

2. USCG Pollution Regulations Foreign Vessels, CFR Title 33 Part 155 and 159, and carry
    - Department of Transportation, USCG Vessel Certificate of Financial Responsibility (COFR), and
    - The State of California, Department. of Fish and Game, Certificate of Financial Responsibility.

The two additional round-trip transits by the ACS and LP per year would not contribute significantly to marine vessel traffic on the Pacific Ocean. Normal ACS ship wastes, including food waste, generated onboard are handled in accordance with the International Convention for the Prevention of Pollution (in compliance with MARPOL 73/78). All other solid waste is stored onboard and properly disposed of at the Home Port. Hazardous waste is accumulated onboard in hazardous waste accumulation areas and lowered to the pier at the Home Port when the vessels return. Waste is then taken to the Central Accumulation Area and disposed of in accordance with local, state, and Federal regulations. Therefore, the proposed vessel operations would cause no significant cumulative effects.

Upon arrival at the launch location, pre-launch operations would only involve final equipment and process checks, coupling of propellant loading lines to the ILV, transfer of kerosene and LOX, and the decoupling of the loading lines. The only aspect of pre-launch operations that poses any potential environmental impact would be propellant loading of the ILV. However, standard propellant operations are expected to result in no loss of kerosene or LOX other than an incidental loss of vapors from the fluid connections, which would dissipate immediately. These propellants are volatile materials and any small amount released to the atmosphere would dissipate shortly thereafter resulting in no cumulative effects. LOX released to the environment during pre-launch loading would instantaneously vaporize upon being exposed to ambient pressure and temperature. Almost 95 percent of any kerosene released during pre-launch loading, which reaches the ocean, would evaporate within a few hours in the tropical conditions observed at the LP. The remaining 5 percent would be dispersed due to turbulence in the top few meters/feet of the ocean and then degraded to CO_2 and H_2O through photochemical oxidation and microbial degradation within days of the initial release (Doerffer, 1992; National Research Council, 1985; Rubin, 1989; ITOPF, 2001; and EPA, 1999). Accordingly, the ocean environment would return to pre-launch conditions within a day or so of these possible effects. Section 4.1.2.2 above discusses the impact of kerosene on marine communities.

In the open ocean, fish and marine mammals are not likely to be harmed by the small amount of kerosene released during pre-launch operations for several reasons:

- As mentioned above, SLLP would not initiate the launch if any whales or sea turtles were detected in the vicinity of the LP (during the visual observation period prior to launch).
- Relatively few fish or marine mammals are located in this region of the Pacific Ocean.
- Kerosene (in the amounts that would possibly be released during normal pre-launch operations) would disperse and degrade within hours of the release, which would minimize potential exposure to marine organisms until the next launch, in roughly 45 days.

Therefore, no cumulative effects are expected from this short term and highly localized impact. Based on the license applicant's proposed action, pre-launch operations would cause no cumulative impact.

4.1.3.3 Launch

Repeated launches over the Pacific Ocean present the potential for cumulative impacts, which may be one of two types:

- Effects of debris blown into the ocean, and
- Effects of heat and noise on marine mammals.

Potential Cumulative Effects of Debris Blown into the Ocean

The launch may blow some scattered debris into the ocean, although experience from SLLP launches to date has resulted in little to no material being lost. Should debris be lost, it would primarily be pieces of insulation or other hardware used to shield the LP during launch. The LP is continually hardened and improved to reduce the probability of such damage in the future. To date, only small, nonmetallic covers on the fairing vents have been lost to the ocean during launch. Because these material inputs would be small in volume and inert, they would sink to the ocean floor or otherwise cause little disruption or impact to the ocean ecosystem. Deck washing and repainting would not cumulatively affect the environment since this maintenance activity would occur on the deck of the LP with any waste put into containers for proper disposal at the Home Port. Although the increase in the number of flights would possibly result in more debris entering the ocean environment, the volume of material would remain very small relative to the scale of the east central Pacific Ocean.

Potential Cumulative Effects of Heat and Noise on Marine Mammals

The energy from heat and sound at launch would have only a momentary impact on the ocean, and would be dissipated within minutes, leaving no lasting or cumulative impact (see Section 4.1.1.2). In terms of heat, a freshwater spray would be used to reduce the energy and heat generated during the launch through evaporation. The ocean surface would deflect and absorb (through evaporation) any additional thermal energy. Increases in ocean temperature would be very localized, minimal, and of short duration with no significant adverse effects on marine organisms, which are primarily concentrated at some depth away from the intense tropical solar energy.

In terms of noise, the steady noise from pre- and post-launch operations (e.g., from ship engines) may reach approximately 70 dB. Research indicates, however, that this level of steady noise would not have a detrimental affect on any animal that would linger in the area (Shulhof, 1994; Richardson, et al., 1997). Each launch, in turn, would be a separate isolated incident lasting less than one minute, with approximately 45 days elapsing between events.

No significant noise impacts would be expected from the launch because of the relatively low level and short duration of launch noise, and the unlikely, continual presence of the higher trophic level organisms near the launch site. After each launch, the ambient noise levels and the local and transient biological communities would return to normal conditions within minutes. Accordingly, no cumulative effects are expected from this short term and highly localized impact.

4.1.3.4 Potential Cumulative Effects of Successful Flights Over the Open Ocean, Oceanic Islands, and South America

The potential cumulative effects of 40 successful flights over a five-year period would include:

- Spent stages and the fairing falling to the ocean,
- Residual propellants from the spent stages released to the ocean and atmosphere, and
- Emissions being released to the atmosphere.

It should be noted that although the license applicant's proposed action includes launches on a range of azimuths from 82.6º to 97.4º, actual flights would likely be along a narrower band of azimuths. Specifically, market forecasts indicate the majority of SLLP payloads would be medium-to-heavy geosynchronous earth orbit (GEO) satellites. Thus, SLLP customers would primarily want an equatorial or near-equatorial azimuth (within an approximate range of 88.5º to 91.5º) for their satellites.

Accordingly, cumulative impacts from successful missions for forecast manifests over the five years of the license applicant's proposed action have been assumed along a concentrated area of the open ocean (i.e., into smaller spent stage deposition areas especially along the equator) as the worst case. Since the EA considers launches within the full range of proposed azimuths the cumulative effects of impacts discussed in this section for successful missions are also applicable for any distribution of launches throughout the proposed range 82.6º to 97.4º. The cumulative impacts of successive failed missions are considered in Section 4.1.3.6.

