Final
Programmatic Environmental Impact Statement
For Commercial Reentry Vehicles

Submitted Pursuant to 42 USC 4332 (2) (c)
by the
U.S. Department of Transportation
Office of Commercial Space Transportation

May 28, 1992

TABLE OF CONTENTS

EXECUTIVE SUMMARY ES-1

LIST OF ABBREVIATIONS and ACRONYMS ACR-1

1.0 INTRODUCTION 1-1
- 1.1 Purpose 1-1
- 1.2 Scope 1-2
- 1.3 Format 1-3

2.0 PROPOSED ACTION AND ALTERNATIVES 2-1
- 2.1 Proposed Action 2-1
- 2.2 Alternative Actions - No Action 2-9

3.0 DESCRIPTION OF THE EXISTING ENVIRONMENT 3-1
- 3.1 The Atmosphere 3-1
  - 3.1.1 Upper Atmosphere 3-1
    - 3.1.1.1 Ionosphere 3-1
    - 3.1.1.2 Mesosphere 3-3
    - 3.1.1.3 Stratosphere 3-3
  - 3.1.2 Lower Atmosphere (Troposphere) 3-4
- 3.2 Objects in Space 3-5
- 3.3 Site-Specific Environment (Earth's Surface) 3-6

4.0 ENVIRONMENTAL IMPACTS AND CONSEQUENCES OF THE PROPOSED ACTION 4-1
- 4.1 Atmospheric Effects 4-1
  - 4.1.1 Upper Atmosphere 4-1
    - 4.1.1.1 Changes in Electron Concentrations 4-6
    - 4.1.1.2 Effects on the Ozone Layer 4-7
  - 4.1.2 Lower Atmosphere 4-12
- 4.2 Noise Sources and Effects 4-15
  - 4.2.1 Reentry Operations (Sonic Booms) 4-15
  - 4.2.2 Landing Operations 4-22
  - 4.2.3 Summary Of Acoustic Noise Effects On The Environment 4-23
- 4.3 Landing Effects 4-24
  - 4.3.1 Water Quality 4-24
  - 4.3.2 Heat Dissipating Effects 4-26
  - 4.3.3 Accidental Fuel Release 4-26
  - 4.3.4 Accidental Hazardous Material/Waste Release 4-27

4.4 Other Effects (Site-Specific) 4-28
4.4.1 Land Management/Quality 4-28
4.4.1.1 Landing Site Construction 4-28
4.4.1.2 Recovery of Payloads and Disposal of Waste Material 4-28
4.4.1.3 Impacts on Wetlands, Floodplains, and Coastal Areas 4-43
4.4.2 Aquatic and Terrestrial Ecology 4-43
4.4.2.1 Flora and Fauna 4-44
4.4.2.2 Endangered and Threatened Species 4-44
4.4.3 Community Impacts 4-44
4.4.3.1 Historical and Cultural Resources 4-44
4.4.3.2 Land Use 4-45
4.4.3.3 Noise 4-45
4.4.3.4 Transportation 4-45
4.5 Socio-Economic Effects 4-45
4.6 Reentry Safety Considerations 4-46
4.7 Secondary Effects 4-47

5.0 ENVIRONMENTAL IMPACTS AND CONSEQUENCES OF THE ALTERNATIVE 5-1
5.1 No Action Alternative 5-1
5.1.1 Physical Effects 5-1
5.1.2 Atmospheric Effects 5-1
5.1.3 Aquatic and Terrestrial Ecology and Water Quality 5-2
5.1.4 Noise 5-2
5.1.5 Transportation 5-2
5.1.6 Socio-Economic Effects 5-2

6.0 RELATIONSHIPS BETWEEN SHORT-TERM USES AND LONG-TERM MAINTENANCE AND ENHANCEMENT OF THE ENVIRONMENT 6-1

7.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES 7-1
7.1 Natural Resources 7-1
7.1.1 Material Requirements 7-1
7.1.2 Energy Requirements 7-2
7.1.3 Changes in Biological Resources 7-2
7.2 Cultural Resources 7-2

8.0 PUBLIC COORDINATION 8-1
8.1 Coordination Process 8-1
8.2 Comments Received and OCST Responses 8-1
8.3 Final EIS Distribution List 8-7

9.0 LIST OF PREPARERS 9-1

REFERENCES REF-1

TABLES

2-1 Current U.S. and Foreign Reentry Capsule Programs 2-4
2-2 Typical Hazardous Materials/Waste Transported by RVs 2-8
4-1 Exhaust Products Emitted Into the Upper Atmosphere by Common Launch Vehicles 4-2
4-2 Typical Chemical Reactions and Phase Changes Occurring in Ablation . 4-5
4-3 Thermal Degradation of Selected Polymers 4-11
4-4 National Ambient Air Quality Standards 4-13
4-5 Exhaust Products Emitted Into the Lower Atmosphere by Common Launch Vehicles 4-16
4-6 Hazardous Substances, Reportable Quantities, and Human Exposure Limits 4-29
4-7 Properties of Liquid Rocket Propellant Oxidizers 4-32
4-8 Properties of Liquid Rocket Propellants/Fuels 4-34
4-9 Properties of Solid Propellant Ingredients 4-36
4-10 Fuel/Propellant Hazards 4-38
4-11 Propellant Flammability and Toxic Properties 4-42

FIGURES

2-1 Example Mission Profile 2-2
2-2 Reentry Vehicle Capsule Shapes 2-6
3-1 Locations of the Earth's Atmospheric Layers 3-2
4-1 Bow Shock Wave About Hypervelocity Sphere 4-10
4-2 Sonic Boom Propagation From an RV at Supersonic Speed 4-18
4-3 Sonic Boom Along and Adjacent to Ground Track 4-19

ABBREVIATIONS AND ACRONYMS

Ar	argon
^oC	degrees Celsius (centigrade)
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CEQ	Council on Environmental Quality
CFC	chlorofluorocarbon
CFR	Code of Federal Regulations
cm	centimeters
CO_2	carbon dioxide
COMET	Commercial Experiment Transporter
dB	decibel
dB(A)	decibel, measured with an "A weighted" frequency network
DOT	Department of Transportation
e	electron
EA	environmental assessment
EIS	environmental impact statement
ELV	expendable launch vehicle
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
^oF	degrees Fahrenheit
ft	foot or feet
ft^3	cubic foot
H	hydrogen
H_2O	water
He	helium
kg	kilogram
km	kilometer
km^3	square kilometer
km/s	kilometers per second
lb(s)	pound(s)
LEPC	Local Emergency Planning Committee
LV	launch vehicle
<u>M</u>	Mach
m	meter
mi	mile
mi^2	square mile
mm	millimeter
MMH	monomethylhydrazine

mph	miles per hour
m/s	meters per second
ms	millisecond

N	Newton
N/m^2	Newton per square meter
N_2 or N	Nitrogen
Na	sodium
NO	nitric oxide
NASA	National Aeronautice and Space Administration
NEPA	National Environm,ental Policy Act
nm	nanometer
NPDES	National Pollutant Dischange Elimination System
O or O_2	oxygen
OCST	Office of Commercial Space Transportation
psf	pounds per square foot
RCRA	Resource Conversation and Recovery Act
RV	reentry vehicle
s or sec	second
SERC	State Emergency Response Commision
U.S.	United States
UV	ultraviolet

EXECUTIVE SUMMARY

The Commercial Space Launch Act of 1984 (Public Law 98-575), as amended, 49 U.S.C. § 2601, et seq. (CSLA), declares that the development of commercial launch vehicles and associated services is in the national and economic interest of the United States. To ensure that launch services provided by private enterprises are consistent with national security and foreign policy interests of the U.S., and do not jeopardize public health and safety and safety of property, the Department of Transportation (DOT) is authorized to regulate and license commercial space launch operations. Within DOT, the Secretary's authority under the CSLA has been delegated to the Office of Commercial Space Transportation (OCST). This authority extends to the licensing of commercial reentry vehicles (RVs) launched from space to Earth.

OCST's licensing process is considered to be a major Federal action subject to the requirements of the National Environmental Policy Act (Public Law 91-190), as amended, 42 U.S.C. § 4321, et seq. Potential impacts from commercial expendable launch vehicle (ELV) launches (from Earth to space) have been evaluated in the DOT's Programmatic Environmental Assessment of Commercial Expendable Launch Vehicle Programs (February 1986). This Programmatic Environmental Impact Statement (EIS) evaluates, on a generic basis, the impacts from the reentry from space of commercial RVs. The alternative to licensing commercial RVs is for OCST not to license or authorize RV operations, i.e., a no-action alternative. This alternative is also evaluated in this EIS.

The effects from propulsion systems that may be used to orient, stabilize, decelerate, and launch the RV from its orbital track into its reentry trajectory are similar to, but smaller in magnitude than, the effects from activities carried out by launch vehicles as evaluated in the 1986 DOT Programmatic EA. Therefore, they are not reevaluated in this EIS.

A major focus of commercial space reentry missions is expected to be microgravity materials research and processing. The actual level of activity expected to occur in the future is uncertain at this time. However, for purposes of establishing a baseline for the EIS, it will be assumed that the activity level subject to licensing by OCST would not exceed an average of seven commercial microgravity missions launched and returned from space by RVs annually between 1993 and 1999. Between 2000-2005, the maximum commercial RV activity probably would not exceed 20 - 30 missions annually.
At this anticipated maximum level of activity, no significant long-term environmental impacts are expected to occur as a direct result of the conduct of RV launches. Specific evaluations of potential impacts resulting from the reentry of RVs from space were conducted in four general areas:

- effects on the upper and lower atmosphere;
- noise sources and effects near the Earth's surface;
- landing effects (environmental); and
- other effects (site-specific).

The results of these evaluations are summarized below:

Effects on the upper and lower atmosphere. Potential impacts to the upper atmosphere are changes in electron concentrations (ionosphere layer) and the depletion of ozone (primarily in the stratosphere layer). Substances such as carbon dioxide, water, and hydrogen, released at altitudes above approximately 140 km (88 miles), can react with ambient electrons and ions and effectively form a "hole" in the upper ionosphere by reducing the concentration of electrons and ions within the path of the vehicle. Such reductions can potentially affect radio communication, such as short-wave broadcasts. However, the quantity of potential electron-depleting substances released during reentry of commercial RVs is expected to be much smaller than that released during the July 1985 experimental test firing of the Space Shuttle maneuvering propulsion unit, which generated an "ion/electron hole" that disappeared within five minutes. Also, the quantity of potential electron-depleting substances released during reentry is far less than similar release for ELVs.

Ozone is destroyed by several processes, including catalytic chain reactions of nitrogen oxides (NO_x). Nitric oxide (NO) is generated in the shock-heated wake of any object entering the Earth's atmosphere. The quantity of NO estimated to be produced by RVs is insignificant when compared to the natural annual production of 10^5 metric tons (2.2×10^9 lb), which is formed by solar energy interactions. Thus, the NO produced by RVs during reentry should have no measurable effect on the normal seasonal and annual atmosphere ozone levels.

The primary environmental concerns of the lower atmosphere are related to the greenhouse effect and acid rain. Extensive evaluation of these concerns in previous EISs and EAs for launch-related activities identified no long-term impacts. RVs which return to Earth ballistically are expected to release no substances into the lower atmosphere, with the exception of particulate matter which may be released with certain parachute systems. If such a system is used, the quantities of material released will be negligible as compared to those released in other activities such as launch, and should therefore have no adverse lower atmospheric effects. RVs which return non-ballistically (i.e., those having lift and glide capability) may release small quantities of exhaust products into the lower atmosphere. The composition of these exhaust products should be similar to that evaluated for launch-related activities and quantities will be minute compared to those released during launch; no adverse lower atmospheric effects are anticipated to be caused by non-ballistic RV reentry.

Noise sources and effects near the Earth's surface. Noise generation by commercial RVs during reentry includes reentry sonic booms and noise generated during tracking and recovery operations. The sonic boom produced by the Space Shuttle is expected to represent an upper-bound estimate of the overpressures expected from commercial RV activity. Sonic boom sound pressure of approximately 135 dB may, therefore, be generated. This level is below the upper tolerance level established by the National Academy of Sciences; with the exception of a slight startle reaction in the population that hears the boom, no other effects are anticipated.

The noise generated by the tracking, landing, and recovery operations is similar to that produced by normal transportation related equipment and will be of short duration; no adverse effects are anticipated.

Landing effects (environmental). Landing effects cannot be fully evaluated until the actual landing area/recovery site is identified. Therefore, these effects will be further evaluated on a case-by-case basis in site-specific landing site EAs/EISs. Potential environmental impacts of the RV landing will be mainly in the immediate vicinity of the impact area and may include impacts to water quality, effects resulting from heat dissipation methods, and accidental releases of fuels and hazardous materials. However, because of the small quantities of materials which may be involved, impacts, if any, are expected to be short-term and insignificant.

Other impacts (site-specific). The site-specific impacts at the landing and recovery site(s) are beyond the scope of this Programmatic EIS. However, general areas of concern and potential site characteristics that may require further detailed analyses in subsequent site-specific EAs/EISs are discussed in this EIS.

1.O INTRODUCTION

1. 1 Purpose

In recent years, the private sector has expressed heightened interest in the launching and recovery of space vehicles, projects which have previously been conducted only by the Federal government. The Commercial Space Launch Act of 1984 (Public Law 98-575), as amended, 49 U.S.C. § 2601, et sea. (CSLA), declares that the development of commercial launch vehicles and associated services is in the national And economic interest of the United States; however, reentry of space vehicles to a designated landing site is not specifically addressed. To ensure that launch services provided by private enterprises are consistent with national security and foreign policy interests of the U.S., and do not jeopardize public safety and safety of property, the Department of Transportation (DOT) is authorized to regulate and license U.S. commercial launch activities. Within DOT, the Secretary's authority under the CSLA has been delegated to the Office of Commercial Space Transportation (OCST). This authority extends to the licensing of commercial reentry vehicles (RVs) launched from space to Earth. Because licensing RVs is considered to be a major Federal action subject to the requirements of the National Environmental Policy Act of 1969 (Public Law 91-190), as amended, 42 U.S.C. § 4321, et seq. (NEPA), the OCST has conducted this Programmatic Environmental Impact Statement (EIS).

This EIS addresses, on a generic basis, the environmental aspects of the reentry from space of commercial RVs. It will be used by OCST, in conjunction with other existing and future documentation, to assess the environmental impacts of the operation of commercial RVs, and to support licensing of such operations. OCST may find it necessary to require the commercial operator to submit additional information to supplement this EIS. Existing documentation concerning the environmental effects of commercial expendable launch programs includes the February 1986 Programmatic Environmental Assessment of Commercial Expendable Launch Vehicle Programs (see Reference 7) and the January 1988 Programmatic Environmental Assessment of Commercial Expendable Launch Vehicle Programs at Vandenberg Air Force Base. California. Additional environmental documentation, which may be used by OCST in its licensing decisions, may include site-specific launch site EAs/EISs mission-specific information, and site-specific landing/recovery area EAs/EISs. The actual design, system testing and evaluation records, maintenance records, launch and landing site range safety plans and procedures, emergency and countermeasures plans, critical failure mode and effects analyses plan, and mission-specific objectives are also reviewed and evaluated by the OCST as a part of the launch licensing process.

This EIS provides information on the reentry impacts associated with RVs and relies on existing preliminary design studies, EAs/EISs, and other environmental documentation prepared for U. S. Government and private industry sponsored programs, such as the Shuttle, Lifesat, COMET, and the Space Station Freedom.

1.2 Scope

This EIS covers the generic aspects of commercial RV reentry operations in accordance with the requirements of NEPA; the Council of Environmental Quality regulations; and the Environmental Impact Statement Guidelines for the Development of Commercial Space Launch Facilities (see Reference 3). It is similar to the Programmatic Environmental Assessment of Commercial Expendable Launch Vehicle Programs (February 1986), and the Programmatic Environmental Assessment of Commercial Expendable Launch Vehicles Programs at Vandenberg Air Force Base. California (January 1988).

For the purpose of this document, RV reentry operations are defined as beginning when the vehicle is in its reentry trajectory (i.e., it is completely removed from its orbital track), and ending at vehicle touchdown. Effects from propulsion systems which may be used to orient, stabilize, decelerate, and launch the RV from its orbital track into its reentry trajectory are similar to the effects from activities carried out by launch vehicles which were evaluated in the Programmatic Environmental Assessment of Commercial Expendable Launch Vehicle Programs (February 1986) and are, therefore, not reevaluated in this EIS.

This document is not vehicle- or site-specific. Rather, it is intended to address environmental concerns resulting from potential commercial RV activities. It also identifies specific concerns which may require further evaluations once landing/recovery sites are identified. Unless these sites have been fully evaluated in other EAs/EISs, a separate document will be required for each landing/recovery site that addresses specific Federal, state, and local environmental requirements.

In addition to site-specific impacts, any peculiar aspects of an RV operation (including its payload) that significantly differ from the variations described in this EIS are outside the scope of this document. The commercial operator may be required to prepare and submit separate assessments concerning these mission- and vehicle specific aspects. Additional information may also be required if the OCST is requested to license launches for other than basic microgravity materials and processing research (i.e., crystal growth; solidification of metals, alloys, and composites; And fluid transport and chemical processes), medical research, and biological research on living organisms with respect to future human exploration of space.

1.3 Format

Section 2.0 provides a description of the proposed generic RV and the no-action alternative. Section 3.0 describes the existing environment potentially impacted by reentry operations. Section 4.0 describes the potential environmental impacts and consequences of the proposed action, while Section 5.0 describes the impact and consequences of the no-action alternative. In Section 6.0, the relationship between short-term use and the long-term effects on the environment is discussed. The commitment of resources for the reentry (and recovery) of the RV's is discussed in Section 7.0. Section 8.0 includes a description of the public coordination, the distribution list, and copies of comments received. The list preparers of the EIS is found in Section 9.0.

2.0 PROPOSED ACTION AND ALTERNATIVES

2.1 Proposed Action

Reentry vehicles (RVs) are vehicles which can transport payloads, such as microgravity experiments, from orbit back to Earth. The vehicles are launched into and from space by expendable launch vehicles (ELVs). Upon command, the reentry vehicle portion of the reentry vehicle system separates from the system and deorbits to a suborbital trajectory which intersects the Earth's atmosphere and surface, causing it to land at a designated site (see Figure 2-1).

RVs are generally capable of:

- o being launched by a variety of launch vehicles; and
- o reentering the atmosphere and softly landing at predesignated water or surface U.S. sites, thereby allowing rapid access to payloads.

Commercial Applications

The expected areas of commercial interest where RVs may be beneficial include microgravity, artificial gravity, radiation and life sciences research (mainly on the effects of the space environment on living organisms, particularly with respect to future human exploration of space), development of commercial materials and processes, and the demonstration of new technologies.

Microgravity materials research and processing is expected to be a major focus of commercial space activity (see Reference 9). Microgravity materials processing can be categorized into 4 general areas:

- o crystal growth;
- o solidification of metals, alloys, and composites;
- o fluid, transport, and chemical processes; and
- o ultrahigh vacuum and containerless Processing.

Objectives of space materials processing include the production of materials in space, research on products and processes for future production in space, research to improve materials and processes on Earth, and production of ideal material standards.

Potential commercial applications in this field are expected to be mainly in finely dispersed alloys, ceramic materials, single crystals of semiconductor materials, and pharmaceuticals. Manufacturing in space in the near future is expected to only be in the latter two applications (see Reference 9). Examples of

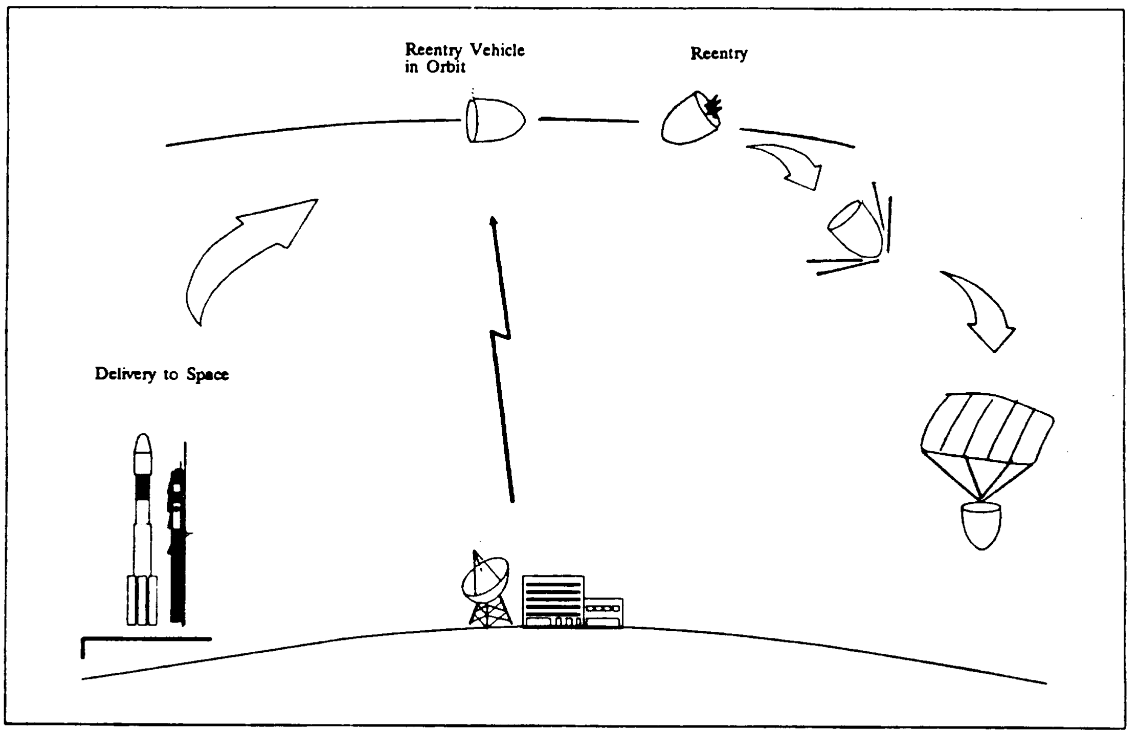


FIGURE 2-1 EXAMPLE MISSION PROFILE

types of crystals used for semiconductor materials are silicon, germanium, gallium arsenide, and indium antimonide.

The current U.S. and foreign Reentry Capsule Programs Are summarized in Table 2-1. Typical RV capsule shapes are illustrated in Figure 2-2. As opposed to the capsule design,the Space Shuttle is a fixed-wing reentry vehicle, with a wing span of 24 m (78 ft). For comparative purposes, the approximate total mass, payload mass, and the on-orbit duration for the Shuttle are 85,000 kg (187,000 lbs), 29,500 kg (65,000 lbs), and 8 - 30 days, respectively. The on-orbit durations for the Shuttle and many RV capsules are generally similar. However, the total mass for each RV capsule listed in Table 2-1 ranges from 0.2% to 8.2% of the total mass of the Shuttle; correspondingly, the payload masses range from 0.07% to 4.1% of that of the Shuttle. For purposes of this analysis, only unmanned commercial RVs were considered (the Space Shuttle was not included).

In May 1991, OCST estimated commercial launch service needs for the period 1993 - 2005. The number of commercial orbital launches which may include RV payloads (i.e., microgravity experiments/processing) was estimated to range between 3 and 18 per year between 1993 and 1999. For the period 2000 to 2005, the estimates ranged from 3 to 24 launches per year (see Reference 4). Because this is a new space activity for which there is no historical commercial experience, the actual level of activity is uncertain at this time. For the purpose of establishing a baseline for the EIS, however, it will be assumed that the activity level subject to licensing by OCST will not exceed an average of seven commercial microgravity payloads are anticipated to be licensed, launched, and returned from space by RVs annually between 1993 and 1999. This demand will be assumed to increase to an average of 10 commercial payloads per year between 2000 - 2005, with an anticipated annual maximum during this latter period of 20 to 30.

Generic RV Mode of Operation/Activities

To comply with the requirements of various commercial applications, RVs may operate in a variety of circular and elliptical orbits. Following the completion of the operational phase of the orbital mission, the vehicle launch systems will typically be used to align, inertially stabilize, and launch the RV to a suborbital trajectory for a touchdown at a pre-selected landing site within a controlled air space. Information on the type of propellants/fuels which may be use by the RVs is contained in **Section 4.3.3.**

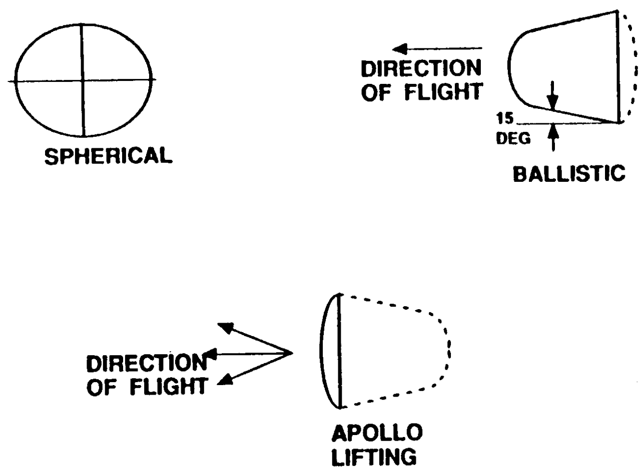
TABLE 2-1. CURRENT U.S. AND FOREIGN REENTRY CAPSULE PROGRAMS

Country	Sponsor (Capsule)	Capsule (Configuration)	Diameter (cm)	Total Mass (kg)	Payload Mass (kg)	On-Orbit Duration (Days)
USA	NASA/CCDS Office of Commercial Programs	TBD	TBD	TBD	80-120	15-30
USA	NASA (Lifesat)	Discoverer Type Ballistic	203	1363	409	60
USA	COR Aerospace (Deliver 24)	Sphere Ballistic	61	311	113	N/A
USA	COR Aerospace (Cheops 64)	Discoverer Type Ballistic	163	1180	714	N/A
USA	Orbital Recovery Corporation (Zeus)	Discoverer Type Ballistic	191	1270	730	7-60
USA	Space Industries Inc. (N/A)	Gemini Type Semi-Ballistic	N/A	N/A	N/A	N/A
Germany	Dornier (Raumkurier)	Gemini Type Ballistic	229	1500	450	7-30
Germany	MBB/Dara (Express)	Discoverer Type Ballistic	140	800	300	7
Italy	Aeritalia (Carina)	Gemini Type Ballistic	112	530	100	7-21
France	MAN Technologie (Ariane 4/5)	Apollo Type Ballistic	361	1812-2600	400-900	7-21
France	Matra Espace (Microliner)	Discoverer Type Ballistic	132	1005	290	Up to 90
United Kingdom	British Aero (Multi-Role)	Apollo Type Semi-Ballistic	396	7000	290	12-30
Japan	NASDA (Expti)	N/A Ballistic	99	200	N/A	N/A
USSR	Glavkosmos (Photon)	Sphere Ballistic	183	6300	500	14-30
USSR	Glavkosmos (Resurs-F)	Sphere Ballistic	183	6300	500	14-30
USSR	Glavkosmos (Biocosmos)	Sphere Ballistic	183	6300	500	14-30

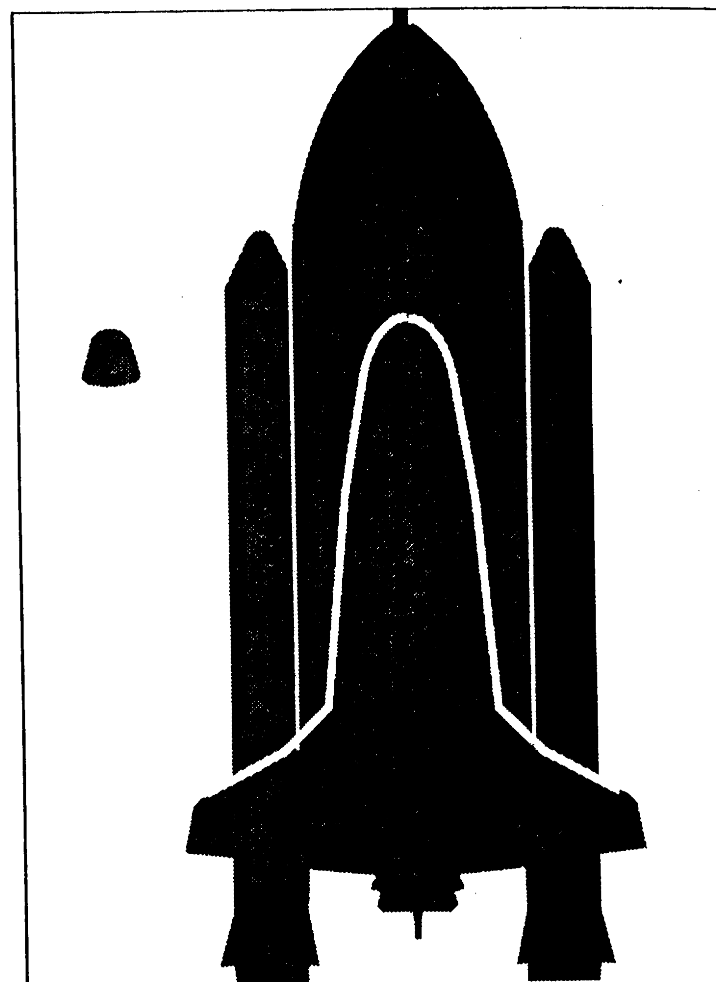
TABLE 2-1. CURRENT U.S. AND FOREIGN REENTRY CAPSULE PROGRAMS (Continued)

Country	Sponsor (Capsule)	Capsule (Configuration)	Diameter (cm)	Total Mass (kg)	Payload Mass (kg)	On-Orbit Duration (Days)
USSR	Glavkosmos (Nika)	Sphere Ballistic	183	N/A	1200	To 120
China	China GWIC (FSW-1)	Discoverer Type Ballistic	160	1900	20-150	5-8
China	China GWIC (FSW-2)	Discoverer Type Ballistic	160	1900*	150-300	10-15

Source: (1) DOT, OCST, Launch Systems Safety Support - Final Report "Survey of Reentry Vehicles" - April 16, 1991; and
(2) Burton, Lee, "Concerning Re-entry Capsules," Space, May-June 1990.



* SOLID LINE DENOTES THE PART OF THE VEHICLE THAT AFFECTS AERODYNAMICS. DOTTED LINE DENOTE THE REST OF THE VEHICLE.



SIZE COMPARISON: TYPICAL COMMERCIAL RV TO SPACE SHUTTLE

FIGURE 2-2 REENTRY VEHICLE CAPSULE SHAPE*
SOURCE: NACA RESEARCH MEMORANDUM L58E07a

During atmospheric reentry, the exterior of the RV is protected from aerothermodynamic heating by a thermal protection system (TPS). Methods which have been used to protect RVs in the past include:

- o ablation (erosion of surface material, such as silicone elastomers); and

- o radiative heat shield (e.g., ceramic-based surface insulation systems).

Either of these methods, or a combination of them, may be used to protect the RV against excessive heating.

After the vehicle reenters the atmosphere, it will decelerate to below sonic speeds. In order to further reduce the velocity of the RV, thus reducing the deceleration force produced during impact with the Earth's surface (or during recovery by air snatch operations) to mission-specific levels, supplemental deceleration systems (e.g., parachutes, retro thrusts) may be used. The landing impact area, which is dependent on site- and mission-specific requirements, will be sufficient to encompass the anticipated normal landing dispersions and all additional areas outside the dispersion area that are needed to ensure public safety.

For land and water recovery sites, crushable materials, inflatable air cushions, or other types of impact attenuation systems may also be used to help absorb the impact loads and diminish their effects on the payload. Another method to reduce landing impact loads is to construct the landing area using a soft material (possibly sand) to help absorb the impact shock. For water landing sites, an inflatable air cushion could provide a dual function by serving as a flotation collar. Although impact attenuation systems may not be required for the air snatch recovery method, a backup impact load absorption system may still be used.

Following touchdown, the RV's payload will be recovered in accordance with the requirements of the operating plans and procedures established for the site-specific landing area.

Consumable inert and toxic materials and waste products which may typically be used/produced during RV missions and then transported back to Earth are identified in Table 2-2. These materials may be in either solid, liquid, or gaseous phases.

TABLE 2-2. TYPICAL HAZARDOUS MATERIALS/WASTE TRANSPORTED BY RVs

* ACETONITRILE
ACETYLENE
ALUMINUM
AMMONIUM PERCHLORATE
AMPHOLYTE
ARGON
ARSENIC
CADMIUM
CARBON DIOXIDE
CARBON MONOXIDE
* DIMETHYLHYDRAZINE,1,1-
DIBORANE
FILM DEVELOPER
FILM FIXER
GALLIUM
GALLIUM ARSENIDE
HELIUM GAS
HELIUM LIQUID
HYDROGEN GAS
* HYDRAZINE
INDIUM
KEROSENE
LEAD
MANGANESE
MERCURY
* METHANOL
NEON
NITROGEN GAS
NITROGEN LIQUID
OXYGEN GAS
* PHOSPHOROUS
SODIUM ALUMINATE
SODIUM CHLORATE
SODIUM HYDROXIDE
* STYRENE
SULFUR HEXAFLUORIDE
TELLURIUM
TIN

* Classified as a hazardous air pollutant in the Clean Air Act

2.2 Alternative Actions - No Action

The proposed action covers a wide variety of RV designs, deceleration methods, and landing area alternatives. Although RV designs and specific operations may vary, similar materials have been used for the construction, thermal protection, and propelling of RVs for almost four decades. No known long-term environmental damage has resulted from reentry operations.

In general, different designs of RVs using materials presently used in launch vehicles and economically practical should have no significant adverse environmental effects. However, any RVs which differ significantly from the generic description (e.g., use of drastically different materials) will have to be evaluated in future documents. Thus, the only alternative to the proposed action is one of no action.

Under the No-Action alternative, U.S. commercial enterprises would not be allowed to operate any type of RV. Customers desiring reentry services would be dependent on the Space Shuttle, or on foreign RVs, for experimentation and manufacturing in space. This could hinder continued U.S. leadership in space research.

Germany, France, Italy, Japan, China, the United Kingdom, and the former Soviet Union are currently developing RV programs which may be made available to U.S. private sector users if they have no other choice. Thus, closing the RV market to the U.S. private sector would both foreclose potential domestic economic benefits and reduce our international competitiveness. If technological advances are achieved during the development and use of their RVs, foreign enterprises would gain further advantages in marketing these new goods/services. Thus, foreign economies could possibly be stimulated, while the U.S. would lag behind, both economically and technologically.

3.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

3.1 The Atmosphere

The Earth's atmosphere is best described in terms of four principal layers (Figure 3-1), hose boundaries are indistinct and vary slightly with latitude. These regions are identified by their temperature, structure, density, composition, and degree of ionization. The four layers can be grouped into the upper and lower atmosphere.

3.1.1 Upper Atmosphere

The upper atmosphere is composed of the ionosphere, the mesosphere,and the stratosphere. The ionosphere, where RVs are expected to orbit, extends from roughly 80 to 1000 km (50 to 620 mi). In this region, the concentration of electrons and positive ions is significant. The ionosphere contains several layers of differing properties, which are important in radio communications. The next lowest layer is the mesosphere, which extends from approximately 50 to 80 km (31 to 50 mi) and is a transitional layer between the ionosphere and the stratosphere. The stratosphere, extending from 10 to 50 km (6 to 31 mi), is a stable stratum containing the ozone layer, which absorbs the biologically harmful wavelengths of solar ultraviolet radiation. Each of these layers is described in greater detail below.

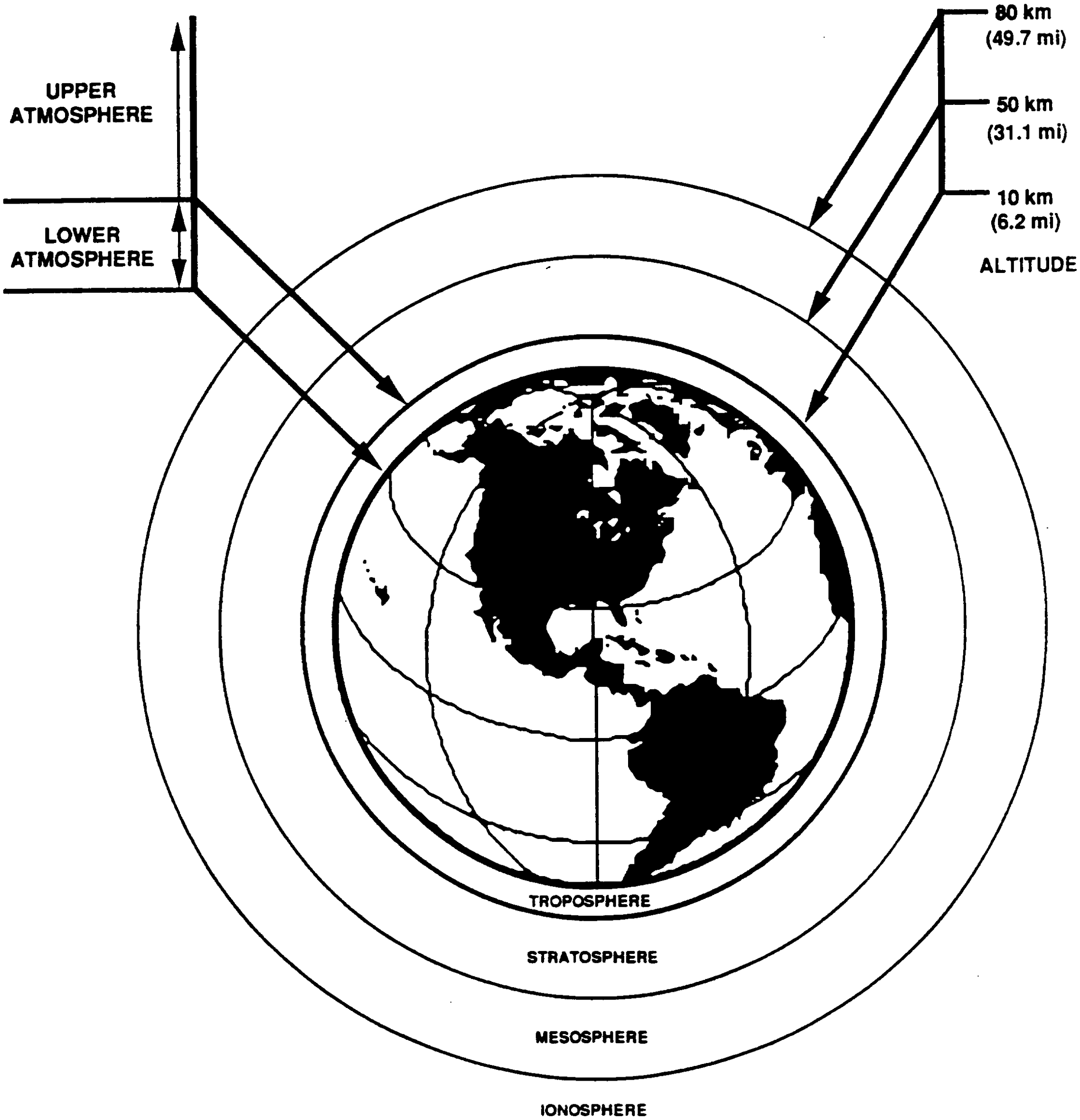
3.1.1.1 Ionosphere

The ionosphere, or thermosphere, is characterized by high ion and electron density. Although this region is a very high vacuum compared to the atmosphere at the Earth's surface, it still causes some drag on satellites orbiting within it. It is defined by Rees (see Reference 24) as the region where:

- energy input is dominated by solar ultraviolet photons and auroral energetic particles, electric fields and currents, and electrons;
- the major neutral constituents are O, N_2, and O_2 and the minor constituents are NO, N, H, He, Ar, and CO_2; and
- neutral atmospheric dynamics are strongly influenced by plasma (partially ionized gas) motions.