Potential Cumulative Effects of Spent Stages and Fairing Debris, Including Hazardous Materials

Stage I, fairing, and Stage II debris from each launch would fall into the equatorial Pacific Ocean. Of all the potential cumulative impacts listed above for successful launches, the stage and fairing debris would be the only launch byproduct that would remain in the environment for a long period of time. Stage I would be expected to occasionally break up upon descent, while Stage II is expected to always break up during its descent from a high altitude. These objects would cool almost immediately upon reaching the water surface, and with the exception of the fairing pieces, would sink to the ocean floor immediately. The stage debris would be composed primarily of aluminum, steel, and graphite composite components, some incorporated with various plastic, ceramic, and rubber parts. These components are largely inert and would have no long-term direct effect on the ocean ecosystem. Fairing pieces are relatively large and solid but lightweight sheets of composite material. Based on the launch industry's experience with composite fairings, the two halves of the SLLP fairing would break up into a number of rigid pieces that would initially float, but gradually become waterlogged and eventually sink to the ocean floor.

From a cumulative impact perspective, the increase in the number of launches would introduce more debris into the equatorial Pacific Ocean in the debris deposition areas. The amount of this debris, however, is negligible when compared to the expanse of the equatorial Pacific Ocean. To evaluate cumulative impacts, a worst case scenario would be that all 40 launches over a five-year period would use the same azimuth. This hypothetical scenario further assumes that the deposited stage and fairing debris do not overlap (i.e., the flattened stage debris sinks to the bottom of the ocean without overlapping with previously deposited stage debris). In such a scenario, only 0.00015 percent of the ocean floor in the impact zones (see Table 4-1) would be affected by the 40 launches. Even with this hypothetical worst case scenario, the resulting impact to the regional seafloor would be insignificant.

In addition, the ocean depths in the Stage I, fairing, and Stage II impact zones are over 2,000 m (1.2 mi), where marine population densities are relatively low. This debris may potentially provide a benefit in the form of new habitat, which could harbor ocean-floor life forms in much the same way as sunken ships in nearshore areas provide new protective habitat for colonization (Chou, et al., 1991).

Potential Cumulative Effects of Residual Propellants Released from the Spent Stages to the Ocean and Atmosphere

The Stage I fuel tanks may rupture prior to impact with the ocean surface, while Stage II tanks would likely always rupture prior to impact. Any residual kerosene that leaks or is released from the tanks during descent would evaporate. The residual kerosene (up to 2,750 kg, or 6,050 lbs, or 760 gallons per mission) remaining in the Stage I fuel tanks that remain intact during descent, would be released to the ocean surface upon impact. For a maximum of eight launches per year, an annual total of 22,000 kg (48,400 lbs or 6,080 gallons) of residual kerosene would be released. Under worst-case conditions (i.e., assuming 40 launches over five years with all fuel tanks rupturing upon impact on the ocean surface), approximately 110,000 kg (242,000 lbs or 30,400 gallons) of residual kerosene would potentially be released to the open ocean. During each launch, the kerosene would evaporate and degrade relatively quickly. Specifically, almost 95 percent of any kerosene released from spent stages would evaporate and be dispersed as smog by reacting with solar energy. This smog would dissipate in the environment with little to no impact. The remaining kerosene on the ocean surface would be dispersed by turbulence in the top few meters of the ocean, and be degraded to CO_2 and H_2O through photochemical oxidation and microbial degradation within days of the initial release (Doerffer, 1992; National Research Council, 1985; Rubin, 1989; ITOPF, 2001; and EPA, 1999). Therefore, the release of kerosene will not result in a cumulative effect because it will evaporate and dissipate in the environment.

LOX released to the environment as the spent stages break up during descent or on the ocean surface would instantaneously vaporize upon being exposed to ambient pressure and temperature. Accordingly, the ocean environment would essentially return to pre-launch conditions within a few days and before the next launch would occur (45 days later under the license applicant's proposed action).

Section 4.1.2.2 discussed the impact of kerosene on marine communities. In the open ocean, fish and marine mammals would not likely be harmed by the small amount of kerosene released from the rupture of Stage I fuel tanks for several reasons:

- Relatively few fish or marine mammals are located in this region of the Pacific Ocean.
- Kerosene would disperse and degrade within hours to days of the release, which would minimize potential exposure to marine organisms until the next launch, in roughly 45 days.

Considering the recovery time of the marine environment following the particular impacts of any single successful launch (i.e., several days as discussed above), and the time between launches (on the order of 45 days), impacts from propellant reaching the ocean would be short term and not evident by the time the next launch would occur. Therefore, no significant cumulative impacts are expected from released propellants.

Potential Cumulative Effects of Emissions to the Atmosphere

The proposed launches would affect the atmosphere as the LV engines burn propellants, with the associated generation of gas, vapor, and particulate matter emissions. Further the passage of the ILV through the atmosphere will create a short-term hole in the atmosphere. Table 4-9 shows the propellant profile for an individual launch, the annual total fuel profile assuming eight launches per year, and the cumulative total propellant profile assuming 40 launches over five years.

TABLE 4-9. ILV PROPELLANT PROFILE*

Propellant	Single Launch (kg (lbs))	Annual Total (8 Launches) (kg (lbs))	5-Year Total (40 Launches) (kg (lbs))
LOX	304,577 (670,069)	2,436,616 (5,360,555)	94,464,640 (207,822,208)
Kerosene**	117,048 (257,505)	936,384 (2,060,045)	37,455,360 (82,401,792)
N_2O_4/MMH/UDMH	95 (210)	760 (1,672)	30,400 (66,880)

*Does not include payload propellants.
** Data on the various types of kerosene under consideration can be found in Appendix E.

Total annual and cumulative (i.e., from 40 launches) emissions by altitude are provided in Table 4-10. The transit time for the ILV to go from launch through the troposphere and stratosphere is 120 to 140 seconds. This transit time is the basis for determining emission quantities at various altitudes.

TABLE 4-10. TOTAL ANNUAL EMISSIONS FOR EIGHT LAUNCHES AND CUMULATIVE

Atmospheric Layer	Altitude* Range (km (mi))	Annual Propellant Consumed (kg (lbs))	Annual Emission Products Assuming Eight Launches in kg (lbs)				
			CO	CO_2	H_2	H_2O	N_2
Lower Troposphere	0.0-2.0 (0.0-1.2)	493,712 (1,086,166)	136,264 (299,781)	215,256 (473,563)	3,456 (7,603)	138,736 (305,219)	0
Free Troposphere	2.0-10.0 (1.2-6.2)	552,800 (1,216,160)	152,576 (336,667)	241,024 (530,253)	3,872 (8,518)	155,336 (341,739)	0
Stratosphere	10.0-51.0 (6.2-32)	1,270,648 (2,795,425)	350,696 (771,531)	554,000 (1,218,800)	8,896 (19,571)	357,056 (785,523)	0
Mesosphere and Thermosphere	51.0-292 (32-182)	997,576 (2,150,667)	271,896 (598,171)	444,064 (976,940)	7,928 (17,442)	273,808 (602378)	290 (640)
	Annual (8 Launches) Total	3,314,736 (7,248,418)	911,432 (2,009,156)	1,454,344 (3,199,110)	24,152 (53,134)	924,936 (2,034,859)	290 (640)
	Cumulative 5-Year (40 Launches) Total	16,573,680 (36,242,090)	4,557,160 (10,045,780)	7,271,720 (15,995,550)	120,760 (265,670)	4,624,680 (10,174,295)	1,450 (3,200)

* Altitude ranges are rounded to the nearest km.

Most emissions would be caused by operation of the Stage I and II engines; smaller quantities of Upper Stage and payload propellants would be expended beginning at approximately 112 km (70 mi) and 35,000 km (22,000 mi) into the flight, respectively, the latter occurring beyond the range of potential atmospheric impacts. During normal Stage I operation, the emissions would be distributed throughout the trajectory in the lower layers of the atmosphere. Stage I separation occurs at an altitude of approximately 70 km (44 mi). Releases from Stage II would occur well above the stratosphere (approximately between altitudes 70 to 190 km [43 to 118 mi]). In addition, emissions are likely to dissipate within a matter of days to weeks. Recently, a consolidated aerosol cloud was observed intact, nine to 12 days after a launch vehicle, using a kerosene-LOX propellant system, was launched in Central Asia (Newman, et al., 2001).

The chemical compounds released during any combustion are thought to contribute to several types of atmospheric environmental impacts, including global warming, acid rain, ozone layer destruction, and photochemical smog. Although CO_2 is a possible contributor to global warming, the amount released by the ILV is not significant compared with the estimated amount of CO_2 cycled at the ocean surface in this region.[j] Estimates of net annual CO_2 flux (from the ocean to the atmosphere) in the area of the launch site are one billion kg (2.2 billion lbs) per 1° latitude/longitude square (Takahasi, et al., 1997). The 215,256 kg (473,563 lbs) predicted to be released annually by SLLP operations within the first two km of altitude represent an increase of 0.02 percent over natural emissions within the same 1° latitude/longitude square. Solar convection mixes the CO_2 inputs from launch and natural sources such that the effect from launch emissions would be assimilated within hours, long before the next launch would occur.

Global warming and ozone depletion would be cumulative effects of the license applicant's proposed action (see Section 4.1.1.2). However, the contribution of these emissions is negligible when compared to

[j] In this region, the primary source of CO_2 is from the ocean air-water interface.

other global sources, natural or man-made. There do not appear to be any specific thresholds for CO_2 in this region and therefore, specific comparisons cannot be made between the potential cumulative effects of the license applicant's proposed action and local thresholds.

The greatest risk for adverse atmospheric impacts due to ILV emissions would be in the area of ozone layer destruction. The ILV does not release chlorine or chlorine compounds (which contribute to ozone destruction) in or below the stratosphere, and the SLLP impact in this regard would not be significant. While chlorine and chlorine compounds are not the sole contributors to ozone destruction - they are a major source because they are ozone destructors rather than simply acting as precursors to ozone depleting substances.

4.1.3.5 Post-Launch

After a successful launch, the crew would reoccupy and clean the LP in preparation for transit to the Home Port. The cleaning operation includes collecting any debris left on the LP, freshwater washing of residues (i.e., scorched, carbonized paint), and repainting the deck of the LP. This waste is put into containers and sent back to Home Port for proper disposal

Based on prior launch experience, little to no debris is typically left on the LP; this has included some damaged insulation that was used to protect equipment from the intense heat. Any debris would be collected and handled onboard as solid waste for later disposal at Home Port. The debris, at the maximum, would total approximately 50 kg (110 lbs) per year (assuming eight launches), or 250 kg (550 lbs) for the proposed five-year period (assuming a maximum of 40 launches). This amount of solid waste is insignificant and would not present any adverse cumulative effects as part of the overall waste stream managed when the vessels return to the Home Port.

4.1.3.6 Cumulative Effects of Multiple Launch Failures in a Single Year in the Same Area

From a cumulative impact perspective, the most significant adverse environmental effect associated with the license applicant's proposed action would be multiple launch failures in a single year along the same azimuth in close proximity to one another. In considering a scenario that would result in a worst-case cumulative impact, two consecutive failures that affect the same geographic area are evaluated. Considering more than two consecutive mission failures, however, is not a practical consideration since such a circumstance would severely challenge the continued viability of the SLLP launch concept.

Time Period Between Launches Following a Failure for An Investigation

Following a launch failure, for both commercial and safety reasons, launches would not resume until the cause of the failure is determined and corrected to the satisfaction of the FAA and SLLP. Considering multiple, successive failures as a hypothetical worst case, given the mandatory investigation process and for the reasons discussed below, the two successive failures would occur many months apart.

Any future SLLP mission failure would be followed by a mandatory FAA investigation lasting at least four and perhaps as much as 12 months before another mission would occur. The FAA conducted a failure investigation following the SLLP Mission 3 failure, which occurred on March 12, 2000. In this case the cause was established within 40 days and the entire investigation was completed within four months. This is atypical for the launch industry in which investigations can take up to 12 months to complete, with a return-to-flight occurring sometime later.

Cumulative Effects of Two Successive Failures in the Same Area

In the context of two successive failures along the same azimuth or in close proximity to one another, there are several failure scenarios that would affect different portions of the environment (i.e., the ocean, Oceanic Islands, Central or South America). These are discussed below.

Possible Failure Scenarios that could have Cumulative Effects on the Ocean

There are several possible failure scenarios that could cumulatively affect the ocean environment:

- Launch abort just prior to launch,
- Thrust termination failure, and
- Explosive failures.

A launch abort just prior to launch occurred during the SLLP Mission 6 launch planned for January 8, 2001. No hazardous materials or propellants were observed contacting the ocean surface and fewer emissions were released to the atmosphere than would occur under a successful launch because less of the propellant was combusted (see Section 4.1.2.1 for more detailed description). Therefore, this abort scenario would not have any significant direct or cumulative effects.

The thrust termination and explosion scenarios represent true mission failures and could possibly occur at the LP (explosive failure only) or at any point during Stage I, II, or Upper Stage flight over the ocean. Upper Stage failure could also occur over the Oceanic Islands or Central or South America and is described below. As analyzed in Section 4.1.2.2 above, thrust termination failure during the first 20 seconds of flight would likely result in the ILV falling intact and rupturing on the ocean surface thereby releasing nearly all of the ILV's propellants and hazardous materials directly to the ocean. This is considered the worst-case failure scenario. Of the explosive failure scenarios, an explosive failure at the LP would have the most significant effects on the ocean because there would be less time for combustion before the propellants and other hazardous materials would reach the ocean surface. Nevertheless, the environmental effects to the ocean of this scenario would still be less than a thrust termination early in flight because more of the propellants and hazardous materials would be consumed in the explosion and the LP provides some degree of protection for the ocean and would likely retain pieces of the ILV. Thrust termination failures later in flight would result in the ILV tumbling, breaking up due to stresses, and possibly exploding if flammable materials are exposed to hot engine parts during the fall. In either case (i.e., with or without an explosion), most of the propellants and other hazardous materials would either incinerate or evaporate before reaching the ocean surface with minimal effects on the ocean other than relatively inert materials settling on the ocean floor. Explosive failures at the LP or during Stage I, II, or Upper Stage flight would result in most of the ILV being consumed and most of the propellants and other hazardous materials being burned before reaching the ocean surface with minimal effects on the ocean other than relatively inert materials settling on the ocean floor.