The ionosphere's several layers of differing properties are particularly important to low frequency radio communications. It is also the region where radiations in the visible spectrum, such as the aurora, originate. The ionosphere is influenced by solar radiation. variations in the earth's magnetic field, and motion of

FIGURE 3-1 LOCATIONS OF THE EARTH'S ATMOSPHERIC LAYERS



the upper atmosphere. Because of these interactions, the systematic properties of the ionosphere vary greatly with time (diurnally, seasonally, and over the approximately 11-year solar cycle) and geographic latitude.

Although the boundaries between the layers within the ionosphere are indistinct, the lowest region is the E layer, occurring between about 80 and 140 km, where NO^+ is the dominant ion (see Reference 24). The F_1 and F_2 regions occur in the general area between 140 and 1000 km. The F_2 region is always present and has the higher electron concentration (se Reference 20). The maximum electron concentration occurs in the F_2 region at around 300 km.

Above its maximum in the F_2 region, the electron concentration decreases monotonically out to several Earth radii, where the Earth's magnetic field and the protonosphere (the outermost portion of the ionosphere) become indistinct from the solar wind or inter-planetary plasma.

3.1.1.2 Mesosphere

The mesosphere (50 to 80 km) is a transition layer between the ionosphere -- which is characterized by high ion and electron density -- and the stratosphere -- where ozone concentration is most significant. The base of the mesosphere marks the upper boundary of the ozone layer. This area is warmed by the absorption of solar ultraviolet energy by ozone; ozone production/destruction occurs in the lower part of the mesosphere, although these mechanisms are most critical in the stratosphere, as described below. The temperature profile of the mesosphere decreases with altitude, reaching a minimum at the top of the mesosphere. This layer is an area of varied wind speeds and directions due to the occurrence of turbulence and atmospheric waves.

3.1.1.3 Stratosphere

The stratosphere (10 to 50 km), where stability and ozone are the identifying factors, is characterized by an increase in temperature with altitude. This is due to the ozone layer, which absorbs biologically harmful wavelengths of ultraviolet solar radiation. The base of the stratosphere is marked by an increase in ozone concentration (over levels found in the troposphere), while the highest concentrations are found near the middle of the stratosphere, in the center of the ozone layer, at approximately 25 km.

An ozone molecule, O_3, contains three atoms of oxygen and is produced by the chemical combination of an oxygen molecule, O_2, with an atom of oxygen (O). Atomic oxygen is produced by photolysis of molecules of oxygen (O_2) , nitrogen dioxide (NO_2), or ozone (O_3).

The ozone distribution in the stratosphere is maintained as the result of a dynamic balance between creation and destruction mechanisms. The distribution fluctuates seasonally and annually by approximately 25% and 5%, respectively. Ozone generation:

- o occurs in the upper stratosphere by the action of solar ultraviolet radiation upon molecular oxygen;

- o is determined by the intensity of solar radiation of wavelengths shorter than 242 nm and by the distribution in altitude of molecular oxygen and of ozone; and

- o is relatively insensitive to human activities.

Although it comprises only several parts per million in the stratosphere, ozone absorbs virtually all ultraviolet solar radiation of wavelengths less than 295 nm, and much of the radiation in the biologically harmful range of 290 to 320 nm (the ultra violet - B (UV-B) region). Ozone also contributes to the heat balance of the Earth by absorbing radiation in the infrared near the 9,600 nm wavelength.

3.1.2 Lower Atmosphere (Troposphere)

The lower atmosphere, or troposphere, extends from the Earth's surface to approximately 10 km (6.2 mi or 32,800 ft). Within this very turbulent region the Earth's weather evolves. This layer contains an estimated 75% of the total mass of the atmosphere. Solar radiation penetrates the atmosphere causing heating at the surface, which then decreases with height within the lower atmosphere. This variation in temperature makes it the most dynamic of the four atmospheric layers under consideration.

The major natural constituents of the lower atmosphere are nitrogen and oxygen, which comprise 76.9% and 20.7%, respectively, of this layer. The relative concentrations of these gases are highly uniform throughout the lower atmosphere. Water vapor is the next largest component (average of 1.4% by volume throughout the lower atmosphere), although its concentration is guite variable near the Earth's surface. Trace gases comprise the remainder of the lower atmosphere. These gases, in order of decreasing abundance in the unpolluted lower atmosphere, are argon, carbon dioxide, neon, helium, methane, krypton, nitrous oxide, hydrogen, xenon, and ozone.

3.2 Objects In Space

In orbit, RVs may Also release some objects into space as part of their operations, including separation bolts.

In comparison, meteoroids, a natural part of the interplanetary environment, sweep through the Earth's orbital space in a matter of minutes at an average speed of 20 km/s (~45,000 mph). At any one instant, a total of 200 kg (441 lbs) of meteoroid mass is within 2,000 km (1,240 mi) of the Earth's surface (see Reference 20). Also within 2,000 km (1,240 mi) above the Earth's surface are an additional estimated 3,000,000 kg (~3,300 tons) of man-made orbiting objects. Most of this mass is concentrated in objects larger than 10 cm (4 in) in diameter. Of the roughly 7,000 tracked objects (those larger than 10 cm) orbiting the earth, most are in low earth orbit (as opposed to the geostationary orbit at an altitude of 35,787 km).

An additional 30,000 to 70,000 man-made objects, ranging in size from 1 to 10 cm in diameter, have also been estimated to be orbiting the earth. However, these objects are too small to be tracked.

Thousands of fragments of all sizes reenter the Earth's atmosphere each year. Similar to natural meteoroids, most disintegrate in the atmosphere and are converted to gases and ash, or break into extremely small pieces. Very few actually reach the Earth's surface intact. The chance of harm from reentering space objects is much less than the chance of being hit by one of the 500-plus meteorites that strike the Earth annually (see Reference 21).

3.3 **Site-Specific Environment (Earth's Surface)**

Landing areas for commercial RVs will be identified and evaluated in site-specific EA/EIS documents; impacts to these areas are beyond the scope of this document. However, the factors that must be addressed in site-specific EAs/EISs during the permitting of landing sites for RVs are:

- o air resources (e.g., air quality, Federal and state ambient air quality standards (both primary and secondary), and the National Emission Standards for Hazardous Air Pollutants);
- o water resources (e.g., surface and groundwater quality);
- o land resources (e.g., topography, geology, soils, and wetlands/floodplains);
- o ambient noise levels;
- o biotic resources (e.g., flora and fauna, including any endangered and/or threatened species), and
- o community description (e.g., local demography, economy, and cultural or archaeological resources)

4.0 ENVIRONMENTAL IMPACTS AND CONSEQUENCES OF THE PROPOSED ACTION

For the purposes of this programmatic EIS, the environmental impacts of the proposed action can be grouped into the following four general categories: 1) effects on the upper and lower atmosphere; 2) noise sources and effects near the Earth's surface; 3) landing effects; and 4) other effects (site-specific). Socioeconomic effects, reentry safety effects, and secondary effects are also discussed.

The following detailed evaluations did not identify any significant adverse environmental effects. As indicated in this programmatic discussion, however, many potential adverse impacts are dependent on the specific vehicle design and mission requirements. Site specific landing site impacts have only been identified and addressed on a generic basis. Landing site impacts will require further detailed site-specific evaluations. Vehicles and operations which fall outside the scope of this Programmatic EIS may require separate evaluations.

4.1 Atmospheric Effects

The atmospheric effects will be categorized by the layer in which they occur, since they differ significantly within each layer. For this programmatic EIS, grouping of the four major layers into the upper and lower atmosphere, as discussed in **Section 3**, is sufficient. The upper atmosphere, from higher to lower altitude, consists of the ionosphere, the mesosphere, and the stratosphere; the lower atmosphere is also known as the troposphere.

4.1.1 Upper Atmosphere

Typical RVs are generally expected to orbit the Earth in the upper (F_2) region of the ionosphere. During reentry, RVs will pass through the other layers of the upper atmosphere.

For those RVs that use a propulsion system to deboost the vehicle, exhaust products may be emitted into the upper atmosphere prior to entering their deorbit trajectory. These exhaust products are similar to the launch exhaust products which have been evaluated in the Programmatic Environmental Assessment of Commercial Expendable Launch Vehicle Programs (see reference 7) and which were found to cause no adverse impacts in the upper atmosphere. Similar findings were reported in other environmental documentation (e.g., the Space Shuttle EIS). **Table 4-1** summarizes data on common launch vehicles, oxidizers/propellants they use, and quantities of selected exhaust products they introduce into the upper atmosphere during launch from Earth to space. The quantities of propellants

TABLE 4-1. EXHAUST PRODUCTS EMITTED INTO UPPER ATMOSPHERE BY COMMON LAUNCH VEHICLES

VEHICLE	STAGE	OXIDIZER/PROPELLANT	QUANTITY OF SELECTED POLLUTANTS EMITTED INTO UPPER ATMOSPHERE PER LAUNCH (kg)[1]				
			HCl	CO	NO[2]	CO_2	H_2O
Scout	2 3 4	Solid Solid Solid	1,200	1,800	4	165	360
Delta	2 3	N_2O_4/Aerozine 50 Solid	0	19,800	70	14,750	13,000
Atlas/Centaur	2	$O_{2(liquid)}/H_{2(liquid)}$	0	22,000	0	16,500	27,000
Titan III Centaur	2 3	N_2O_4/Aerozine 50 $O_{2(liquid)}/H_{2(liquid)}$	24,000	46,400	2,300	40,100	66,250

[1]To convert from kilograms (kg) to pounds (lbs) mutiply by 2.20

[2]The NO formed from N_2 impurity in the stages using liquid oxygen is not included. The concentration of NO in the exhaust of such stages has been estimate at 3 ppm for N_2 impurity level of 600 ppm. The resulting NO emissions are negligible.

SOURCE: Programmatic Environmental Assessment of Commercial Expendable Launch Vehicle Programs (February 1986) necessary to deboost the RV are typically much less than these launch quantities and therefore are similarly expected to have minimal impact on the environment.

In addition, RVs may have potential effects on the upper atmosphere due to their thermal protection systems. At orbital velocity, RVs possess a tremendous amount of kinetic energy, which must be dissipated during reentry as the vehicles decelerate to their impact or landing velocity. The RV typically reenters the Earth's atmosphere at velocities of Mach (M) 25 to 30. As the RV passes through the atmosphere, atmospheric friction decelerates it to below M 1, and converts its kinetic energy primarily into thermal energy (heat). Within the stagnation zone, an area immediately in front of the RV, an area of compressed, extremely hot, ionized and stagnant air is formed. Heat from the hot gas is transferred to the surface of the RV.

The heat generated during reentry is not only dependent on atmospheric density, but is also inversely proportional to the square root of the radius of the RV's nose cone and proportional to the cube of its velocity. Hence, blunt nose RVs are heated less than slender ones; and lifting RV designs, which use the glider principle, produce less heat than ballistic hyperbolic descent designs because their velocity is typically lower. Thus, a full evaluation of thermal impacts during reentry is dependent on both vehicle- and mission-specific criteria.

Temperatures generated within the hottest area (the stagnation zone) during ballistic reentry may exceed 11,100°C (20,000°F) (Reference 13). Heat generation is not as severe on vehicles which are capable of some degree of lift during reentry; the temperature of the Apollo capsule surface reached about 2,760°C (5,000°F) (Reference 13). Thus, it is expected that thermal protection systems will be required for commercial RVs to ensure the vehicle does not burn up during reentry. The choice of systems to be used is dependent upon the vehicle design, the reentry temperatures the RV may be subject to, and mission-specific requirements of the commercial payload.

Thermal protection systems for the exterior of RVs which may be feasible include ablation, radiative heat shield, heat sink, transpiration, and radiator. However, to date, heat sink, transpiration, and radiator systems have not been used to protect the exterior surface of RVs from the thermal stress of reentry; therefore will not be covered by this EIS.

Thermal protection systems which are evaluated in this document include ablative and radiative heat shields (e.g., ceramic tile) systems.

Ablation. Ablation cooling or simple ablation is a process in which heat energy is absorbed by a material (the heat shield) through melting, vaporization and thermal decomposition and then dissipated as the material vaporizes or erodes. In addition, high surface temperatures are reached and heat is dissipated by surface radiation, pyrolysis of the surface material causing formation of a "char," and the generation of chemical by-products which move through the char carrying heat outward towards the surface boundary. The rejected chemical by-products then tend to concentrate in the ablation boundary layer where they further block convective heating. These ablative materials may be chemically constructed or made from natural materials.

A common man-made ablative material in current use is a firm silicone rubber whose chemical name is phenolmethylsiloxane. It has a silicone elastomer base, with silica filler and carbon fibers for shear strength. Its primary use is in high shear, high heatflux environments; it is used on control surfaces and nose cones of hypervelocity vehicles, including some parts of the Space Shuttle. This material yields a carbonaceous char on pyrolysis, which is a glassy, ceramic-type material composed of silicon, oxygen, and carbon (Reference 1). An ablative material known as polydimethylsiloxane has been used on manned reentry capsules in the past, including the Mercury program. An elastomeric silicon ablative material was used in the Discoverer program. **Table 4-2** gives examples of typical chemical reactions and phase changes occurring during ablation. An example of a natural material is the oak wood heat shield used on the Chinese FSW reentry vehicles.

Carbon char and polymer binder fibers could also potentially increase particulate loading in the atmosphere along the reentry trajectory. Because of the small quantity of particulates and the dispersive properties of the atmosphere, no adverse atmospheric effects are expected based on the projected level of commercial activity. Furthermore, to date no adverse effects have been identified from prior reentries.

Radiative Heat Shields. Some radiation cooling takes place with any thermal protection system. If virtually all heat dissipation is due to radiation from the outer shell of the RV, the method can be considered as a radiative heat shield. The ceramic tiles used on parts of the Space Shuttle are an example of this method.

TABLE 4-2.
TYPICAL CHEMICAL REACTIONS AND PHASE CHANGES OCCURRING IN ABLATION

TYPE OF REACTION	EXAMPLE*
Depolymerization	$(C_2F_4)_n \rightarrow nC_2F_4$
Pyrolysis (resin)	Phenolic $\rightarrow$ Products
Cracking (volatiles)	$CH_4 \rightarrow C + 2H_2$
Char-volatile reactions	$C + H_2O \rightarrow CO + H_2$
Char-reinforcement reactions	$3C + 2SiO_2 \rightarrow SiC + 2CO$
Phase transitions	Alpha-Quartz $\rightarrow$ Beta-Quartz
Melting and vaporization	$SiO_{2(s)} \rightarrow SiO_{2(l)} \rightarrow SiO_{2(g)}$
Sublimation	$C_{(s)} \rightarrow C_{(g)}$
Dissociative vaporization	$SiO_{2(l)} \rightarrow SiO_{2(g)} + 1/2\ O_{2(g)}$
Combustion	$C + O_2 \rightarrow CO_2$
Chemical corrosion	$SiO_2 + 4HF \rightarrow SiF_4 + 2H_2O$
Molecular dissociation	$N_2 + M \Longleftrightarrow N + N + M$
Wall-catalyzed recombination	$H + H + M \Longleftrightarrow H_2 + M$
Atomic species reactions	$C + N + M \Longleftrightarrow CN + M$
Electron-producing reactions	$N + O \Longleftrightarrow NO^+ + e^-$
Charged particle reactions	$CHO^+ + H_2O \Longleftrightarrow CO + H_3O^+$

*Base on a typical silicone-based elastomer.

As the surface is heated by the airstream, some of the heat is radiated back until an equilibrium temperature is reached. The material must be able to stand extremely high surface temperatures without melting; choice of materials is limited by their radiative properties, oxidation chemistry, and melting temperatures. The Space Shuttle for example, uses silica-based ceramic tiles. In the past, metals such as beryllium, titanium, vanadium, zirconium, molybdenum, and tungsten have been evaluated as possible materials for radiative heat shields (Reference 9).

Radiative heat shield systems are self-contained and generally do not introduce substances into the atmosphere; no adverse effects have been identified from the ceramic tiles used on parts of the Space Shuttle. Thermal protection systems on commercial RVs utilizing heat shield systems are not anticipated to cause any adverse atmospheric impacts. Potential RV impacts within the upper atmosphere are changes in electron concentrations (ionosphere layer) and the depletion of ozone (principally in the stratosphere layer). As discussed below, no adverse effects in the upper atmosphere are anticipated to occur as a result of the proposed action.

4.1.1.1 Changes in Electron Concentrations

Of the exhaust products previously evaluated (those generated during launch from Earth to space), carbon dioxide (CO_2), water (H_2O), and atomic hydrogen (H) were found to have an effect on electron concentrations in the upper atmosphere. These compounds can react with ambient electrons and ions and effectively form a "hole" in the F-region of the ionosphere by reducing the concentration of electrons and ions within the path of the vehicle. The reduction in the electron and ion concentration can potentially affect radio communication, such as short-wave broadcasts, which interact with the ionosphere. This effect in the F-region is believed to be caused by a rapid charge-exchange reaction between the exhaust products and ambient atomic oxygen ions (O^+), the dominant positive ions above 140 km, as follows:

$$H_20 + O+ \text{-->} H_20^{+} + O$$

followed by the rapid recombination:

$$H_2O^{+} + e^{-} \; > OH + H$$

Similar rapid reactions also occur with carbon dioxide and hydrogen. These reactions result in a net decrease in electron concentration in the F-region. At lower altitudes of the ionosphere (below 140 km or 88 mi) this reaction is not as effective because the dominant positive ions are NO^+ and O_2^+, not atomic oxygen (O^+).