Therefore, thrust termination failure early in flight is considered the worst-case scenario in terms of ocean effects and the cumulative effects of two consecutive thrust termination failures early in flight in close proximity to one another is addressed below. A single occurrence of this scenario is addressed in Section 4.1.2.2 of this EA, which provides the technical basis and supporting references for the consideration of possible cumulative impacts.

Potential Cumulative Effects of Propellants and Other Hazardous Materials Released into the Ocean Under the Worst-Case Failure Scenario

Under the thrust termination failure early in flight scenario, the ILV would fall intact and rupture on the ocean surface. Nearly all of the ILV's propellants and other hazardous materials would remain unused and would be released directly to the ocean. This would include approximately 304,577 kg (670,069 lbs) of LOX, 117,048 kg (257,505 lbs) of kerosene, 95 kg (210 lbs) of N_2O_4/MMH/UDMH, and minor amounts of starting fluids (see footnote "d" on page 4-13 above). In the event of two successive thrust termination failures early in flight, the amount of propellants and other hazardous materials released into the ocean would double. However, the cumulative impacts are expected to be insignificant. For a discussion of the types and potential impacts of batteries used in the Zenit-3SL please refer to section 4.1.2.3 "Effects of Debris, Including Hazardous Materials in Open Ocean." The cumulative impacts are expected to be insignificant.

For a discussion of the impacts of releases of kerosene and LOX please refer to section 4.1.2.2 "Release of Hazardous Materials to the Ocean." No cumulative environmental impacts are expected due to releases to the ocean.

Recovery Timeframe

Even under the worst-case failure scenario, where the entire amount of propellants and other hazardous materials on the ILV are released directly to the ocean, the ocean environment would recover to natural conditions within a week. The subsequent launch, accounting for the required investigation, would not occur for four to 12 months. The elapsed period of four to 12 months would provide more than sufficient time for the ocean environment to recover, even if the subsequent launch results in a thrust termination failure early in flight and the ILV impacts the same area of the ocean surface. Therefore, no cumulative impact to the ocean environment would occur as a result of two successive, worst-case failures, even those that happen to affect the same area of the ocean.

Potential Cumulative Effects on the Oceanic Islands or South American Landmasses Under the Worst-case Failure Scenario

The Oceanic Islands and Central or South America could only be affected by a possible failure during Upper Stage flight (any failures earlier in flight would only affect the ocean environment). A possible Upper Stage failure could be the result of either thrust termination or explosion. As discussed below, both of these types of failures would have the same environmental effects and therefore are collectively considered the worst-case scenario in terms of potential cumulative impacts to the Oceanic Islands or Central or South America. The cumulative effects of two consecutive Upper Stage failures that strike the Oceanic Islands or Central or South American landmasses in close proximity to one another are addressed below. A single occurrence of this scenario is addressed in Section 4.1.2.3 of this EA, which provides the technical basis and supporting references for this consideration of cumulative impacts.

Potential Cumulative Effects of Propellants and Other Hazardous Materials Released Onto Landmasses

A failure during Upper Stage flight would result in most of the ILV components and all of the propellants and other hazardous materials being heated in the atmosphere and vaporized or burned from frictional effects before reaching the Earth's surface because of the speed and altitude of the Upper Stage during this period of flight. Approximately 42 components from the Upper Stage and payload would survive reentry friction and reach the Earth's surface (see Table 4-5). These objects range from 0.04 m (0.13 ft) to 1.2 m (3.9 ft) and total approximately 10 m^2 in size. Potential cumulative impacts from releases resulting from an Upper Stage failure would be insignificant.

Recovery Timeframe

As described above, the only effects of an Upper Stage failure on the Oceanic Islands or Central or South American landmasses would be from the components that survive reentry. These components would be inert after being subject to the intense heat generated while re-entering the upper atmosphere. The surviving components, which would cool during the descent through the lower atmosphere, would be unlikely to pose a risk of fire. Therefore, the only potential cumulative effects from the components would be the physical damage associated with striking terrestrial plant or animal species.

If debris struck an animal, it could be injured or killed. There is an extremely remote chance that a threatened or endangered species could be hit by falling debris. Should such harm occur, replacement in terms of population dynamics would depend on the individual species' abundance, reproduction characteristics, and recruitment success.

No scientific studies were found specific to this scenario, however, recovery following severe events (e.g., hurricanes, logging, and poor farming practices) in tropical regimes have been studied. These reports indicate that vegetation in moist regimes would recover from these more severe conditions over a few years to decades, respectively (Mack, 1998; Kuerpick, 1997; Boucher, 1997; Living Earth, 2001; and Donfack, 1995). In light of habitat recovery times in these extreme situations, and given the significantly smaller impact that could possibly occur during a failure of the Upper Stage, it may be inferred that any damage to the islands' habitats would be minor, but could require some period of time to fully recover.

Recovery time would be relatively long in this scenario as compared with the ocean environment, and any damaged or injured plants or animals may not recover by the time of the subsequent launch (assuming four to 12 months for the failure investigation). Assuming that the subsequent launch also fails and that the surviving components strike approximately the same portion of the Oceanic Islands or Central or South American landmasses, there would be additional incremental injury to the plant or animal or the local ecosystem.

These additional cumulative impacts, however, would likely be minor, with the exception of any endangered species that may be hit. The probability of these components falling on the Galapagos Islands, for example, is very low (0.00067, see Table 4-6), and the probability of striking an endangered species would be even more remote.

Although an injured individual or ecosystem population may not have had the time to return to pre-event conditions, the incremental damage caused by the second event would marginally prolong recovery time for that species or for the ecosystem as a whole. For example, a delay of six months between two launches that end in failures that cause physical damage to exactly the same area in a rain forest would, in effect, add approximately six months to the time it would take for that rain forest community to recolonize the damaged area. Accordingly, cumulative effects following two successive, worst-case failures affecting the same area would only marginally delay the recovery process. In this hypothetical case, the second impact would double the affected area, marginally prolonging the recovery of the first or second impact due to the corresponding impairment of neighboring habitat that would otherwise facilitate recovery through recolonization (i.e., reestablishment of floral or faunal colonies). However, the likelihood of such events occurring is extremely small.

4.1.4 Other Environmental Concerns

4.1.4.1 Environmental Justice

Although E.O. 12114 requires consideration of Federal actions abroad with the potential for impacts to the environment, the Executive Order specifically defines environment as "the natural and physical environment and excludes social, economic and other environments…." Therefore, potential impacts to environments other than the natural and physical are not analyzed in this document. Nevertheless, given the limited amount of time that the LP and the ACS will be present at the launch location, social and economic considerations are assumed to be negligible.