An experimental test firing of the propulsion unit used by the Space Shuttle for maneuvering within the ionosphere was conducted in July 1985. The propellants used, monomethylhydrazine (MMH) and nitrogen tetroxide (N_2O_4), are similar to propellants used for routine launches of other space vehicles; however, quantities used for orbital maneuvering of the Shuttle are much smaller than that consumed during launch.

Exhaust products from the 290 kg (640 lbs) total mass of MMH and N_2O_4 consumed during the experimental test firing consisted of approximately 117.7 kg (40.6%) nitrogen, 92.5 kg (31.9%) carbon dioxide, 75.7 kg (26.1%) water, and 4.1 kg (41.4%) hydrogen by mass, assuming complete combustion. Thus, about 172 kg of potential electron-depleting substances (CO_2, H_2O, and H) were emitted. The associated "ion/electron hole" disappeared into the lower F-region within 5 minutes. Assuming the quantity of propellants utilized by RVs during reentry is equivalent to that used in the above test, and the by-products are equivalent, the reentry by-products represent only 0.2% of by-products produced in the upper atmosphere during a typical launch from Earth to space.

During reentry, the ablative processes begin in the upper atmosphere when the pyrolysis temperature of the material is reached resulting from an increase in atmospheric friction. At altitudes above 120 km (75 mi), atmospheric density is generally insufficient to cause the onset of ablation. Therefore, since the ablative processes/reactions are generally initiated at altitudes below the F-region, impacts to the electron concentrations in the ionosphere layer are expected to be negligible.

4.1.1.2 Effects on the Ozone Layer

Ozone is destroyed by several processes, including the catalytic chain reaction of nitrogen oxides (NO_X). Other relevant destruction mechanisms include direct reaction of oxygen atoms (O_X) with ozone and catalytic chain reactions with chemical radicals containing hydrogen, chlorine, or nitrogen (HO_X, ClO_X, NO_X). Radical species can be generated by the reaction of chloroflurocarbons with ultraviolet radiation, or by several naturally occurring chemical reactions have been identified as ozone destruction mechanisms. The nitrogen, hydrogen, and chlorine oxide radicals involved in these reactions are not used up by the reactions, but are regenerated and therefore remain capable of reacting with additional ozone molecules.

ozone destruction: $NO + O_3 \rightarrow NO_2 + O_2$
Catalyst regeneration: $NO_2 + O \rightarrow NO + O_2$

Each catalyst chemical species is, therefore, capable of removing thousands of ozone molecules before being removed from the cycle by some other process (e.g. reaction of NO_2 with the hydroxyl radical OH, to form nitric acid, HNO_3). Consequently, even though the concentration of these catalytic molecules in the stratosphere is quite low (1 to 10 parts per billion), they can have important effects .

The impact of space vehicle operations on ozone depletion has been extensively evaluated in previous EAs/EISs (References 7,18) and subsequent analyses. RVs generate chemical reactions that can affect the ozone by three mechanisms:
1) propellants, 2) kinetic energy, and 3) thermal protection system by-products.

Propellants. The types and quantities of potential propellants for use in RVs have been summarized in Section 4.1.1. Recent studies have assessed the effects of the Space Shuttle launch vehicle and other large launch vehicles which use solid and/or liquid propulsion systems on the ozone. One study indicated that while rocket launches can temporarily disturb the local stratosphere within the exhaust plume up to three hours after launch, even with extreme conditions, the reduction in column ozone was probably less than ten percent over a small area, and the rate of reduction for the impacted area decreases to near zero within a day. The regional effects are smaller than can be detected by satellite observations (Reference 25).

While there are a number of uncertainties in ozone research and the effects of chemicals on the ozone, atmospheric modeling studies which assume the present rate of rocket launches do not show a significant global impact on the ozone layer. Other products of rocket launches which can potentially destroy ozone have even smaller effects from those substances as far as global effects are concerned. However, even with the quantities of chlorine and other exhaust products released by NASA's Space Shuttle and the Titan IV, the global impact to the ozone layer from rocket launches is insignificant compared to other sources of chlorine release (Reference 25). Rockets used for RV launches use far less propellants that the Space Shuttle and therefore can be expected to have less impact. In addition, the amount of exhaust due to RV operations is expected to be much less than for launch vehicles.

Kinetic Energy. Much of the RV's kinetic energy will be dissipated within the atmospheric layers containing ozone. In the shock heated wake of the RV, atmospheric nitrogen and oxygen will be converted to NO. This effect is common to any object entering the Earth's atmosphere. The quantity of NO generated, which is proportional to the amount of kinetic energy dissipated, is dependent upon the RV's design and operating conditions. The larger the vehicle, the greater its kinetic energy and the more NO produced. The Space Shuttle is predicted to produce about 9 metric tons (19,800 lbs) of NO per reentry. In comparison, natural NO production (through solar energy interactions) is estimated to be about 10^5 metric tons (2,200,000,000 lb) per year. Assuming that all commercial RVs were a size comparable to the Space Shuttle, the annual NO production from the currently projected commercial RV activity would be less than 0.03% of the natural annual production. Thus, it would take over 111,000 reentries per year (about 300 a day) for a vehicle the size of the Space Shuttle to equal the natural annual production of NO. However, RVs typically **(see Table 2-1**) range in total mass (vehicle and payload) from 0.27% to 12.3% of the total mass of the shuttle. In addition, the RV production of NO is highly localized along the trajectory and disappears in a few days (Reference 18). Because of the very small quantities of NO potentially produced by RVs, impact to the ozone due to kinetic energy is negligible.

Ablation. NO may also be generated as a by-product of the thermal protection system(s) employed. For cases of RVs that use ablative thermal protection systems, ablation occurs in the upper atmosphere and ends when the surface heating rate of the RV no longer supports pyrolysis. The following chemical species, and their sources, have been identified in or are expected to be present in the reentry bow shock and wake region (**see Figure 4-1**) during the ablative process (Reference 12,13):

associated with the air: N_2, O_3, O_2, NO, N, O, NO^+, O_2^+, O^+, and e^-

associated with ablation products: H_2, H_2O, OH, H, CO, CO_2, C, and polymer binder fibers (e.g., carbon). **Table 4-3** summarizes the thermal degradation products of selected polymers.

other species (uncertain of source): Na, Na^+, $Na(H_2O)^+$, H_30^+, O^-, O_2^-, and OH^-

In order to assess the potential effects of ablation on the ozone layer, a vehicle equivalent in size to the cargo bay of the Space Shuttle (a cylinder 15m long by 5m in diameter) with a uniform thickness of 2.0 cm of ablative material over the lower half of the vehicle was used as an upper limit for sizes of ablative heat shields for RVs. Given ablative material similar to the LifeSat

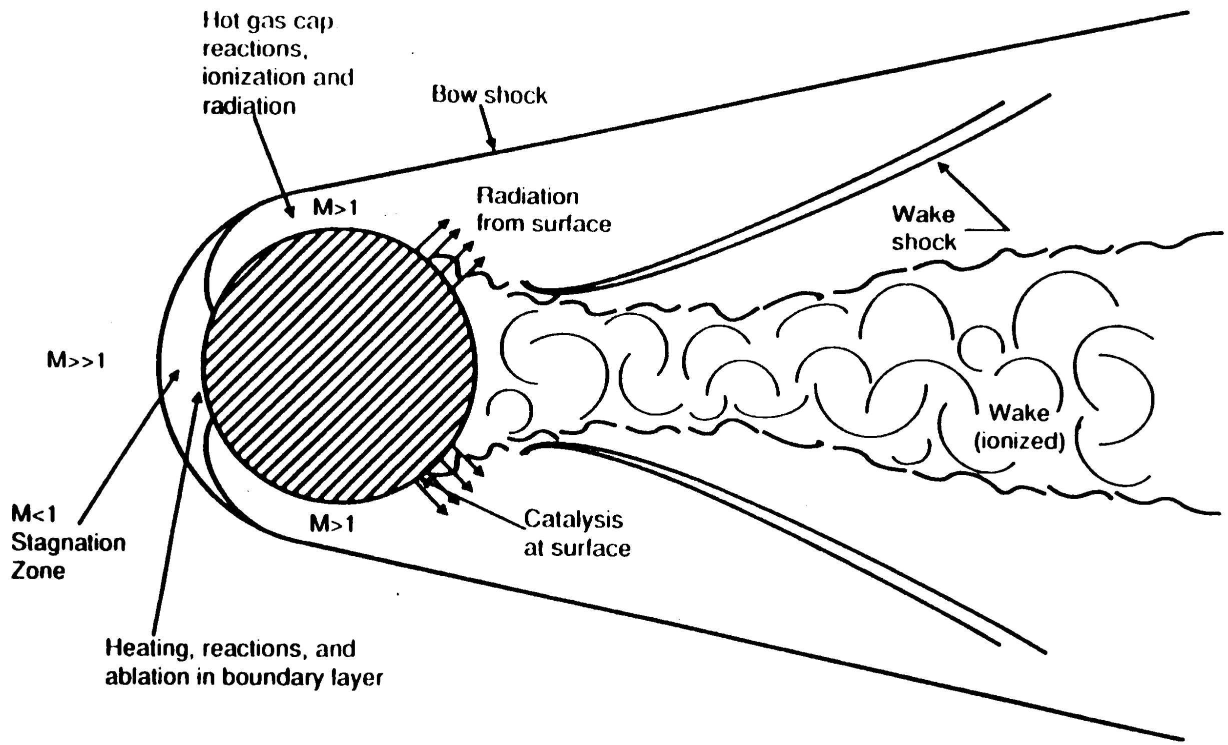


FIGURE 4-1 BOW SHOCK WAVE ABOUT A HYPERVELOCITY SPHERE

TABLE 4-3.
THERMAL DEGRADATION OF SELECTED POLYMERS

Polymer, Poly-	Structure	Degradation Products
Ethylene	$-CH_2-CH_2-$	<1% monomer
Styrene	$-CH_2-CHO/-$	40% monomer
Alpha-methylstyrene	$-CH_2-C(CH_3)O/-$	95% monomer
Methacrylate	$-CH_2-CH-COOCH_3$	<1% monomer
Methyl methacrylate	$-CH_2-C(CH_3)-COOCH_3$	95% monomer
Acrylonitrile	$-CH_2-CHCN-$	<1% monomer
Methacrylonitrile	$-CH_2-C(CH_3)CN-$	85% monomer
Trifluoroethylene	$-CF_2-CFH-$	<1% monomer
Tetrafluoroethylene (Teflon)	$-CF_2-CF_2-$	>95% monomer
Vinyl chloride	$-CH_2-CHCl-$	>95% of HCl
Butadiene	$-CH_2-CH=CH-CH_2-$	20-30% monomer

vehicle, the heat shield would be on the order of 2,700 kg. (Note: the LifeSat vehicle has 140 kg of ablative material). The specific ablative material may vary for different RVs; however, any of the by-products which could affect the ozone (i.e., H_2O, CO_2, H, NO) would not appreciably exceed this order of magnitude. Thus, NO produced by ablation is negligible in comparison to the quantities described above.

Of the substances that contribute to ozone depletion, primarily nitric oxide (NO) is expected to be generated during the RV reentry (Reference 18). In summary, the amount of NO produced by RV's is small in comparison to natural NO production and the exhaust released by other space activities. NO is only one of the substances which contribute to ozone depletion. In fact, research to date has indicated that NO is not the major contributor to ozone depletion (Reference 19). Moreover, ozone levels within the upper atmosphere fluctuate both seasonally and annually by approximately 25% and 5%, respectively. Consequently, NO production resulting from commercial RV activities is not expected to have any measurable effect on ozone levels.

Concern has also been raised regarding the effect of "seeding" the atmosphere with particulates which could also serve to catalyze the depletion of stratospheric ozone. Whether this occurs, however, given the ablation particulates generated from RV operations, and the extent to which this may occur are not known. As atmospheric research and development continues, this issue will be reexamined, as appropriate, in future tiered EAs/EISs.

4.1.2 Lower Atmosphere

Pollution and the degradation of the air quality in the lower atmosphere are regulated principally by the Clean Air Act (CAA) of 1970, as amended through 1990. The main pollutants of concern are oxides of nitrogen and sulfur, carbon monoxide, ozone, particulates, lead, hazardous air pollutants, chlorofluorocarbons (CFCs), and volatile organic compounds (VOCs) contained in some solvents. In order to protect human health and the environment, EPA has designated air quality control regions within each state, each of which contains multiple sampling stations. The National Ambient Air Quality Standards (NAAQS) (**Table 4-4**) are set to ensure protection of public health by providing standards for concentrations of specific pollutants over designated time periods.

As discussed below, the proposed action will have no adverse effects on the lower atmosphere. EPA has set NAAQs for ozone, carbon monoxide, lead, particulate matter, sulfur oxides and nitrogen oxides. Under normal conditions, RV operations should not

TABLE 4-4. NATIONAL AMBIENT AIR QUALITY STANDARDS

	PRIMARY STANDARD		SECONDARY STANDARD	
	($\mu g/m^3$)	(ppm)	($\mu g/m^3$)	(ppm)
Particulate matter $(PM)_{10}$				
Annual geometric	50		Same	
24-Hour	150[1]		Same	
Sulfur dioxide (SO_2)[2]				
Annual arithmetic	80	0.03	None	
24-Hour	365	0.14	None	
3-Hour	None		1,300[1]	
Carbon monoxide (CO)[3]				
8-Hour	10,000	9	Same	
1-Hour	40,000	35	Same	
Ozone (O_3)[3]				
1-Hour[4]	235	0.12	Same	
Nitrogen dioxide (NO_2)[3]				
Annual arithmetic	100	0.053	Same	
Lead (Pb)				
Calendar quarter	1.5		Same	

Annual and quarterly standards and limits are not to be exceeded. Other standards are based on the highest high for one year and the highest, second-high for five years.
[1]Concentration not to be exceeded more than once per year.
[2]These standards are defined in micrograms per cubic meter ($\mu g/m^3$). Conversion to ppm is based on reference conditions of 25°C and atmospheric pressure of 760 mm of mercury (1,013.2 millibars).
[3]These standards are defined in parts per million (ppm). Conversion to micrograms per cubic meter (ug/m^3) is based on reference conditions.
[4]Not to be exceeded more than once per year based on a 3 year average of the number of concentrations >0.12 ppm.

add an appreciable emission burden and, therefore would not have a significant effect on ambient air quality.

It is important to note, however, that the assessment of RV operations contributions to air quality and the failure of an area to attain the NAAQS is site-specific and will be addressed, as appropriate, in individual EAs/EISs.

The 1990 amendments to the CAA regulate many hazardous air pollutants and provide for reduction of pollutants associated with global warming (the greenhouse effect) and acid rain.

Greenhouse Effect. The Earth's surface is heated by short-wave solar radiation which is transmitted through the upper atmosphere. This radiation is absorbed and re-radiated back towards space in the form of long wave, or infrared, radiation. Some of this outgoing infrared radiation is "trapped" by atmospheric constituents/pollutants, thus causing a slight rise in tropospheric temperature. The main environmental concern is that rising global temperatures could cause glacial melting, which in turn would raise sea levels and inundate coastal areas.

Acid Rain. "Acid rain" is the acidification of rainfall by pollutants emitted into the lower troposphere. These compounds, mainly sulfur dioxide and NO_X, are formed principally by the combustion of fossil fuels. Reactions in the atmosphere form sulfuric and nitric acid causing a lowering of the pH (increasing the acidity) of the rainwater. In areas of chronic acid deposition, lakes, streams, and forests can be acidified to the point where considerable biological damage occurs.

Hazardous Pollutants. Title III of the Clean Air Act Amendments of 1990 addresses hazardous air pollutants that EPA must regulate. The Act listed 189 chemicals and compounds as hazardous pollutants. **Table 2-2** shows substances classified as hazardous air pollutants which may be transported by RVs. **Tables 4-6 thru 4-11** note the characteristics of common rocket propellants. The Act regulates emissions from new and modified major sources - any stationary source of air pollutants which emitted an aggregate of at least 10 tons per year of any hazardous air pollutant or at least 25 tons per year of a combination of listed hazardous air pollutants. Individual new or modified launch sites expected to have sufficient launches to exceed these emission thresholds may be affected by these provisions. Conceivably, there may be very small amounts of fuel remaining in the reentry vehicle upon recovery, which would not be released under normal conditions. These issues would need to be addressed in site specific EAs/EISs.

The Clean Air Act Amendments also set an objective to prevent the sudden, accidental release of extremely hazardous substances and to minimize the consequences of any such release. The owners and operators of facilities that deal with such substances must use hazard assessment techniques to identify hazards from such releases, design and maintain a safe facility, and minimize the consequences of accidental releases. EPA is developing a list of extremely hazardous air pollutants, and to develop guidance for accident prevention and correction. Accidental release risk would need to be addressed for individual launch operations and recovery sites.

During a ballistic RV reentry, no substances are expected to be released into the lower atmosphere, other than a particulate or other discharge which may be released by some landing systems (e.g., parachute deployment via mortar). The quantities of particulates RV operations should be negligible when compared to those emitted during launch which are considered to pose only short-term insignificant impacts.

During a non-ballistic RV reentry (i.e., lift and drag capability), some exhaust products may be introduced into the lower atmosphere, depending on the specific vehicle design. The composition of these exhaust products would be similar to those evaluated in previous EAs/EISs for launch activities (Reference 7,18), and the quantity emitted in the lower atmosphere during reentry would be much smaller than that emitted during launch (**Table 4-5**). Since launch exhausts were found to have no significant long-term impacts, even at the projected level of commercial RV activity, no adverse effects are anticipated in the lower atmosphere from RV operations.

4.2 Noise Sources and Effects

Noise generation by the commercial RVs during reentry can be grouped into the following two primary divisions: 1) sonic boom generation by the RV as it descends towards the Earth's surface; and 2) noise generated by tracking and recovery equipment. As discussed below, no significant adverse noise effects are anticipated from the commercial RV activity.

4.2.1 Reentry Operations (Sonic Booms)

Sonic booms are impulse noises which produce startling audibility and dynamic characteristics similar to manmade explosions and thunder produced by lightning. At supersonic speeds, acoustical disturbances travel slower than the body. Consequently at the high speeds, a shock wave is created by the body with rapid pressure

TABLE 4-5. EXHAUST PRODUCTS EMITTED INTO LOWER ATMOSPHERE BY COMMON LAUNCH VEHICLES

VEHICLE	STAGE	OXIDIZER/PROPELLANT	QUANTITY OF SELECTED POLLUTANTS EMITTED INTO LOWER ATMOSPHERE PER LAUNCH (kg)[1]		
			HCl	CO	NO[2]
Scout	1	Solid	2,530	4,500	7
Delta	0 1	Solid $O_{2(liquid)}$/RP-1	6,600	21,300	23
Atlas/Centaur	0 1	$O_{2(liquid)}$/RP-1 $O_{2(liquid)}$/RP-1	0	40,650	0
Titan III Centaur	0 1	Solid N_2O_4/Aerozine 50	71,900	127,000	200

[1]To convert from kilograms (kg) to pounds (lbs) multiply by 2.20.
[2]The NO formed from N_2 impurity in the stages using liquid oxygen is not included. The concentration of NO in the exhaust of such stages has been estimate at 3 ppm for N_2 impurity level of 600 ppm. The resulting NO emissions are negligible.

SOURCE: Programmatic Environmental Assessment of Commercial Expendable Launch Vehicle Programs (February 1986) changes occurring across the shock front of the body and produces sonic booms. The shock wave and associated sonic booms then radiate behind the body in a conical shape. An observer hears a sonic boom when the shock wave passes overhead (**Figure 4-2**). The region in which the boom is heard is also illustrated. Here the intensity is greatest directly below the reentry trajectory and decreases with radial distance from the ground track (**Figure 4-3**).

Although of very short duration (approximately 300 ms), the booms typically have high sound pressure levels of 130 to 134 dB (approximately 65 to 101 N/m^2) and occur over a large area below the RV. Air turbulence, and wind and temperature variations within the atmosphere also have been shown to affect sonic boom ground pressure levels. Although temperature effects on overpressures are small, wind effects tend to increase as the M speed of the RV decreases. Headwinds (which tend to increase the apparent ground velocity of the shockwave following the RV) with a large vertical gradient also tend to increase overpressures, while tailwinds decrease them. The extent or distance that a sonic boom can be heard on each side of the reentry ground track, and its intensity, are dependent upon such variables as the RV's speed (i.e., the velocity vector parallel to the ground track), altitude, weight, exterior configuration, flight conditions, and prevailing atmospheric conditions. Sonic boom generation may begin where atmospheric density increases enough for shock wave formation, or at altitudes of 100 - 120 km. Therefore, sonic boom effects from RV reentry are dependent on vehicle- and mission-specific parameters. Environmental effects of sonic booms include those on human, animal, and marine receptors. Potential structural effects of the accompanying pressure waves should also be evaluated.

Any body moving faster than the local speed of sound can produce a sonic boom which is independent of the noise produced by the body. Thus, the boom produced by an unpowered projectile (e.g., a ballistic RV) traveling supersonically has essentially the same characteristics as a powered projectile, and under ideal conditions will produce the idealized N-wave associated with sonic booms.

Comparative Measures of Sonic Booms Effects

The following present points of reference by which one can measure the impact of sonic booms:

Examples of Sonic Booms. Thunder overpressure resulting from lightning strikes at a distance of 1 km (0.6 miles) is estimated to be near 100 N/m^2, and is almost indistinguishable from that of a sonic boom. The unexpected, loud impulsive noise of sonicbooms, similar to thunder, tends to cause a startle effect

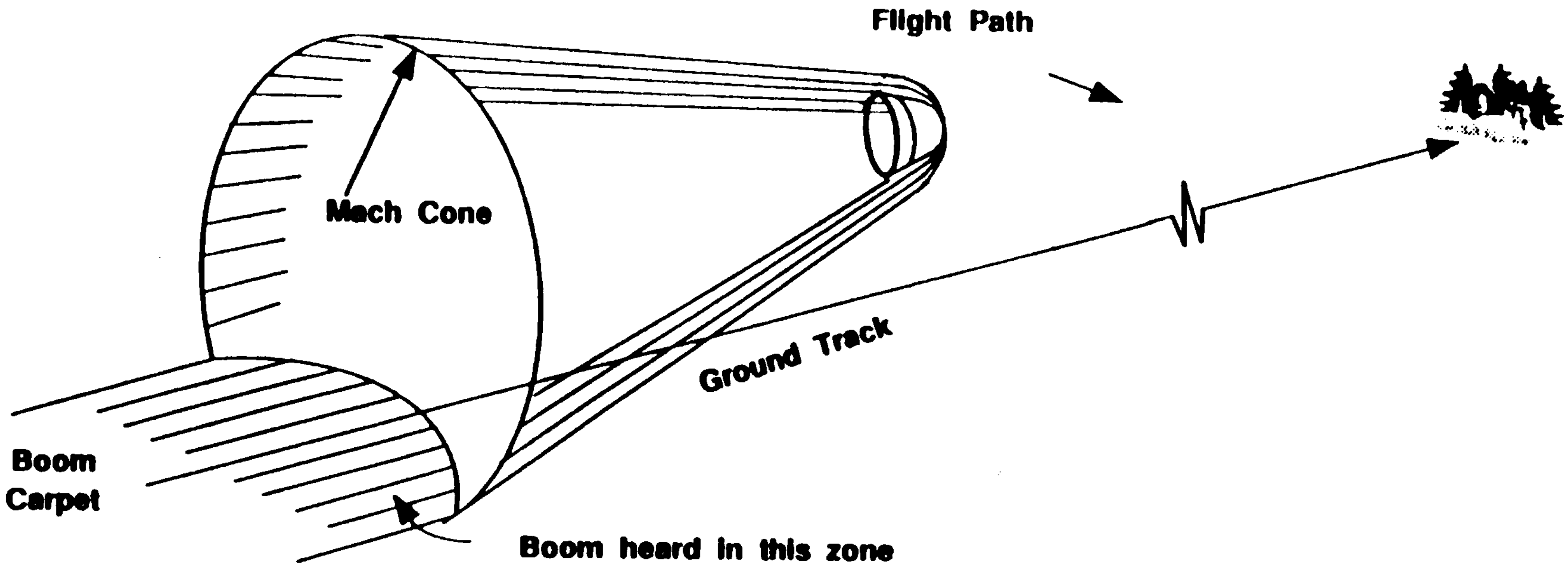


FIGURE 4-2 SONIC BOOM PROPAGATION FROM AN RV AT SUPERSONIC SPEED

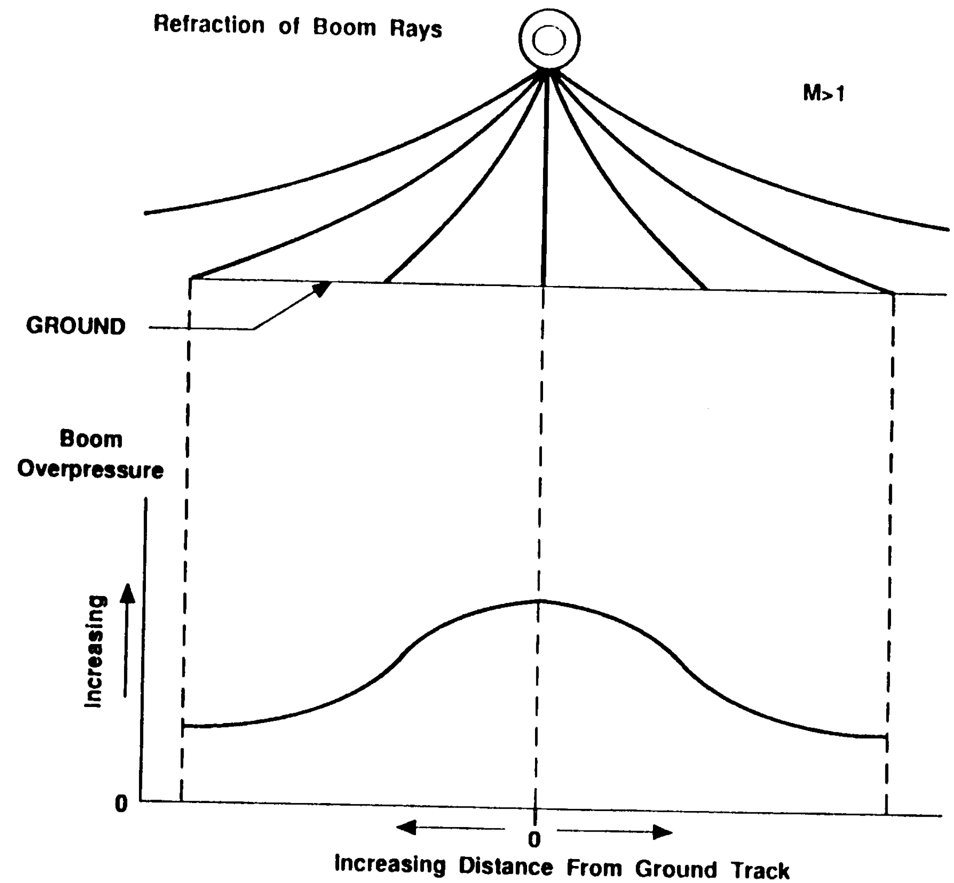


FIGURE 4-3 SONIC BOOM ALONG AND ADJACENT TO THE GROUND TRACK

in both people and animals. However, when animals and humans are exposed to impulse noises with similar characteristics on a repeated basis, they tend to become conditioned to the stimulus and the resulting startle effect is generally no longer provoked. Under certain circumstances, short-term exposure to overpressures of a considerable magnitude can also be experienced without significant discomfort. Inside standard sedan automobiles or station wagons with the windows up, overpressures up to 200 N/m^2 (4 psf) can be generated when the door is slammed. Overpressures up to 425 N/m^2 (8.5 psf) can be produced in a compact car under similar conditions. In public viewing areas, overpressures of up to 600 N/m^2 (12 psf) have been produced during firework displays.

Effects on Humans. The National Academy of Sciences/National Research Council (NAS/NRC) Committee on Hearing, Bioacoustics, and Biomechanics (CHBB) has developed criteria for impulse noise, including an upper tolerance limit. Impulse noise levels which exceed the CHBB limit can produce cochlear damage and hearing loss. The CHBB limit for one impulse per day lasting about 200 ms is a sound pressure level of about 145 dB or 365 N/m^2 (7.25 psf).

The physiological effects of single sonic booms on humans can be grouped as follows:

Sonic boom overpressure, **db** (N/m^2)	Behavioral effects
118 (16)	Orienting, but no startle response; eyeblink response in 10% of subjects; no arm/hand movement.
124 (30) to **135** (111)	Mixed pattern of orienting and startle responses; eyeblink in about half of subjects; arm/hand movements in about a fourth of subjects, but no gross bodily movements.
136 (130) to **144** (310)	Predominant pattern of startle responses; eyeblink response in 90% of subjects; arm/hand movements in more than half of subjects with gross body flexion in about a fourth of subjects.
144 (340) to **150** (640)	Arm/hand movements in more than 90% of subjects.

Effects on Animals. In one of the limited number of studies on the effects of sonic booms on wildlife, minks exposed to 300 N/m^2 (6 psf) overpressure sonic booms were found to react by sticking their heads out of their cages. However, there were no frantic reactions or panic, and the minks shortly resumed their normal activities.

Effects on Marine Life. Sonic booms will not propagate into water as a shock wave when the horizontal velocity of an RV is less than the speed of sound in water, which is equivalent to M 4.4 in air. At greater horizontal velocities, the sonic boom will propagate into the water as an acoustic wave, whose peak pressure attenuates rapidly with water depth. The pre~sure wave is reduced to about one-tenth of its surface amplitude at a depth of 6 to 9m (20 to 30 ft). The principal effect of the sound and shock waves on marine life is expected to be a startle reaction. Fish have been subjected to intense sonic booms of 27,500 N/m^2 (550 psf) without noticeable effects. The wave in these tests, however, only lasted about 0.05 ms, as opposed to the 200 ms duration expected during reentry.

Effects on Structures. Primary (loadbearing) structures meeting acceptable construction standards or in good repair showed no sign of damage from overpressures of up to about 950 N/m^2 (20 psf). Nonprimary structures such as plaster, windows, and tiles sustained some damage at overpressures of 48 to 144 N/m^2 (1 to 3 psf).

Sonic Boom Overpressures Due to Reentry

The Space Shuttle, because of its size, weight and mass, complexity of surface configuration, low angle of reentry, lifting/gliding capability, and relatively high velocity parallel to its ground track is representative of the upper-bound estimate for sonic boom overpressures which will be generated by commercial RVs. Overpressures, and resulting environmental effects, generated by commercial RVs are anticipated to be less than those produced by the Space Shuttle during reentry. For comparison, the environmental effects from the reentry of the Space Shuttle are summarized as follows:

Overpressure

During the reentry of the Space Shuttle from a nominal mission, the maximum sonic overpressure along the ground track trajectory is less than 24 N/m^2 (0.5 psf) at distances greater than 650 km (400 mi) from the landing site. This overpressure increases to approximately 48 N/m^2 (1.0 psf) at a distance of about 185 km (115 mi) from the landing site. The maximum overpressure resulting from the reentry of the Space Shuttle is less than 101 N/m^2 (2.1 psf). Overpressures exceeding 96 N/m^2 (2.0 psf) are expected to occur only within 44 km (27 mi) of the landing cite. Thus, the land area subject to overpressures exceeding 96 N/m^2 (2.0 psf) is generally small (less than 100 mi^2) and is located close to the landing site.

Space Shuttle Sonic Boom Effects

During the reentry of the Space Shuttle, the accompanying sonic boom impacts an area of about 60 x 120 km (27 x 75 miles) or about 7,000 km^2 (2,760 mi^2). Depending on the landing site selected, reentry booms can occur over populated areas. The overpressure may reach a maximum value of 101 N/m^2 (2.1 psf). This corresponds to an impulse sound pressure level of 134 dB (101 N/m^2) which is safely below the CHBB damage limit of 145 dB (365 N/m^2). Except for a slight startle reaction in the population that hears it, the reentry boom has not produced any known adverse effects. This startle reaction may result in an eye blink and a slight movement of the arms and legs by about one-half and one-quarter, respectively, of the affected population. The relatively long duration of the pressure wave from these sonic booms may, however, rattle loose windows.

Animals and marine life may also be exposed to sonic booms during reentry. Limited available data on the effects of the booms on wildlife and marine life indicate that reentry booms may also produce a startle effect similar to that experienced in humans.

No significant short- or long-term environmental effects are known to have occurred as a direct result of sonic booms produced during the reentry of the Space Shuttle. Therefore, at the current and projected levels of activity, sonic booms generated by commercial RVs are not anticipated to result in any significant adverse impacts.

4.2.2 Landing Operations

As the RV approaches the landing site, recovery equipment will be readied to locate the vehicle as quickly as possible. For an airsnatch recovery, specially equipped aircraft and helicopters may be used to locate and retrieve the RV prior to touchdown. The RV would then be transported directly by the recovery plane/helicopter to the landing area support facility for payload recovery. For a land-based touchdown, typical recovery equipment may include standard trucks, autos, and helicopters. The noise generated by these vehicles while searching for, recovering, and transporting the RV to the support facility should be comparable to that from normal daily transportation activities. The landing site, however, may be in a remote area that is seldom visited by automobiles or aircraft. Nonetheless, the noise generated during recovery operations should not exceed 110 decibels and will be of a short duration. Therefore, no adverse environmental impacts are expected.

If the RV lands in the ocean, recovery equipment would consist of ships, boats, and helicopters. Noise generated by this equipment also should not exceed 110 decibels, would be of short duration, and would probably occur in a remote area away from land. Hence, no adverse environmental impacts are expected due to noise generation by ocean-based landing and recovery operations.

STOP

4.2.3 Summary of Acoustic Noise Effects on the Environment

The extent and intensity of sonic booms are mission- and vehicle specific. However, based on information derived from the Space Shuttle, an area of about 60 x 120 km (27 x 75 mi) or about 7,000 km^2 (2,760 mi^2) may be impacted by reentry booms; and depending upon the actual landing site selected, reentry booms may occur over populated areas. No direct human, animal or primary structural damage is expected to occur within this impact area. However, the acceptance of sonic booms by the general public is complex and very subjective, involving the personal opinions, experiences and attitudes of the exposed population. Studies in which a sample population was exposed to 10-15 separate sonic booms per day have shown that approximately 10% found an overpressure of 48 N/m^2 (1 psf) to be annoying; while nearly 100% of the sample population found overpressures of 144 N/m^2 (3.0 psf) annoying (Reference 18). Based on this data, a single sonic boom with an overpressure of 36 N/m^2 (0.7 psf) is expected to represent the lower limit where sonic booms begin to annoy an affected population (Reference 18). The same annoying effect is expected in the animal population.

The noise generated by landing and recovery operations does not represent a significant change from noise levels usually associated with transportation and/or construction environments. The landing/recovery area range safety requirements can specify that the sound level at publicly accessible areas and/or at any nearby residences be maintained at or below an acceptable exposure (e.g., EPA's suggested 24-hour average daytime exposure of 70 dB(A)) during all recovery operations.

Even though these potential noise impacts may occur in an area that is usually tranquil, they are of a short duration and are not expected to produce any long-term impacts. Future site-specific EISs for landing/recovery areas should, however, further evaluate the effects of noise on the surrounding environment, particularly as it may impact any identified threatened or endangered species.

4.3 Landing Effects

Potential environmental impacts of the RV landing will mainly be in the immediate vicinity of the touchdown area. Sources, if present, include accidental fuel or hazardous material/waste release, and localized disturbance in the area of the recovery operations. Impacts to the landing area will be evaluated in the site-specific EAs/EISs. Landing site(s) located in ecologically sensitive areas will generally not be permitted by OCST. Therefore, short-term landing area disturbances are not expected to cause significant environmental impacts.

4.3.1 Water Quality

No significant impact on water quality is expected as a result of the commercial RV activity. Potential effects on surface and water landing sites are discussed below.

Surface Landing Sites. Some RVs may contain a small amount of residual fuels (e.g., hydrazine) in tanks designed to withstand landing forces and environments without leaking. However, in the event of a fuel spill and/or leak of hazardous material during surface landing, the material is expected to evaporate, be ignited upon impact, or adsorbed onto the soil within the immediate impact area. If the actual site-specific landing area is traversed by local or regional streams or rivers, the site-specific EA/EIS will be required to address potential water impacts in detail. Both surface and subsurface water quality issues, including impacts on principal aquifers in the area, should be evaluated.

Water Landing Sites. Although the RV used for such landings will likely be designed to float, there is a small chance that it may sink. If it should sink in shallow water, the vehicle would probably be recovered. If the RV should sink in deep water, no hazards are anticipated to either shipping or the marine environment.

The potential sources of pollutants during ocean landing events are expected to be similar to those present for a land-based touchdown. These substances are expected to be similar to, but typically in smaller quantities than those contained on the Space Shuttle during reentry. Based on the Shuttle EIS, the substances and associated marine impacts are summarized below.

potential source	Major pollutant
solid propellants	ammonium perchlorate(NH_4Cl0_4)
liquid propellants	MMH hydrazine (N_2H_4) nitrogen tetroxide (N_2O_4)
lubricants, hydraulic fluid	hydrocarbons

To assess the potential marine impacts for the Shuttle EIS, it was assumed that the maximum amount of toxic material available was released into the sea, and the volume of water required to dilute this material to Maximum Allowable Concentration (Reference 18) for MMH, nitrogen tetroxide, hydrazine, ammonium perchlorate and hydrogen chloride was calculated as follows:

Chemical compound	Affected volume of seawater (liters)	Dimension of cube containing affected volume, (m)
MMH	3.8×10^9	156
Nitrogen tetroxide	8.3×10^7	44
Hydrazine	9.6×10^8	99
Ammonium perchlorate	1.4×10^{10}	240
Hydrogen chloride	5.9×10^{11}*	830*

_ — _ _ _ _ _ _ _ _ _ _ _ _

*Dilution to pH = 5, neglecting the buffering capacity of seawater.