4.1.4.2 Exclusive Economic Zones

Under successful flight conditions, any potential environmental impact from the stages and fairing would occur outside the EEZ—defined as 200 nautical miles (370 km or 230 statute miles) of all countries bordering the affected environment. (Table 4-2 lists the closest expected distances between stage and fairing impacts to the nearest land areas.) Only in the event of a mission failure during Upper Stage flight would the deposition of debris potentially occur within an EEZ. Potential environmental impacts of such an occurrence are discussed in Section 4.1.2.3. As with all mission failures, an intensive investigation as to the cause of the failure would be completed. A return to flight for the SLLP project would be re-instated only after corrective actions are undertaken to the satisfaction of the FAA and SLLP.

4.1.4.3 Social and Economic Considerations

Although E.O. 12114 requires consideration of Federal actions abroad with the potential for impacts to the environment, the Executive Order specifically defines environment as "the natural and physical environment and excludes social, economic and other environments…." Therefore, potential impacts to environments other than the natural and physical are not analyzed in this document. Nevertheless, under the license applicant's proposed action SLLP would occupy the launch location for two to seven days during each launch cycle (or up to 56 days per year). For each launch, the LP and ACS sail directly to the launch location and return directly to the Home Port. The relatively brief duration of activity and the relative degree of isolation of the launch location provide an effective barrier between the license applicant's proposed action and the social, economic, and cultural character of Kiribati society. Since there would be no significant interaction with Kiribati society, the presence of the ACS and LP for up to 56 days per year at the launch site would have no significant social or economic effects.

The license applicant's proposed action would have no effect on the social or economic conditions of the Galapagos Islands, Cocos Island, or Malpelo Island, or that portion of South America that lie under the flight path as for successful launches, the ILV would simply fly over these areas and would have no beneficial or adverse effects. Under the mission failure scenarios, only a failure during the Upper Stage would have any effect on the Oceanic Islands or Central or South America, and this would be limited to the few fragments of the Upper Stage and payload that would not burn up or vaporize in the atmosphere. The deposition of this debris on the Oceanic Islands or Central or South America would have no significant effect on social or economic conditions.

4.2 ENVIRONMENTAL EFFECTS OF ALTERNATIVE WITH AVOIDANCE OF THE OCEANIC ISLANDS

This section of the EA evaluates the environmental effects of the alternative to the license applicant's proposed action in which the Oceanic Islands are avoided. Under this alternative, only azimuths between 82.60º to 83.28º, 84.50º to 85.07º, 86.36º to 88.80º and 92.89º to 97.4º would be used. While the environmental impacts described in Section 4.1 would largely apply, a different analysis would apply in regard to the Oceanic Islands and the corresponding portions of South American continent, which would not be overflown in this alternative action.

The evaluation of this alternative uses the same operational phases and actions (i.e., Home Port, pre-launch, launch, successful flight, post-launch and possible failure scenarios) to frame the discussion as those identified in Section 4.1. Where discussions of impacts are identical to those for the license applicant's proposed action the reader is referred to that section to avoid redundancy.

4.2.1 Environmental Effects of Successful Flight

4.2.1.1 Home Port

The impacts to Home Port from this alternative are the same as those discussed in Section 4.1.1.1.

4.2.1.2 Pre-launch, Launch, and Stage I and II Flight Over Open Ocean

The impacts to pre-launch, launch, and Stage I and II flight over open ocean from this alternative are the same as those discussed in Section 4.1.1.2.

4.2.1.3 Upper Stage Flight Over South America

Upper Stage and payload flight would progressively transit over open ocean waters and the northern part of South America. Upper Stage flight during a successful mission would have no effect on the ocean or land environments or the lower atmosphere because its operation occurs at very high altitudes. Launch impacts from this alternative are the same as those discussed in Section 4.1.1.3.

4.2.1.4 Post-Launch Operations

The impacts of post launch operations from this alternative are the same as those discussed in Section 4.1.1.4.

4.2.2 Environmental Impacts of Possible Failed Mission Scenarios

The impacts of possible failed mission scenarios from this alternative are the same as those discussed in Section 4.1.2, except for potential impacts to Oceanic Islands which would be avoided.

4.2.2.1 Failure at the Launch Platform Scenario

The impacts of failure at the launch platform from this alternative are the same as those discussed in Section 4.1.2.1.

4.2.2.2 Failure During Stage I and II Flight Over Open Ocean Scenario

The impacts of failures during Stage I and II flight from this alternative are the same as those discussed in Section 4.1.2.2.

4.2.2.3 Failure During Upper Stage Flight Over the Ocean or South America Scenario

The impacts of failure during Upper Stage flight for this alternative would be the same as those discussed in Section 4.1.2.3 with the exception that no impact would occur on or near the Oceanic Islands.

Summary of Failure Scenarios and Impacts

Table 4-8 summarizes the estimated types of failures and their consequences for several different failed mission scenarios.

4.2.3 Cumulative Impacts

The potential cumulative impacts from this alternative are the same as those discussed in Section 4.1.3.

4.2.3.1 Home Port

The potential cumulative impacts to the Home Port facility from this alternative are the same as those discussed in Section 4.1.3.1.

4.2.3.2 Pre-Launch

The potential cumulative impacts of pre-launch operations from this alternative are the same as those discussed in Section 4.1.3.2.

4.2.3.3 Launch

The potential cumulative impacts of launch operations from this alternative are the same as those discussed in Section 4.1.3.3.

4.2.3.4 Successful Flight Over the Open Ocean and South America

The potential cumulative impacts of successful flights over the open ocean and South America from this alternative are the same as those discussed in Section 4.1.3.4. The exception is that no potential cumulative impact would occur on or near the Oceanic Islands.

4.2.3.5 Post-Launch

The potential cumulative impacts of post-launch operations from this alternative are the same as those discussed in Section 4.1.3.5.

4.2.3.6 Cumulative Effects of Multiple Launch Failures in a Single Year in the Same Area

The potential cumulative impacts of multiple launch failures in a single year in the same area from this alternative are the same as those discussed in Section 4.1.3.6.

Possible Cumulative Effects of Two Successive Failures in the Same Area

In the context of two successive failures along the same azimuth or in close proximity to one another, there are several failure scenarios that would affect different portions of the environment (i.e., the ocean, and Central or South America). These are discussed below.

Possible Failure Scenarios Affecting the South American Landmass

Central or South America could only be affected by a failure during Upper Stage flight (any failures earlier in flight would only affect the ocean environment). An Upper Stage failure could be the result of either thrust termination or explosion. Both of these types of failures would have the same environmental effects and therefore are collectively considered the worst-case scenario in terms of impacts to Central or South America. A single occurrence of this scenario is addressed in Section 4.1.2.3 of this EA, which provides the technical basis and supporting references for this consideration of cumulative impacts. The potential cumulative impacts of launch operations from this scenario are the same as those discussed in Section 4.1.3.6.