A qualitative indication of the potential size of the region affected by a failure is given in the last column, which expresses the linear dimension of a cube containing the affected volume. Small schools of fish could be affected, but no large-scale or permanent effects on marine life are expected. The compounds are all chemically active and are not expected to persist in the marine environment (Reference 18).

Potential adverse impacts to the marine environment from residual fuels/propellants aboard a typical RV would be much less than those posed by both expended stages from launch vehicles, which are routine launch operations, and by launch vehicle failures that land in the ocean. Less residual fuels/propellants will be contained

4-25

in the RV. The potential marine impacts of an aborted launch with an ocean landing were evaluated in the 1986 DOT Programmatic EA (Reference 7); these impacts were found to be short-term, very localized, and generally insignificant.

4.3.2 Heat Dissipating Effects

The exterior temperature of the RV at touchdown is expected to be approximately 150°F (66°C) (Reference 22). Accordingly, additional heat dissipating methods are not anticipated to be required to gain access to the RV and its payload. However, additional heat dissipation can be provided, if required, by the use of mobile mechanical ground support cooling. The mechanical cooling units could be connected to internal RV cooling loops through external access ports to cool both the exterior surface or interior payloads. As an alternative, ground support equipment (e.g., water trucks) could also use a water spray to cool the exterior surface of the RV. If a water spray is used, runoff should be collected to prevent erosion. The collected water should also be analyzed, and if applicable, discharged in accordance with the requirements of a NPDES Permit issued in compliance with the Clean Water Act. In the unlikely event that the collected runoff is determined to be hazardous, it should be treated and disposed of in accordance with applicable Federal and state hazardous waste disposal regulations. The need for, and methods of, providing supplemental heat dissipation should be further evaluated as a part of either the site- or mission-specific environmental evaluations.

4.3.3 Accidental Fuel Release

Data on the propellants/fuels, oxidizers, and associated materials which could potentially be used in an RV launch, and the hazards presented by them, are found in **Tables 4-6** through **4-11.** If these materials are present on-board the RV and are spilled in volumes greater than the Reportable Quantities established by EPA (under the Comprehensive Environmental Response, Compensation, and Liability Act - CERCLA) and listed in **Table 4-6**, the spill must be reported to the National Response Center within 24 hours. Spill cleanup shall then be performed in accordance with the procedures defined in the National Contingency Plan (40 CFR 300).

In the event that the RV contains and potentially releases any extremely hazardous substances identified in 40 CFR 355, Appendix A (e.g., diborane), it may also be necessary to notify the State Emergency Response Commission (SERC) and the Local Emergency Planning Committee (LEPC) established under the Emergency Planning and Community Right-to-Know Act (EPCRA).

The site-specific impacts and specific spill response plans at the landing and recovery site(s) due to accidental fuel release are beyond the scope of this programmatic EIS. Potential impacts cannot be fully evaluated until the actual landing area/recovery site is identified. Therefore, these effects will be further evaluated on a case-by-case basis in site-specific landing site EAs/EISs, and license applicants will be required to submit plans that will address responding to accidental Spills.

4.3.4 Accidental Hazardous Material/Waste Release

Reentry vehicles will house experimental packages including, but not limited to, commercial microgravity materials and life science research. Experiments may generate waste products that may require confinement during reentry for disposal on Earth. Tanks and containers will be designed to withstand landing shocks in excess of those expected: and under normal circumstances, there will be no direct contact between the hazardous materials/waste products and the environment. However, there is a remote chance of a tank rupture. Typical products, wastes, and toxic materials, which may be generated by microgravity materials and life science research, and require transport to and from space for disposal on Earth are listed in **Table 2-2**; reportable quantities for spills and human exposure limits for selected substances are presented in **Table 4-6**. Because of the relatively small payload capacity of the proposed commercial RVs, which limits the quantity of toxic materials that can be carried, no significant long-term environmental impacts are expected due to microgravity and life science payloads involved in a reentry accident. Similarly, quantities of other potentially toxic substances which may be aboard a RV (including any batteries used as a power source or fluids used for thermal control) should not pose potentially significant environmental impacts. However, as discussed above in **Section 4.3.3**, spill reporting requirements **(Table 4-6**) under CERCLA and EPCRA may apply.

Potential impacts to biotic resources and human health should also be insignificant and confined to the immediate impact area. Any possible site-specific adverse environmental impacts will be addressed in the EAs/ETSs prepared for the landing sites, once they are identified. Furthermore, mission-specific evaluations of the actual toxic substances aboard the RV will aid in determining environmental impact.

4.4 Other Effects (Site-Specific)

Site-specific effects at the landing and recovery site(s) are beyond the scope of this programmatic EIS. However, general areas of concern and potential site characteristics that may require further detailed analyses in subsequent site-specific EAs/EISs are identified and discussed below.

4.4.1 Land Management/Quality

Land management and the environmental effects on land quality from RVs involve the following three areas/activities: construction of the landing site; recovery of the payloads and disposal of any wastes; and consideration of any special land areas such as floodplains, wetlands, and coastal areas.

4.4.1.1 Landing Site Construction

Generally, minimal construction (infrastructure) will be needed to support recovery of the typical RV. In some cases, existing facilities may be used, requiring no new construction. If construction at the landing site is necessary, soil erosion may be of concern. Construction involving open excavation can lead to soil erosion at the construction site, particularly during inclement weather. Silt-laden runoff can drain to local waterways and cause unnaturally turbid conditions, which are detrimental to aquatic plant and animal life. Erosion control and runoff management measures (e.g., silt fences, sedimentation ponds, and vegetative filtering areas) should be implemented. Local regulations may require the use of these and/or additional protective measures during construction. Attempts should be made to minimize disturbance and to restore disturbed areas to prevent post-construction erosion.

Any noise-related impacts from construction activities at or in support of the reentry landing site will be assessed in subsequent specific landing site EAs/EISs.

4.4.1.2 Recovery of Payloads and Disposal of Waste Material

RV payloads will be recovered by using typical transportation equipment such as trucks and helicopters. Areas immediately adjacent to the impact area will be disturbed, but these activities will be short-lived (under two hours) and should present no environmental problems.

Experiments may generate waste products that could require confinement during reentry for disposal on Earth. Under normal

TABLE 4-6. HAZARDOUS SUBSTANCES, REPORTABLE QUANTITIES, AND HUMAN EXPOSURE LIMITS

SUBSTANCE	REPORTABLE QUANTITY[1] kg (lbs)	NIOSH REL[2]		ACGIH TLV[3]		OSHA PEL[4]		IDLH[5] ppm (mg/m³)	WATER QUALITY STANDARDS[6]	
		TWA ppm[P] (mg/m³)[M]	STEL ppm[P] (mg/m³)[M]	TWA ppm[P] (mg/m³)[M]	STEL ppm[P] (mg/m³)[M]	TWA ppm[P] (mg/m³)[M]	STEL ppm[P] (mg/m³)[M]		FRESH (Acute) µg/l	MARINE (Acute) µg/l
Acetonitrile	2,270 (5,000)	20 (34)	- -	40 (67)	80 (101)	40 (67)	80 (101)	4,000		
Acetylene		A -	- -	A -	- -	A -	- -			
Aluminum				- (2-10)	- -	- (15)	- -			
Ammonium perchlorate									Temperature dependent for ammonia	
Argon				A -	- -					
Arsenic[7]	2,270 (5,000)	- -	- (0.002)	- (0.2)	- -	- (0.01)	- -	*	360	69
Cadmium[7]	0.454 (1.0)			- (0.05)	- -	- (0.2)	- (0.6)[C]	(40)	3.9[H]	43
Carbon dioxide		- -	30,000[F] (54,000)[F]	5,000 (9,000)	30,000 (54,000)	10,000 (18,000)	30,000 (54,000)	50,000		

[1]40 CFR Part 302
[2]Recommended Exposure Limit by the National Institute for Occupational Safety and Health; Time Weighted Average (TWA) and Short-Term Exposure Limit (STEL).
[3]Threshold Limit Value by the American Conference of Governmental Industrial Hygienists.
[4]Permissible Exposure Limit by the Occupational Safety and Health Administration.
[5]Immediately Dangerous to Life and Health by the NIOSH and OSHA.
[6]Environmental Protection Agency Standards.
[7]Identified as either a confirmed or suspected human carcinogen.
[A]Asphyxiant
[C]Ceiling limit, concentration should not be permitted to exceed.
[H]Hardness dependent.
[P]Parts of vapor or gas per million parts of contaminated air by volume at 25°C and 760 torr.
[M]Milligrams of substance per cubic meter of air.
[SK]Adverse effects may result from dermal contact.

TABLE 4-6. HAZARDOUS SUBSTANCES, REPORTABLE QUANTITIES, AND HUMAN EXPOSURE LIMITS (continued)

SUBSTANCE	REPORTABLE QUANTITY[1] kg (lbs)	NIOSH REL[2]		ACGIH TLV[3]		OSHA PEL[4]		IDLH[5] ppm (mg/m³)	WATER QUALITY STANDARDS[6]	
		TWA ppm[a] (mg/m³)[b]	STEL ppm[a] (mg/m³)[b]	TWA ppm[a] (mg/m³)[b]	STEL ppm[a] (mg/m³)[b]	TWA ppm[a] (mg/m³)[b]	STEL ppm[a] (mg/m³)[b]		FRESH (Acute) µg/l	MARINE (Acute) µg/l
Carbon monoxide		35 -	200 -	50 (57)	400 (458)	35 (40)	200[c] (229)[c]	1,500		
Dimethylhydrazine,1,1-[7]	0.454 (1.0)	- -	0.06 (0.15)	0.5[SK] (1.2)[SK]	- -	0.5[SK] (1.0)[SK]	- -	[f]		
Diborane										
Film developer										
Film fixer										
Gallium										
Gallium arsenide									See arsenic	
Helium(g)				A -	- -					
Helium(l)										
Hydrazine[7]	0.454 (1.0)	- -	0.03 (0.04)	0.1[SK] (0.13)[SK]	- -	0.1[SK] (0.1)[SK]	- -	[f]		
Indium				- (0.1)	- -	- (0.1)	- -			
Kerosene										
Lead[7]	varies	- (0.1)	- -	- (0.15)	- -	- (0.05)	- -		82[e]	140
Manganese				- (5)[c]	- -	- (5.0)[c]	- -	(10,000)		

TABLE 4-6. HAZARDOUS SUBSTANCES, REPORTABLE QUANTITIES, AND HUMAN EXPOSURE LIMITS (continued)

SUBSTANCE	REPORTABLE QUANTITY[1] kg (lbs)	NIOSH REL[2]		ACGIH TLV[3]		OSHA PEL[4]		IDLH[5] ppm (mg/m³)	WATER QUALITY STANDARDS[6]	
		TWA ppm[a] (mg/m³)[b]	STEL ppm[a] (mg/m³)[b]	TWA ppm[a] (mg/m³)[b]	STEL ppm[a] (mg/m³)[b]	TWA ppm[a] (mg/m³)[b]	STEL ppm[a] (mg/m³)[b]		FRESH (Acute) µg/l	MARINE (Acute) µg/l
Mercury	0.454 (1.0)	- (0.05)	- (0.0)	- (0.05)[SK]	- -	- (0.05)[SK]	- -	(28)	2.4	2.1
Methanol	2,270 (5,000)	200 (262)	800 (1,048)	200[SK] (262)[SK]	250[SK] (328)[SK]	200[SK] (260)[SK]	250 (310)[SK]	25,000		
Neon				A -	- -					
Nitrogen(g)				A -	- -			50		
Nitrogen(l)										
Oxygen(g)										
Phosphorous	0.454 (1.0)			- (0.1)	- -	- (0.1)	- -			
Sodium aluminate										
Sodium chlorate										
Sodium hydroxide	454 (1,000)	- -	- (2)	- (2)[C]	- -	- (2)[C]	- -	(250)		
Styrene[f]	454 (1,000)	50 (215)	100 (425)	50[SK] (213)[SK]	100[SK] (426)[SK]	50 (213)	100 (426)	5,000		
Sulfur hexafluoride				1,000 (5,970)	- -	1,000 (5,970)	- -			
Tellurium				- (0.1)	- -	- (0.1)	- -			
Tin		- (2)	- -	- (2)		- (2)	- -	(400)		

TABLE 4-7. PROPERTIES OF LIQUID ROCKET PROPELLANT OXIDIZERS

OXIDIZER	FORMULA	MOLECULAR WEIGHT	FREEZING POINT °C (°F)	BOILING POINT °C (°F)	DENSITY g/cc @ °C (°F)	VISCOSITY cp	COMMENTS
Bromine pentafluoride	BrF_5	174.92	-61.3 (-78.34)	40.3 (104.53)	2.466 25.0 (77.0)	No information	Equipment must be kept clean to prevent possibility of fire and explosion
Bromine trifluoride	BrF_3	136.92	8.8 (47.84)	2.843 8.87 (47.8)	2.843 8.78 (47.8)	No information	Reacts explosively with most organic substances andvery rapidly with many inorganic compounds
Chlorine trifluoride	ClF_3	97.457	-83.0 (-117.4)	11.3 (52.34)	1.75 20.0 (68.0)	No information	More reactive than fluorine
Fluorine	F_2	38.0	-223.0 (-369.4)	-188.0 (-306.4)	1.108 -187.2 (-305.0)	0.555 -186.2 (-303.2)	Gas and liquid ignite nearly anything
Hydrogen peroxide	H_2O_2	34.106	-0.89 (30.4)	Decomposes before boiling	1.543 15.6 (60.0)	1.272 19.4 (67.0)	May cause spontaneous combustion if allowed to remain in contact with readily oxidizable organic materials
90% Hydrogen peroxide	90% H_2O_2 10% H_2O	31.24	10.7 (12.7)	140.6 (285.0)	1.3922 20.0 (68.0)	1.301 18.0 (64.4)	Explosive hazard due to catalytic decomposition if tanks are not vented
Iodine pentafluoride	IF_5	221.91	8.5 (47.3)	97.0 (206.6)	3.50 97.0 (206.6)	No information	
Liquid oxygen	O_2	32.0	-218.4 (-361.12)	-183.0 (-297.4)	1.14 -184.0 (-299.2)	0.119 -156.7 (-250.0)	Liquid O_2 forms gels with organic substances which are shock sensitive
Nitrogen tetroxide	N_2O_4	92.02	-11.1 (12.0)	21.1 (70.0)	1.45 20.0 (-68.0)	0.4720 8.9-8.3 (48.0-47.0)	Not flammable but corrosive
Ozone	O_3	48.0	-192.1 (-318.78)	111.1 (-168.0)	1.46 -111.1 (-168.0)	1.42 -183.0 (-297.4)	Gas and liquid are explosive
Oxygen fluoride	OF_2	54.0	-223.8 (-370.84)	-144.8 (-228.64)	1.53 -144.8 (-228.64)	0.2826 -145.0 (-229.0)	Spark explodes moist but not ddry gas

*Average Concentration

TABLE 4-7. PROPERTIES OF LIQUID ROCKET PROPELLANT OXIDISERS (continued)

OXIDIZER	FORMULA	MOLECULAR WEIGHT	FREEZING POINT °C (°F)	BOILING POINT °C (°F)	DENSITY g/cc @ °C (°F)	VISCOSITY cp	COMMENTS
Nitrogen trifluoride	NF_3	71.01	-218.8 (-357.88)	-120.0 (-184.0)	1.573 -128.9 (-200.0)	No information	
Perchloryl fluoride	ClO_3F	102.3	-146.0 (-230.8)	-46.8 (-52.2)	1.434 20.0 (68.0)	0.184 20.0 (68.0)	
Red fuming nitric acid	84% HNO_3 14% NO_2 2% H_2O	59.09	-45.6 (-50.0)	60.0 (140.0)	1.573 (max) 15.6 (60.0)	1.37 25.0 (77.0)	Forms explosive mixture with organic materials
Tetra-nitro methane	$C(NO_2)_4$	196.042	13.0 (55.4)	125.7 (258.3)	1.65 12.8 (55.0)	No information	Very explosive-undependable
White fuming nitric acid	97.5% HNO_3 2.0% H_2O 0.5% NO_2 *	59.912	-42.8 (-45.0)	85.6 (186.0)	1.46-1.52 20.0 (68.0)	0.84 20.0 (68.0)	Explosive with hydrocarbons and organic material

TABLE 4-8. PROPERTIES OF LIQUID ROCKET PROPELLANTS/FUELS

FUEL	FORMULA	MOLECULAR WEIGHT	FREEZING POINT °C (°F)	BOILING POINT °C (°F)	DENSITY g/cc @ °C (°F)	VISCOSITY cp @ °C (°F)	FLASH POINT °C	AUTO IGNITION °C (°F)	EXPLOSIVE LIMITS		NOTE
									LOWER-%	UPPER-%	
Aluminum trimethyl	$Al(CH_3)_3$	72.072	15.0 (59.0)	126.1 (258.98)	0.8 20.0 (68.0)	No info	-	-	—	—	1
Anhydrous ammonia	NH_3	17.03	-77.7 (-107.86)	33.35 (-28.03)	0.6386 0.0 (32.0)	0.00982 20.0 (68.0)		651.1 (1204.0)	16.0	25.0	2
Analine	$C_6H_5NH_2$	93.124	-6.1 (21.02)	184.4 (364.0)	1.022 20.0 (68.0)	5.299 15.0 (59.0)	158.0 168.0	768.3 (1415.0)			3
Decaborane	$B_{10}H_{14}$	122.312	99.7 (211.5)	213.0 (415.4)	0.78 100.0 (212.0)	Solid at Room Temp					4
Diborane	B_2H_6	27.69	-165.5 (-265.9)	-92.5 (-134.5)	0.43 86.4 (187.6)	0.245 -127.39 (-197.3)			25.0	75.0	5
Ethylene oxide	$(CH_2)_2O$	44.05	-112.5 (-170.5)	10.72 (51.3)	0.8711 20.0 (68.0)	0.32 0.0 (32.0)	-17.8	429.0 - 571.1 (804.2 - 1060.0)	3.0	100.0	6
Propyl nitrate	$C_3H_7NO_3$	105.094	-101.1 (-150.0)	110.6 (231.0)	1.059 15.0 (59.0)	0.51 37.8 (100.0)	70.0 68.0	192.78 (379.0)	2.0	100.0	7
UDMH	$((CH_3)_2NNH_2$	60.1	-57.06 (-70.7)	62.5 (144.5)	0.7782 26.7 (80.0)	0.405 40.0 (104.0)	34.0 -6.0	234.4 (454.0)	2.5	95.0	

*Dangerous
**Low fire hazard

Comments:
1. Spontaneously flammable in air, decomposes explosively in water.
2. Unstable to sudden heat and sunlight
3. Vapor explosive when mixed with air.
4. Explodes in O_2 at 100°C (212°F).
5. Flashes at very low temperature.
6. Extremely flammable.
7. Classified by ICC as non-flammable.
8. Sudden exposure to even small quantities of liquid to air will result in explosion
9. May cause spontaneous combustion.