4.2.4 Other Environmental Concerns

4.2.4.1 Environmental Justice

The impacts on environmental justice from this alternative are the same as those discussed in Section 4.1.4.1.

4.2.4.2 Exclusive Economic Zones

The impacts on exclusive economic zones from this alternative are the same as those discussed in Section 4.1.4.2.

4.2.4.3 Social and Economic Considerations

See Section 4.1.4.3.

4.3 ENVIRONMENTAL EFFECTS OF ALTERNATIVE WITH AVOIDANCE OF THE GALAPAGOS ISLANDS

This section of the EA evaluates the potential environmental effects of the alternative to the license applicant's proposed action in which the Galapagos Islands are avoided. Under this alternative, only azimuths between 83.60º to 86.80º, and 92.89º to 97.40º would be used. While the environmental impacts described in Sections 4.1 and 4.2 above would largely apply, a different analysis would apply in regard to Galapagos Islands and the corresponding portions of the South American continent, which would not be overflown under this alternative action.

The evaluation of this alternative uses the same operational phases and actions to frame the discussion as were identified in Section 4.1 for the license applicant's proposed action. The reader will be directed to the relevant section in this EA.

4.3.1 Environmental Effects of Successful Flight

4.3.1.1 Home Port

The impact to Home Port from this alternative will be the same as those discussed in Section 4.1.1.1.

4.3.1.2 Pre-launch, Launch, and Stage I and II Flight Over Open Ocean

The impact to pre-launch, launch, and Stage I and II flight over open ocean from this alternative will be the same as those discussed in Section 4.1.1.2.

4.3.1.3 Upper Stage Flight Over the Oceanic Islands and South America

Upper Stage and payload flight would progressively transit over open ocean waters, the Oceanic Islands (excluding the Galapagos Islands), and the northern part of South America. Upper Stage flight during a successful mission would have no effect on the ocean or land environments or the lower atmosphere because its operation occurs at very high altitudes. Launch impacts from this alternative are the same as those discussed in Section 4.1.1.3.

4.3.1.4 Post-Launch Operations

The impacts of post launch operations from this alternative are the same as those discussed in Section 4.1.1.4.

4.3.2 Environmental Impacts of Possible Failed Mission Scenarios

The impacts of possible failed mission scenarios from this alternative are the same as those discussed in Section 4.1.2, except for potential impacts to the Galapagos Islands which would be avoided.

4.3.2.1 Possible Failure at the Launch Platform

The impacts of possible failure at the launch platform from this alternative are the same as those discussed in Section 4.1.2.1.

4.3.2.2 Possible Failure During Stage I and II Flight Over Open Ocean

The impacts of possible failures during Stage I and II flight from this alternative are the same as those discussed in Section 4.1.2.2.

4.3.2.3 Possible Failure During Upper Stage Flight Over the Ocean, Oceanic Islands (excluding the Galapagos Islands), or South America

The impacts of possible failure during Upper Stage flight for this alternative would be the same as those discussed in Section 4.1.2.3 with the exception that no impact would occur on or near the Galapagos Islands.

Summary of Possible Failure Scenarios and Impacts

Table 4-8 summarizes the estimated types of failures and their consequences for several different possible failed mission scenarios.

4.3.3 Cumulative Impacts

The potential cumulative impacts from this alternative are the same as those discussed in Section 4.1.3.

4.3.3.1 Home Port

The potential cumulative impacts to the Home Port facility from this alternative are the same as those discussed in Section 4.1.3.1.

4.3.3.2 Pre-Launch

The potential cumulative impacts of pre-launch operations from this alternative are the same as those discussed in Section 4.1.3.2.

4.3.3.3 Launch

The potential cumulative impacts of launch operations from this alternative are the same as those discussed in Section 4.1.3.3.

4.3.3.4 Successful Flight Over the Open Ocean, Oceanic Islands (excluding the Galapagos Islands), and South America

The potential cumulative impacts of successful flights over the open ocean Oceanic Islands excluding the Galapagos Islands and Central and South America from this alternative are the same as those discussed in Section 4.1.3.4.

4.3.3.5 Post-Launch

The potential cumulative impacts of post-launch operations from this alternative are the same as those discussed in Section 4.1.3.5.

4.3.3.6 Cumulative Effects of Multiple Launch Failures in a Single Year in the Same Area

The potential cumulative impacts of multiple launch failures in a single year in the same area from this alternative are the same as those discussed in Section 4.1.3.6.

Possible Cumulative Effects of Two Successive Failures in the Same Area

In the context of two successive failures along the same azimuth or in close proximity to one another, there are several possible failure scenarios that would affect different portions of the environment (i.e., the ocean, Cocos or Malpelo Island, South America).

Possible Failure Scenarios Affecting Cocos Island, Malpelo Island, or South American Landmasses

The Cocos and Malpelo Islands and Central and South America could only be affected by a failure during Upper Stage flight (any failures earlier in flight would only affect the ocean environment). A possible Upper Stage failure could be the result of either thrust termination or explosion. As discussed below, both of these types of failures would have the same environmental effects and therefore are collectively considered the worst-case scenario in terms of Cocos and Malpelo Islands or Central or South American effects. The cumulative effects of two consecutive Upper Stage failures that strike the Cocos and Malpelo Islands or Central or South American landmass in close proximity to one another is addressed below. A single occurrence of this scenario is addressed in Section 4.1.2.3 of this EA, which provides the technical basis and supporting references for this consideration of cumulative impacts.

Possible Cumulative Impacts of Propellants and Other Hazardous Materials Released Onto Landmasses

For a discussion of the possible cumulative impacts of propellants released onto landmasses please refer to Section 4.1.3.6 *"Potential Cumulative Effects of Propellants and Other Hazardous Materials Released onto Landmasses"* with the exception that no impact would occur on or near the Galapagos Islands.

4.3.4 Other Environmental Concerns

4.3.4.1 Environmental Justice

See Section 4.1.4.1.

4.3.4.2 Exclusive Economic Zones

The impacts on exclusive economic zones from this alternative are the same as those discussed in Section 4.1.4.2.

4.3.4.3 Social and Economic Considerations

See Section 4.1.4.3.

4.4 NO ACTION ALTERNATIVE

Under the No Action alternative FAA would not issue the LOL to SLLP for eight launches per year for five years, for azimuths ranging from 82.6° to 97.4° or the launch specific license for a 90° launch of the Galaxy IIIC. SLLP would continue to prepare and submit launch-specific applications for individual licenses to launch up to six satellites per year within the launch parameters analyzed in the February 11, 1999 EA. Home Port operations would continue at their present level. If a customer required a different launch azimuth, SLLP would prepare individual environmental analyses and documentation (to support launch-specific applications) for each launch.

The launch-specific application and license process would be repeated approximately every 60 days, as warranted by commercial demand.

4.5 SUMMARY OF ENVIRONMENTAL IMPACTS FOR LICENSE APPLICANT'S PROPOSED ACTION AND ALTERNATIVES

Table 4-11 provides a brief summary of the potential environmental impacts associated with the license applicant's proposed action and reasonable alternatives including no action. Table 4-11 provides a brief summary comparing the license applicant's proposed action and alternatives.

TABLE 4-11. POTENTIAL ENVIRONMENTAL EFFECTS OF THE LICENSE APPLICANT'S PROPOSED ACTION ON THE ATMOSPHERE, OPEN OCEAN, OCEANIC ISLANDS, AND SOUTH AMERICA

		License Applicant's Proposed Action	**Alternative with No Oceanic Island Overflight**	**Alternative with Avoidance of Galapagos Islands**	**No Action**
	Probability of Effect[k]	**Potential Environmental Effects**	**Potential Environmental Effects**	**Potential Environmental Effects**	**Potential Environmental Effects**
Atmosphere					
Release of residual propellants (kerosene, LOX)	Unavoidable[l]	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA
Release of combustion emissions (CO, CO_2, H_2, and H_2O)	Unavoidable	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA
Open Ocean					
Debris deposition[m]	Unavoidable	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA
Release of residual propellants into ocean	Unavoidable	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA

[k] In Table 4-11, the column titled "Probability of Effect" refers to the likelihood of the potential effect occurring.

[l] In this instance, unavoidable effects refer to those impacts that will occur because they are part of the normal operations.

[m] In this instance, debris refers to jettisoned spent stages that are part of the normal operations of expendable launch vehicle launches.

		License Applicant's Proposed Action	Alternative with No Oceanic Island Overflight	Alternative with Avoidance of Galapagos Islands	No Action
	Probability of Effect	**Potential Environmental Effects**	**Potential Environmental Effects**	**Potential Environmental Effects**	**Potential Environmental Effects**
Injury or mortality of marine organisms from heat and noise associated with launch	Unlikely	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA
Injury or mortality of marine organism from impact with falling debris	Unlikely	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA
Oceanic Islands					
Damage to terrestrial habitat/vegetation from impact with falling debris	Unlikely	Insignificant	None	Probability of impact is slightly lower than license applicant's proposed action (reduced by 0.00067)	Same as impacts in February 11, 1999 EA
Injury or mortality of terrestrial organism from impact with falling debris	Unlikely	Insignificant	None	Probability of impact is slightly lower than license applicant's proposed action (reduced by 0.00067)	Same as impacts in February 11, 1999 EA
Damage to coral reef communities from impact with falling debris	Unlikely	Insignificant	None	Approximately the same as license applicant's proposed action since majority of coral reefs surround Cocos Island and not the Galapagos	Same as impacts in February 11, 1999 EA

		License Applicant's Proposed Action	Alternative with No Oceanic Island Overflight	Alternative with Avoidance of Galapagos Islands	No Action
	Probability of Effect	**Potential Environmental Effects**	**Potential Environmental Effects**	**Potential Environmental Effects**	**Potential Environmental Effects**
South America					
Damage to terrestrial habitat/vegetation (i.e., rain forest) from impact with falling debris	Unlikely	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA
Damage to commercial vessel or aircraft or injury or mortality of human from impact with falling debris	Unlikely	Insignificant	Same as license applicant's proposed action	Same as license applicant's proposed action	Same as impacts in February 11, 1999 EA

4.6 ENVIRONMENTAL MONITORING AND PROTECTION PLAN (EMPP)

The EMPP is an evolving document, incorporating improvements approved by the FAA, including those identified by the FAA or SLLP, or those recommended by public reviewers (see Appendix G of this document for the current EMPP). The plan consists of four elements:

- Visual observation for species of concern.
- Remote detection of atmospheric effects during launch.
- Collection of surface water samples to detect possible launch effects.
- Notification to mariners and air traffic.

By reviewing EMPP reports, for example, the FAA determined that more specific visual observation training of personnel was required. Additional training was conducted and improvements in this area continue to be evaluated periodically. Similarly, the water sampling processing has undergone changes to improve the accuracy of results. SLLP has implemented a three pre-launch and nine post-launch water sampling method in which samples are taken on points on a grid located down-current from the LP and positioned to intercept waters flowing past the LP, as estimated by the set and drift of the surface current. Additionally, SLLP and FAA are currently evaluating automated water sampling equipment and photometering equipment to determine if their use would improve the accuracy of results while maintaining the required level of safety for onboard crew. Nighttime water sampling occurred once but it was determined to pose an unacceptable safety risk to the crew. The notification process for mariners and air traffic has also been refined, as feedback to prior notices has been collected.

As part of SLLP's ongoing EMPP program, crew members have made visual observations for species of concern. Sightings have included sharks, tuna, dorado, and gulls, all not included as species of concern. The only species of concern (as listed in the EMPP) to be sighted to date was one Hawaiian Dark-Rumped Petrel, sighted on the fourth launch.

Also as part of SLLP's ongoing EMPP program, crew members have taken samples of the downstream surface water within 30 minutes of launch to analyze for the presence of kerosene on the ocean surface. For six of the seven launches to date water sampling has been conducted (water sampling was not conducted during one night launch for safety reasons). The chemical analysis for each of these samples (three pre-launch and nine post-launch) has returned a result of "no detection" for kerosene. Sampling methods are being reviewed to improve the ability to capture possible contaminant releases during the pre- and post-launch period.

Under the EMPP, SLLP collects video- and radar-scan data on atmospheric effects of each launch. Data are available for three of the four launches to date. Visible plumes were recorded on two of the launches; night conditions and low-cloud cover prevented video scans for the other two launches. The results of the scans for the fourth mission, by way of example, are discussed below.

A visible plume associated with the launch was sighted between 61 and 72 seconds after launch. This equates to the base of the plume beginning at approximately 13.5 km (8.4 mi), and the top of the plume ending at 18.4 km (11.5 mi) above sea level. In the tropics, a layer of High Altitude Tropical (HAT) cirrus clouds (ice crystals) extends about 3 to 5 km (1.9 to 3.1 mi) below the tropopause. The HAT cirrus clouds are occasionally visible; at other times, the concentration of ice crystals is not sufficient to be visible to the naked eye. Based on data SLLP obtained from a weather balloon released 40 minutes before the launch, the base of the tropopause was at approximately 16.2 km (10.1 mi) at the time of launch. The base of the ILV contrail was thus observed approximately 2.7 km (1.7 mi) below the tropopause base.

As the ILV plume, which is rich in water vapor, transits the lower layer of the HAT, ice crystals form in the water vapor of the plume and mix with existing ice crystals. The increased concentrations of ice crystals make the contrail visible. This process involves the same mechanism that generates airplane contrails. As the ILV transitions into the stratosphere, where ambient moisture is practically nonexistent, ice crystal formation is dramatically reduced and the contrail abruptly terminates at about 18.4 km (11.5 mi).