TABLE 4-8. PROPERTIES OF LIQUID ROCKET PROPELLANTS/FUELS

FUEL	FORMULA	MOLECULAR WEIGHT	FREEZING POINT °C (°F)	BOILING POINT °C (°F)	DENSITY g/cc @ °C (°F)	VISCOSITY c/p @ °C(°F)	FLASH POINT °C	AUTO IGNITION °C (°F)	EXPLOSIVE LIMITS		NOTE
									LOWER-%	UPPER-%	
Aluminum trimethyl	$Al(CH_3)_3$	72.072	15.0 (59.0)	126.1 (258.98)	0.8 20.0 (68.0)	No Info	–	–	—	—	1
Anhydrous ammonia	NH_3	17.03	-77.7 (-107.86)	33.35 (-28.03)	0.6386 0.0 (32.0)	0.00982 20.0 (68.0)		651.1 (1204.0)	16.0	25.0	2
Analine	$C_6H_5NH_2$	93.124	-6.1 (21.02)	184.4 (364.0)	1.022 20.0 (68.0)	5.299 15.0 (59.0)	158.0 168.0	768.3 (1415.0)			3
Decaborane	$B_{10}H_{14}$	122.312	99.7 (211.5)	213.0 (415.4)	0.78 100.0 (212.0)	Solid at Room Temp					4
Diborane	B_2H_6	27.69	-165.5 (-265.9)	-92.5 (-134.5)	0.43 86.4 (187.6)	0.245 -127.39 (-197.3)			25.0	75.0	5
Ethylene oxide	$(CH_2)_2O$	44.05	-112.5 (-170.5)	10.72 (51.3)	0.8711 20.0 (68.0)	0.32 0.0 (32.0)	-17.8	429.0 - 571.1 (804.2 - 1060.0)	3.0	100.0	6
Propyl nitrate	$C_3H_7NO_3$	105.094	-101.1 (-150.0)	110.6 (231.0)	1.059 15.0 (59.0)	0.51 37.8 (100.0)	70.0 66.0	192.78 (379.0)	2.0	100.0	7
UDMH	$((CH_3)_2NNH_2$	60.1	-57.06 (-70.7)	62.5 (144.5)	0.7782 26.7 (80.0)	0.405 40.0 (104.0)	34.0 -6.0	234.4 (454.0)	2.5	95.0	

*Dangerous
**Low fire hazard

Comments:
1. Spontaneously flammable in air, decomposes explosively in water.
2. Unstable to sudden heat and sunlight
3. Vapor explosive when mixed with air.
4. Explodes in O_2 at 100°C (212°F).
5. Flashes at very low temperature.
6. Extremely flammable.
7. Classified by ICC as non-flammable.
8. Sudden exposure to even small quantities of liquid to air will result in explosion
9. May cause spontaneous combustion.

TABLE 4-8. PROPERTIES OF LIQUID ROCKET PROPELLANTS/FUELS (continued)

FUEL	FORMULA	MOLECULAR WEIGHT	FREEZING POINT °C (°F)	BOILING POINT °C (°F)	DENSITY g/cc @ °C (°F)	VISCOSITY c/p @ °C (°F)	FLASH POINT °C	AUTO IGNITION °C (°F)	EXPLOSIVE LIMITS		NOTE
									LOWER-%	UPPER-%	
Ethanol	C_2H_5OH	46.068	-114.15 (-173.47)	78.5 (173.3)	0.7894 20.0 (68.0)	1.075 25.0 (77.0)	54.0	371.1 (700.0)	3.28	18.95	
Furfuryl alcohol	$C_4H_3OCH_2OH$	98.10	-31.0 (-23.8)	171.0 (339.8)	1.135 20.0 (68.0)	5.8 20.0 (68.0)	167.0	490.56 (915.0)	1.8	16.2	
Liquid hydrogen	H_2	2.061	-259.2 (-434.56)	-252.77 (-422.99)	0.070 -253.0 (-423.4)	0.0139 -253.0 (-423.4)		580.0 (1076.0)	4.0	74.2	
Isopropyl alcohol	C_3H_7OH	60.094	-89.4 (-129.0)	82.3 (180.2)	0.785 20.0 (68.0)	2.3 20.0 (68.0)	53.0	398.89 (750.0)	2.02	12.0	
Methanol	CH_3OH	32.04	-97.9 (-144.22)	64.7 (148.5)	0.7915 20.0 (68.0)	0.623 15.0 (69.0)	52.0	470.0 (878.0)	6.0	36.50	
Penta borane	B_5H_9	63.172	-46.82 -52.28)	60.06 (140.11)	0.61 20.0 (68.0)	0.342 13.2 (55.8)					8
Anhydrous hydrazine	N_2H_4	32.05	1.14 (34.05)	113.3 (236.0)	1.005 20.0 (68.0)	0.95 20.0 (68.0)	124.0 104.0	165.0 (329.0)	4.7	100.0	9
Hydrazine hydrate*	$N_2H_4H_2O$	50.06	-40.0 (-40.0)	118.5 (245.3)	1.035 20.0 (68.0)	2.0 20.0 (68.0)					
Diethylene triamine**	$NH_2CH_2CH_2$- NH CH_2CH_2- NH_2	103.1	<-38.9 (<-38.0)	206.7 (404.0)	0.946 25.0 (77.0)	6.6 21.1 (70.0)					
U-Deta		72.0	<49.4 (<121.0)	71.7 (161.0)	0.858 15.6 (60.0)	1.98 15.6 (60.0)	45.7 (114.3)				
RP-1			-40.0 (-40.0)		0.815 20.0 (68.0)	16.5	43.3 (110.0)				

TABLE 4-9. PROPERTIES OF SOLID PROPELLANT INGREDIENTS

INGREDIENT	MOLECULAR WEIGHT	EXPLOSION TEMP* (°C)	DENSITY (g/cm³)**	DOT HAZARD CLASSIFICATION	UN SHIPPING NUMBER	COMMENTS
Aluminum (powder), Al	26.98		1.0 - 1.2	Flammable Solid	1309	Mixed with air, aluminum powder is an explosion hazard.
Aluminum hydride, AlH_3	29.97		1.43	Flammable Solid	2463	Dangerous if wet.
Ammonium nitrate, NH_4NO_3	80.0	462.8 (865.0°F)	1.73	Oxidizer	1942	Oxidizers, while not generally combustible themselves, may cause or contribute to the combustion of other materials.
Ammonium perchlorate, NH_4ClO_4	117.5	435.0 (815.0°F)	1.95	Oxidizer	1442	Oxidizer, as above.
Beryllium, Be	9.0122		1.848	Poison B	1567	Poison and flammable solid.
Bis (2,2-dinitropropyl)-formal, BDNPF	312.0		1.415	Forbidden		
Black powder	N/A	427.0 (800.6°F)	1.6	Class A Explosive	0027	Can cause a mass explosion which can affect entire shipment almost instantaneously.
Composition C-3, 77% RDX	N/A	280.0 (536.0°F)	1.60	Class A Explosive	0060	Can cause a mass explosion, or will burn with high intensity, but only if in small amounts.
Composition C-4, 91% RDX	N/A	290.0 (554.0°F)	1.59	Class A Explosive	0060	Will detonate easily; highly sensitive.
Cyclotetramethylene tetranitramine, Beta HMX	269.17	327.0 (620.6°F)	1.903	Class A Explosive	0226	Highly explosive.
Cyclotrimethylene trinitramine, RDX	222.0	260.0 (500.0°F)	1.802	Class A Explosive	0072	Extremely sensitive if pure.
Diethylene glycol dinitrate, DEGN	196.0	237.0 (458.6°F)	1.38	Forbidden		
2,4 Dinitrotoluene	182.13	310.0 (590.0°F)	1.521	ORM-E	2038	Poisonous.
Ethyl acrylate	100.11	Flash pt.: 15.6 (60.1°F)	No data	Flammable Liquid	1917	Flammable liquid.

*Detonating point in 5 seconds.
**Units are in g/ml.

TABLE 4-9. PROPERTIES OF SOLID PROPELLANT INGREDIENTS (Continued)

INGREDIENT	MOLECULAR WEIGHT	EXPLOSION TEMP* (°C)	DENSITY (g/cm³)	DOT HAZARD CLASSIFICATION	UN SHIPPING NUMBER	COMMENTS
Lead azide, N_6Pb	291.0	340.0 (644.0°F)	4.80	Class A Explosive	0129	Initiating explosives (wet).
Mercury fulminate, $C_2N_2O_2Hg$	285.0	210.0 (410.0°F)	4.43	Class A Explosive	0135	Initiating explosives (wet).
Methyl acrylate	86.1	Flash pt.: -3.0 (26.6°F)	Sp.gr.: 0.9574 @ 20.0°C (68.0°F)	Flammable Liquid	2614	Flammable liquid.
Metriol trinitrate, MTN	255.0	235.4 (455.8°F)	1.47	Class A Explosive		
Nitrocellulose	272.3	autoig. @ 170 (330°F)	1.66**	Flammable Solid	0340	
Nitroglycerin, $C_3H_5(ONO_2)$	227.07	222.0 (431.6°F) autoig. @ 180 (356°F)	1.596	Forbidden	0143 1204 0144	Extremely sensitive.
Nitroguanidine, $CH_4N_4O_2$	104.0	275.0 (527.0°F)	1.72	Class A Explosive	0282	
Pentaerythritol tetra-nitrate, PETN	316.0	225.0 (437.0°F)	1.77	Class A Explosive	0150	
Potassium chlorate $KClO_3$	122.55	N/A	2.32**	Oxidizer	1485	Oxidizer, as above.
Sulfur, S_8	256.48	N/A	≈2.00**	ORM-C	1350	Inflammable solids.
Tetryl	287.0	257.0 (494.6°F)	1.73	Class A Explosive	0208	Initiating explosives.
Triethyleneglycol di-nitrate, TEGDN	240.172	223.0 (433.4°F)	1.33 @ 60 (140.0°F)	Class A Explosive	2259	
Trinitrotoluene, TNT	227.0	475.0 (887.0°F)	1.65	Class A Explosive	0209,0388 0389,1356	Flammable solid - be extremely careful, different mixtures in this group (<30% water by weight).
Zirconium (powder), Zr	91.22	autoig. @ 260 (500°F)	6.49**	Flammable Solid	1358	Flammable solid w/not less than 25% water (a visible excess must be present).

TABLE 4-10. FUEL/PROPELLANT HAZARDS

PROPELLANT	TYPE	FLAMMABILITY	HAZARD	TLV[1] (PPM)	FLAMMABILITY LIMITS (% IN AIR BY VOLUME)[2]		RECOMMENDED FIRE-EXTINGUISHING AGENTS
					LOWER	UPPER	
Methyl alcohol (methanol)	Fuel	Flammable	Toxic	200.0	6.7	36.0	Carbon dioxide, dry chemical, alcohol resistant foam, Halon 1211 and 1301
Ethyl alcohol (Ethanol)	Fuel	Flammable	Narcotic	1000.0	3.3	19.0	Water fog, alcohol-resistant foam, carbon dioxide, dry powder, Halon 1211 and 1301
Furfural alcohol	Fuel	Flammable	Irritating, narcotic	50.0	1.8	16.3	Carbon dioxide, alcohol-resistant foam, dry powder, Halon 1211 and 1301
Isopropyl alcohol	Fuel	Flammable	Narcotic	400.0	2.0	12 (appr) @ 20°C (68°F)	Water fog, alcohol-resistant foam, carbon dioxide, dry powder, Halon 1211 and 1301
Alkyl boranes HFE-2 HFE-3	Fuel	Flammable	Highly toxic	0.010	Data classified		Water fog, inert-gas foam; do not use carbon dioxide and halogenated vaporizing liquids
Anhydrous ammonia	Fuel	Flammable, explosive when contacted with mercury	Irritating	50.0	15.5	28.8 (appr) @ 20°C (68°F)	Water, carbon dioxide, dry powder, Halon 1211 and 1031
Aniline	Fuel	Nonflammable at room temperature	Toxic	5.0	1.3 @ 20°C (68°F) Vapor explosive when mixed with air		Foam, dry powder, water, water fog

[1]Threshold Limit Values (TLV) given in parts per million (PPM) is the value to which most individuals may be exposed for eight hours per day, day after day, without adverse effects.
[2]Flammability limits are based on a pressure of 1 atm. The general effect of an increase in pressure or temperature is to lower the lower flammability limit and raise the upper limit. A decrease in pressure or temperature has the opposite effect.
[3]See Table 44 Bulletin 503, Bureau of Mines, Limits of Flammability of Gases and Vapors.
[4]TLV not established, value is approximated.

TABLE 4-10. FUEL/PROPELLANT HAZARDS (continued)

PROPELLANT	TYPE	FLAMMABILITY	HAZARD	TLV[1] (PPM)	FLAMMABILITY LIMITS (% IN AIR BY VOLUME)[2] LOWER	UPPER	RECOMMENDED FIRE-EXTINGUISHING AGENTS
Chlorine trifluoride	Oxidant	Reacts vigorously with most known materials, including water	Highly toxic, corrosive, burns skin and eyes	0.10	More reactive than fluorine		Water fog, dry powder (soda ash or bicarbonate)
Ethylene oxide	Monopropellant	Flammable up to 100% vapor concentration	Toxic	50.0	3.6	100.0 @ 57°C (135°F)	Water fog, carbon dioxide, dry powder, Halon 1211 and 1301
Fluorine	Oxidant	Reacts vigorously with most known materials, including water	Highly toxic, corrosive, burns skin and eyes	0.10	Gas and liquid ignite most materials		Water fog, dry powder (soda ash or bicarbonate), fine spray
Hydrazine	Fuel monopropellant	Flammable up to 100% vapor concentration	Toxic, burns tissues	1.0	4.7	100.0 @ 100°C (212°F)	Water spray, water foam, water fog, carbon dioxide, dry powder, Halon 1211 and 1301
Hydrocarbon fuels	Fuel	Flammable, sensitive to mechanical shock when mixed with oxidants	Narcotic can be highly toxic	Various	–[3]	–[3]	Foam, carbon dioxide, dry powder, vaporizing liquids, Halon 1211 and 1301
Liquid hydrogen	Fuel	Flammable	Nontoxic, causes freeze "burns"	Not applicable	4.0	75 (appr)	Water, carbon dioxide, Halon 1211 and 1301
Hydrogen peroxide 90%	Oxidant monopropellant	Nonflammable but supports combustion	Irritating, burns	1.0	Not applicable		Water
Monomethyl-hydrazine	Fuel	Flammable between 2.5% and 89% vapor concentration	Toxic	0.50[4]	2.5	92 to 98	Water foam, water spray, water fog, carbon dioxide, dry powder, Halon 1211 and 1301

TABLE 4-10. FUEL/PROPELLANT HAZARDS (continued)

PROPELLANT	TYPE	FLAMMABILITY	HAZARD	TLV[1] (PPM)	FLAMMABILITY LIMITS (% IN AIR BY VOLUME)[2] LOWER	UPPER	RECOMMENDED FIRE-EXTINGUISHING AGENTS
Fuming nitric acid	Oxidant	Nonflammable but supports combustion	Toxic, corrosive, causes severe burns	5.0	Not applicable		Water fog, water
Nitrogen tetroxide	Oxidant	Nonflammable but supports combustion	Toxic, corrosive, burns skin and eyes	2.50	Not applicable		Water fog
Liquid oxygen	Oxidant	Nonflammable but supports combustion vigorously	Nontoxic, causes freeze "burns"	None at std. atmosphere[4]	Not applicable		Burning proceeds with detonations; remotely applied measures suitable for the fuel; if fuel can be diluted water may be used
Pentaborane	Fuel	Flammable and pyrophoric	Highly toxic	0.0050	Sudden exposure of even small quantities of liquid to air will result in explosion		Water, foam
Perchloryl fluoride	Oxidant	Nonflammable but supports combustion	Irritating, causes freeze "burns"	3.0	Not applicable		Water fog
Propyl nitrate normal	Monopro-pellant	Flammable	Toxic	25.0	2.0	100.0 @ 100°C (212°F)	Carbon dioxide, water fog, dry powder; do not use halogenated hydrocarbons

TABLE 4-10. FUEL/PROPELLANT HAZARDS (continued)

PROPELLANT	TYPE	FLAMMABILITY	HAZARD	TLV[1] (PPM)	FLAMMABILITY LIMITS (% IN AIR BY VOLUME)[2]		RECOMMENDED FIRE-EXTINGUISHING AGENTS
					LOWER	UPPER	
Unsymmetrical dimethylhydrazine	Fuel	Flammable, hypergolic with some oxidants	Toxic, irritating to skin and eyes	0.50	25°C (77°F) 2.3 @ 150°C (302°F) 1.8 (appr)	25°C (77°F) 80 (appr) @ 100°C (212°F) 86 to 96 @ 150°C 302°F) 96±2	Water spray, water foam, water fog, carbon dioxide, halon 1211 and 1301

TABLE 4-11. PROPELLANT FLAMMABILITY AND TOXIC PROPERTIES

PROPELLANT	FLAMMABILITY	HAZARD	RECOMMENDED FIRE-EXTINGUISHING AGENTS
Aluminum (powder)	Flammable	Nontoxic	Dry sand
Aluminum hydride	Flammable; explosive when contacted with water, acids and oxidizers	Nontoxic	Dry sand or powder; do not use water, carbon dioxide, carbon tetrachloride or any foams
Ammonium nitrate	Flammable	Irritating	Water
Ammonium perchlorate	Flammable; explosive when contacted with sulfur, organic matter, or finely divided metals, particularly magnesium and aluminum	Irritating	Water
Beryllium (powder)	Flammable	Toxic	No information
BDNPF	Flammable, burns without detonating	Irritating	Foam, dry chemical, carbon dioxide
Black powder	Highly explosive	Toxic, if ingested	None: evacuate
Composition C-3	Highly explosive	Toxic	None: evacuate
Composition C-4	Highly explosive	Irritating	None: evacuate
Beta HMX	Highly explosive	Nontoxic; irritating	None: evacuate
RDX	Highly explosive	Irritating	None: evacuate
DNT	Flammable	Irritating	Water, carbon dioxide, dry chemical, carbon tetrachloride; by remote control
Ethyl acrylate	Flammable liquid	Irritating	Water spray, carbon dioxide, foam, or dry chemical preferred
Lead azide	Flammable	Toxic; irritating	None: evacuate
Mercury fulminate	Flammable	Irritating	None: evacuate
Methyl acrylate	Flammable liquid	Irritating	Water spray, carbon dioxide, foam, or dry chemical preferred
Nitroglycerin	Highly explosive	Irritating	None: evacuate
PENT	Highly explosive	Irritating	None: evacuate
Potassium chlorate	Flammable	Irritating	Water, water fog
Resorcinol	Flammable	Irritating	Water, carbon dioxide, dry chemical
Sulfur	Flammable	Mild irritant	Water
Tetryl	Flammable	Irritating	By remote control only
TEGDN	Flammable	Irritating	Carbon dioxide, dry chemical
TNT	Flammable	Irritating	Evacuate and fight by remote control only
Zirconium (powder)	Flammable	None	Dry chemical salt, dry sand, powdered talc; do not use water

circumstances, there will be no direct contact between the wasteproducts and the environment. Typical products, wastes, and toxic materials which may be generated by microgravity materials and life science research, and require transport to and from space for disposal on Earth were listed in **Table 2-2**. All transport of toxic or hazardous waste material will be conducted in accordance with DOT regulations. EPA regulations concerning hazardous waste disposal will also be observed.