C-Band Doppler weather radar scans have generated data for three of the four launches. The radar scan is used to determine the presence of particles within the nonvisible spectrum. No particles were detected in the second and third launches. In the first launch particles were detected with a density reading of 5 particles per cubic centimeter (cm^3); however, because no visible plume was detected at the same time, it is hypothesized that the particles were less than 1mm in diameter. It is further hypothesized that this concentration of particles was possible only with the aid of external atmospheric features. In fact, a significant wind-shear was detected at the launch site at an 8-km (5 mi) altitude from this analysis.

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6.0 GLOSSARY

accretion	Gradual buildup of land or seafloor formed by magma rising to the surface along some tectonic plate boundaries.
agouti	A neotropical burrowing rodent, similar to a raccoon.
anaerobic	Absence of oxygen.
annelids	Multi-segmented, worm-like animals.
ascent groundtrack	The projection, on the surface of the earth, of the launch vehicle flight path from liftoff until orbit insertion.
basalt	A dark-colored, fine-grained rock of volcanic origin.
bathymetry	Generally, the study of the bathyal zone of the ocean, extending from the seaward edge of the continental shelf down to approximately 4,000 meters below the surface.
benthic	Pertaining to or found at or on the bottom of a large body of water.
biomass	The dry weight of living matter present in a species or ecosystem pollution for a given habitat area or volume.
boundary layer	The lowest portion of the atmosphere where the fractional effects of the earth's surface are substantial.
breaching	Usually in reference to whales, a formal term for when a fish or mammal breaks the ocean surface.
caldera	Volcanic basin, commonly at the summit of a volcano, formed by explosion during eruption or the collapse of the volcanic summit.
capybara	A large (1.2-1.5 m) neotropical, semi-aquatic rodent; the largest known rodent.
crater lake	Lake, usually with a diameter at least three times depth, lying inside a volcanic caldera.
Coriolis effect	Deflection of a moving object relative to the earth's surface; objects moving north and south of the equator are deflected to the right and left respectively.
demersal	Living at or near the bottom of the sea.

echinoderms	Dermersal marine organisms with an internal skeleton and a system for flushing water through the body to permit movement, respiration, nourishment, and perception.
ecosystem	A conceptual view describing the interrelationships, including the flow of materials and energy, between living and non-living features of a natural community.
exclusive economic zone (EEZ)	An offshore boundary, set at 200 nautical miles (320 km), establishing a nation's economic sovereignty over the resources present within that perimeter.
failure	A condition of a component, subsystem or system in which the intended design or specified operation is not met.
flight azimuth	The angular direction of the launch and flight trajectory of a launch vehicle measured in degrees.
food chain	Scheme for describing feeding relationships by trophic levels among the members of a biological community.
fumarole	Natural vent formed by escaping volcanic steam and gases.
geosynchronous	Designating or of a satellite or spacecraft in an orbit above the equator revolving at a rate of speed synchronous with that of the earth's rotation so as, in effect, to be hovering over a point on the earth's surface.
habitat	The physical environment in which a plant or animal lives.
impact limit line (ILL)	A predetermined line defining a limit beyond which a failed ILV or its jettisoned spent stages will not be allowed to impact on the ground, in order to protect people or property.
inert	Not reactive; lacking a usual or anticipated chemical or biological action.
instantaneous impact point (IIP)	An impact point following thrust termination of a launch vehicle. The IIP may be calculated with or without atmospheric drag effects.
ionosphere	That part of the earth's upper atmosphere ionized by solar ultraviolet radiation so that the concentration of free electrons affects the propagation of radio waves.
lava tube	Natural conduits through which lava travels beneath the surface of a lava flow; partially empty conduits beneath the ground.
lithosphere	The solid, rocky part of the Earth; the Earth's crust.

long-lining	A non-selective method of commercial fishing which employs strings of baited hooks, usually tens of miles long, to capture large open-ocean species.
mass balance	The accounting of all matter that is in flux between or stable within subdivisions of a physical process or ecosystem.
mesosphere	That part of the earth's atmosphere above the stratosphere characterized by a temperature that generally decreases with altitude.
microbial degradation	The breakdown of material, usually organic, by the natural processes of microorganisms.
ozone	A form of oxygen, O_3, naturally found in the ozonesphere within the stratosphere.
paca	A medium sized (0.5 m) neotropical nocturnal rodent.
peccary	A small pig-like mammal of Central and South America.
pitch	The movement up or down of the nose or tail or an object in flight.
photometer	An instrument used in measuring the intensity of light.
photochemical oxidation	Oxidation resulting from the chemical action of radiant energy and especially light.
phytoplankton	Passively floating or weakly self-propelled aquatic plant life.
primary productivity	A new organic matter produced by plant life.
pumice	An igneous rock formed from magma that trapped air bubbles while cooling, giving it a characteristic “honey-combed” appearance.
purse seining	A commercial fishing method used to capture schools of fish in the open ocean using a large, bag-shaped net with a drawstring-type closure at the bottom.
seamount	A submerged, flat-topped mountain.
shield volcano	Volcanic dome, much broader than tall, built over geologic time from lava poured out in a succession of quiet eruptions.
sonic boom	Sound, resembling an explosion, produced when a shock wave formed at the nose of an aircraft or launch vehicle traveling at supersonic speed reaches the ground.

stratosphere	That part of the Earth's atmosphere between the troposphere and the mesosphere in which the temperature increases with altitude.
subduction zone	Region along which one lithospheric block descends relative to another lithospheric block.
substrate	The base on which an organism lives (e.g., soil, rock).
tapir	Mammal of South American and southern Asian forests with a stout body, short legs, and flesh proboscis.
trachytic intrusion	Of or pertaining to the internal structure of some igneous rocks, in which hair-like, feldspar crystals are in nearly parallel rows.
tectonics	Movement and deformation of the earth's surface caused by fluid circulation beneath the surface.
thermosphere	That part of the earth's atmosphere extending from the tip of the mesosphere to outer space, including the exosphere and ionosphere, marked by more or less steadily increasing temperatures with altitude.
transform fault	A type of rupture in the Earth's surface that is most often associated with oceanic ridges.
trophic level	A broad grouping of organisms within an ecosystem defined as being in the same tier in the food chain hierarchy; most generally, the first trophic level is the photosynthetic plants, the second is the herbivores, and the third is the carnivores.
troposphere	That part of the atmosphere extending from the earth's surface to an altitude of 10 to 20 km, in which the temperature generally decreases with altitude.
tuff	Rock consolidated from volcanic ash.
upwelling	The process by which water rises from a deeper to a shallower depth; may be caused by a variety of physical phenomena.
yaw	To turn by angular motion about the vertical axis.
zooplankton	Passively floating or weakly self-propelled aquatic animal life.

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