During recovery operations, the effects of an accident would be similar to those of an accidental release during touchdown described in **Sections 4.3.3.** and **4.3.4**.

4.4.1.3 Impacts on Wetlands, Floodplains, and Coastal Areas

In accordance with DOT orders 5650.2 (Floodplain Management and Protection) and 5660.1A (Protection of Wetlands), Executive Orders 11990 (Protection of Wetlands) and 11988 (Floodplain Management), and the Coastal Zone Management Act (1972), identification and protection of wetlands, floodplains, and coastal areas is required. Preservation and maintenance of the existing natural system is of primary importance. Thus, it is unlikely that a landing site would be proposed in or around these types of areas. However, the effects of construction of landing facilities and the actual impact of the RV and recovery equipment on these areas must be addressed in the site-specific EAs/EISs, if applicable.

In the event that the RV lands in the ocean, a controlled touchdown would typically occur far enough offshore as to eliminate any chance of impacts to wetlands or coastal areas.

4.4.2 Aquatic and Terrestrial Ecology

Generally, impacts on aquatic and terrestrial ecology, if any, will occur in the immediate vicinity of the landing area during touchdown of the RV. For the purposes of this programmatic EIS, ecological damage from the RV itself is expected to be within a 610m radius of the actual landing site. If a heat shield (or other component of the vehicle) is jettisoned prior to impact, a small area (about 5 m in diameter) could be affected by its impact. Recovery equipment may temporarily disrupt very localized areas (i.e., in the direct path of the equipment). Such disruption will be short-lived and therefore may cause minimal short-term disturbance to the local ecology. Based on the current projected level of commercial RV activity, no significant long-term impacts would be expected, even if all landings were at one site.

Impacts to the local ecology during a typical ocean landing would be comparable to those from everyday maritime traffic, and would thus be insignificant.

The site-specific impacts on aquatic and terrestrial ecology will be assessed in subsequent EAs/EISs prepared for the actual landing areas, once they are selected.

4.4.2.1 Flora and Fauna

If the landing site is not in an ecologically sensitive area, the RV activity should have no adverse long-term effects on local flora and fauna. For a surface landing, short-term effects will typically be limited to temporary migration of local fauna and possibly crushing of flora in the immediate area of the RV and in the paths of the ground-based recovery equipment. Nevertheless, as a precautionary measure, potential impacts from the RV and associated recovery operations on the local flora and fauna (not limited to endangered or threatened species) should be assessed in the site-specific EAs/EISs.

4.4.2.2 Endangered and Threatened Species

In accordance with the provisions of the National Environmental Policy Act and the Endangered Species Act, once landing/recovery sites and support facilities are selected, an assessment to determine whether any endangered and/or threatened plant or animal species are present in their vicinity must be conducted. The U.S. Fish and Wildlife Service's List of Endangered and Threatened Wildlife and Plants can be found in 50 CFR 17.11 and 17.12. The appropriate U.S. Fish and Wildlife Service district office should be contacted during preparation of the site-specific EA/EIS for aid in determining the presence of endangered or threatened species.

4.4.3 Community Impacts

RV activities can potentially impact the community in several areas. A general characterization of the expected scope of impacts is presented below; these areas will be treated in detail in sitespecific EAs/EISs.

4.4.3.1 Historical and Cultural Resources

Once the landing site, recovery area, and support sites are selected, consultation and coordination with the State Historic Preservation Officer will be necessary to examine whether any potential historical or cultural resource impacts exist.

4.4.3.2 Land Use

Land use patterns may change in the area of the landing, recovery, and support facility sites, particularly if the RV activity causes a significant influx of new population to a community. This possibility will be evaluated as part of the site-specific EAs/EISs.

4.4.3.3 Noise

If landing and recovery support facilities are constructed, noice will be generated. These construction-related noise impacts will be evaluated in the site-specific EAs/EISs.

During reentry of the RV, the communities within an area of approximately 60 x 120 km (27 x 75 miles) of the landing site may be subjected to a sonic boom, as discussed in **Section 4.2.** Sonic booms will be of short duration, will occur infrequently, and will be predicted in advance. The sonic boom may cause a startle effect in some people; however, no other effects are anticipated.

4.4.3.4 Transportation

Transportation of the reentry vehicle to the support area and refurbishment sites will typically be accomplished by helicopter or truck. Waste materials, both hazardous and non-hazardous, will be transported by standard transportation methods for treatment and disposal. In all cases, applicable local, state, and Federal laws, regulations and ordinances on air, water, hazardous- and nonhazardous waste, and transportation will be observed. These transportation activities will contribute to the consumption of fossil fuels (i.e., gasoline, diesel, and jet fuel), but should have no effect on traffic patterns on either a local or regional scale. No significant environmental impacts are anticipated due to these transportation activities.

4.5 Socio-Economic Effects

Development and growth in commercial RV activity may result in the employment of skilled and professional workers and, therefore, can be considered to be economically beneficial. This impact will be strongest on the local communities affected by the increased personal income and tax base. An influx of additional workers will create a need for more services which, in turn, creates more jobs. The relative impact to the local community depends on whether there are other major employers in the area. The impact on the national economy will probably be small, but is dependent on the number and success of private ventures into commercial RV-related operations.

4.6 Reentry Safety Considerations

As part of the licensing process carried out under the CSLA, the OCST conducts a Safety Review and a Mission Review. The Safety Review is the procedure for determining whether the license applicant can operate safely; and the OCST examines, among other things, the applicant's safety personnel, procedures and equipment. The RV Safety Review includes evaluation of the vehicle from a safety perspective to determine whether it will perform as intended within an acceptable degree of public risk. This Programmatic EIS is therefore applicable to RV missions which are completed as planned, as well as to effects which may result from malfunctions affecting the planned operations of the mission.

One possibility is that the RV could break up during its reentry into the Earth's atmosphere. Although the chances of this occurring are remote, it is a potential landing/impact area safety consideration. The breakup of RVs prior to encountering an atmospheric density sufficient to ensure continued reentry (at about 120 km) is similar to ELV operations. Breakup during reentry is similar to natural reentry that occurs sometime after every launch of an ELV - i.e. second and third stages. If an RV breakup occurs near this altitude, much of the RV and its payload would probably disintegrate (i.e., burn up) during descent, due to heat generation via atmospheric friction. In general, the higher the altitude at which the breakup occurs (up to about 120 km), the greater the probability that more of the mass of the RV (and its payload) will disintegrate before reaching the Earth's surface: the smaller the pieces are, the more chance they will completely disintegrate during descent. Conversely, the larger the pieces and the closer to Earth the breakup occurs, the greater the probability that distinguishable objects will reach the Earth's surface. The type of material involved will also affect its disintegration rate. Materials such as wood and most plastics will burn much more easily than metal, while any liquids aboard the RV would probably be vaporized during descent. If a breakup occurred in which fuel tanks or the payload (or a portion of it) reached the Earth's surface, the effects would be similar to those described in **Sections 4.3.3** and **4.3.4**., respectively.

In addition to launch-related objects which return to Earth (e.g., spent rocket stages), approximately 14,000 trackable man-made space objects have fallen to Earth over the past 30 years. Only in a few instances have any pieces of the latter objects reached the Earth's surface intact and been discovered (Reference 21). Most disintegrate in the atmosphere. The risk to individuals is extremely cmall; there is a greater chance of being hit by one of the 500 or so meteorites that strike Earth annually, than of being harmed by reentering man-made space objects (Reference 21).

4.7 Secondary Effects

As mentioned in **Section 4.5**, commercial RV activities, once firmly established, may cause economic growth in the communities where the commercial RV infrastructure is established. This growth may include an increase in local workforces and construction of new facilities. Secondary impacts such as increases in traffic, automobile and industrial emissions, municipal waste, and increased demand on pub'ic services and utilities may occur. These secondary impacts are highly dependent on the site location and the existing degree of development in surrounding areas (i.e., the more developed the area, the less the potential secondary impacts); they should be addressed in site-specific documentation.

5.0 ENVIRONMENTAL IMPACTS AND CONSEQUENCES OF THE ALTERNATIVE

5.1 No Action Alternative

Under this alternative, the dedication of resources to commercial RV activities would cease; therefore, environmental effects from their development and operations would be avoided.

Cultural and socio-economic impacts, however, would result from the cancellation of RV activities. This alternative would have an impact on the regional and local economies of the areas where development, manufacture, and recovery operations take place. The positive socio-economic impacts would be lost.

5.1.1 Physical Effects

Much of the planned commercial RV user research would not be performed under this alternative. For example, research into the long-term biological effects of exposure to the space environment and microgravity research projects have no alternative means for their accomplishment, other than the Space Shuttle. The economic benefits of commercial RVs and their quick turnaround time, as opposed to that of the Space Shuttle, also would be lost.

5.1.2 Atmospheric Effects

Cancellation of commercial RV activities would also cancel the additional launching of LVs needed to support the RV activity. If the total number of such flights each year is reduced accordingly, the environmental impact from rocket launches would be reduced. However, non-commercial (i.e., government) launches will probably continue at their present rate. The 1986 DOT Programmatic EA demonstrated that the expected commercial addition to the government-sponsored launchings is minimal; thus the impacts from commercial activities account for only a small portion of the total atmospheric impacts of space-related activity.

If commercial users are restricted to the Space Shuttle as the only means of RV capability, an increase in the number of shuttle flights is possible. The impact of this increase on the layers of the atmosphere would be similar to that described for the Shuttle EIS.

As discussed in **Section 4.1.1.2**, commercial RVs are not expected to affect adversely the ozone layer. Therefore the effects of disallowing them will be the same as for the proposed action. Also, although they would have been permitted discharges that should have no adverse environmental effect, the additional emmisions to the troposphere from the manufacturing, assembly, recovery, and refurbishment of RVs would be avoided.

5.1.3 Aquatic and Terrestrial Ecology and Water Quality

No construction activities would be needed. Therefore, any impact from these activities at or near the landing site would be eliminated. Similarly, disruption to the local ecology during recovery operations would not occur. Possible adverse effects on local ecology and water quality from a crash landing of the RV could also be discounted.

5.1.4 Noise

The prospect of noise impact due to construction activities at or near the landing site would be eliminated, as would the potential for sonic booms near the landing site.

5.1.5 Transportation

Transportation of the RV from the landing site to the recovery facility, and subsequent transportation for its refurbishment would be eliminated. The additional payloads, propellants, and fluids for the proposed action would not be transported. However, the overall effect on transportation would remain about the same as that for the proposed action.

5.1.6 Socio-Economic Effects

Disallowing commercial RV activities would cancel any beneficial effects on local employment in areas where RV design and manufacture of structures and components occur. If the contracts are cancelled after employment decisions have been made, those people contributing to the project will possibly be without work or transferred. The further into the development program the termination occurs, the more costly it would be and the more negative an impact it would have on the economy.

Past commercial use of space launch vehicles usually was part of a turnkey operation (i.e., a customer rarely purchased/leased a space satelite independently of associated launch services). Assuming that this trend would continue with RVs, not allowing them would not only inhibit potential space researchers/manufacturers (i.e., users), but also remove an avenue of future growth for the space launch industry in general.

A decision against proceeding with the commercial RV activities would also hinder continued U.S. leadership in space. Germany, France, Italy, Japan, China, the United Kingdom, and the former Soviet Union are currently developing RV programs which may be made available to U.S. private sector users if they have no other choice. Thus, closing the RV market to the U.S. private sector would both foreclose potential domestic economic benefits and reduce our international competitiveness. If technological advances are achieved during the development and use of their RVs, foreign enterprises would gain further advantages in marketing these new goods/services. Thus, foreign economies could possibly be stimulated, while the U.S. would lag behind, both economically and technologically.

6.0 RELATIONSHIPS BETWEEN SHORT-TERM USES AND LONG-TERM MAINTENANCE AND ENHANCEMENT OF THE ENVIRONMENT

The short-term benifits resulting from commercial RV activities could have a considerable impact on the productivity of the country, while not significantly affecting the environment. Reentry vehicles will provide the foundation for commercial users cost-effectively to conduct research and possibly manufacturing activities. Advances in material science, the life sciences, and pharmaceutical research/manufacturing could enhance the technological and economic power of the U.S. The environment should not be detrimentally affected; on the contrary, research conducted via RVs may indirectly benefit the environment by furthering understanding of materials science, which could lead to better conservation of natural resources.

7.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

RVs will enable research into the effects of space environment (i.e., fractional or microgravity, cosmic radiation, and the change and/or interruption of circadian rhythms) on small animals, plants, lower life forms, and tissue samples. They will present a platform for the demonstration of advanced technologies and experimental manufacturing processes in space.

RVs require the commitment of both natural and cultural resources. The commitment of natural resources includes the consumption of mineral and biological resources. The commitment of cultural resources includes human and land resources. These basic commitments are not different from those necessary for many other research and development programs; they are similar to the activities that have been carried out in previous space program activities over the past 25 years.

7.1 Natural Resources

Commercial RV activities will consume various quantities of materials and energy. In some cases, a minor change in ecological resources may result due to construction activities. This section attempts to estimate, where possible, those natural resources which will be committed as a result of RV activities.

7.1.1 Material Reguirements

Materials that will be required for RV activities can be divided into two principal classes: those for construction and use of facilities, and those for development, production and transport of RV hardware.

Any modification or construction of new facilities will require use of typical building materials such as steel, aluminum, concrete, asphalt, wood, and wire. The operation and maintenance of recovery facilities may require the consumption of such materials as natural gas, oil, coal, gasoline, diesel fuels, paper, water, paint, and cleaning agents. Existing contractor facilities will probably be used to develop and construct the RVs. Any new construction at or near the landing sites, once they are selected, will be assessed in subsequent documents.

The manufacture of RV flight hardware will require a modest amount of metals, such as aluminum, nickel, stainless steel, carbon, copper, titanium, and other materials. These materials are readily available in large quantities. The amounts which will be required for RV activities are minute compared to the quantities routinely produced. The interstate transportation of RV hardware is considered routine and will contribute to the consumption of fossil fuels. Both ground and air transport will be used, consuming gasoline, diesel fuel, and jet fuel.

Solid and liquid propellants and other consumable fluids will be expended during launch of the RV. The February 1986 Programmatic Environmental Assessment (see Reference 1) describes these materials and their quantities. Once in orbit, the typical RV will use a liquid propellant such as hydrazine for attitude control; an aluminized ammonium perchlorate-based solid rocket fuel is typically used for deorbit thrust. Both these fuels are available in vast quantities.

7.1.2 Energy Reguirements

The energy requirements of RVs are mainly for the manufacture of components and payloads, and ground based activities during inflight support and recovery of the RV.

The manufacturing of components and payloads will be performed at existing commercial facilities. The energy requirements are presently being supplied by existing utilities. No significant increase in energy demand is expected as a result of RV activity. The ground-based activities will also be performed at existing facilities whose energy needs are supplied by existing utilities. RV activities should cause no significant increase in energy consumption at these facilities. If new facilities are constructed to support recovery of the RV near the landing sites, it i6 not expected that these facilities would have abnormal energy demands; this would be addressed in subsequent documents.

7.1.3 Changes in Biological Resources

Component manufacture and test areas are predominantly located in industrial settings where wildlife use is already minimal. Biological resources in and around landing and support facilities will be assessed in subsequent site-specific EAs/EISs. However, because landing sites will probably not be in ecologically/biologically sensitive areas, no effects are expected.

7.2 Cultural Resources

No significant changes to cultural resources, employment, land use, recreational and historical resources are expected.

8.0 PUBLIC COORDINATION

8.1 Coordination Process

A notice of intent was publi~hed in the Federal Register on August 22, 1992 announcing the preparation of a programmatic Environmental Impact Statement (EIS) addres~ing the effects associated with the planned reentry of commercial vehicles from space. No formal scoping meetings were planned, however the notice stated that if sufficient interest was expressed in holding a public meeting, those requests should be forwarded to OCST. No interest in holding public meetings was expressed. Comments on the draft Programmatic Environmental Impact Statement (EIS) for Commercial Reentry Vehicles were requested directly from Federal Agencies, industry, and individuals who expressed an interest in being included on the distribution list. The notice of availability of the EIS was published by the Environmental Protection Agency (EPA) in the Federal Register on January 24, 1992. Responses were received from the Department of Agriculture, which had no comment, and EPA. EPA's concerns were evaluated and are addressed in the final EIS.

8.2 Comments Received and OCST Responses

United States Department of Agriculture | Forest Service | Washington Office | 14th & Independence SW P.O. Box 96090 Washington, DC 20090-6090

Reply To: 1950-4
92 MAR 18 PM 2:06
Date:

Ms. Sharon Boddie
Department of Transportation
Office of Commercial Space Travel
Room 5402A MS-52
400 Seventh Street SW
Washington, DC 20590

Dear Ms. Boddie:

Our agency has reviewed the January 1992 DEIS for Commercial Re-entry Vehic.es published by your agency and has no comments on this proposed action.

Thank you for the opportunity to review your document.

Sincerely,

David E. Ketcham
DAVID E. KETCHAM
Director of
Environmental Coordination

Caring for the Land and Serving People

FS-6200-28b(4/88)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 6 1992

OFFICE OF ENFORCEMENT

Ms. Stephanie E. Myers
Director
Office of Commercial Space Technology
400 Seventh St., SW (S-50)
Washington, DC 20590

Dear Ms. Myers:

The Environmental Protection Agency (EPA) has reviewed the draft programmatic Environmental Impact Statement (EIS) for **Commercial Reentry Vehicles** (RVs). Our comments on this draft EIS are provided pursuant to EPA's responsibilities under the National Environmental Policy Act (NEPA) and section 309 of the Clean Air Act.

We have classified this draft EIS as EC-2, environmental concerns-insufficient information. (See enclosed "Summary of Rating Definitions and Follow-up Action.") This rating reflects our concerns regarding the issues of atmospheric seeding and the National Ambient Air Quality Standards (NAAQS).

The EIS concludes that the effects on stratospheric ozone depletion of 20-30 RVs per year are negligible. Based upon existing knowledge, and based upon conclusions cited from a previous EIS pertaining to launch conditions, EPA does not find flaws in the reasoning used to reach this conclusion. However, there are two comments, not explicitly addressed in the EIS, that should be borne in mind by OCST. The first concerns ablation and the second addresses the current state of atmospheric research.

Section 4.1.1.2 of the draft EIS attempts to address the possible effects of ablation. The issue of seeding the atmosphere with particulates, which may greatly catalyze stratospheric ozone depletion, is not mentioned. In fact, it has been shown that the particulate loading of the lower stratosphere increased by an order of magnitude from 1976-84, with much of the increase identified as aluminum oxide particles thought to emanate primarily from ablating spacecraft materials. It is also believed that these particles serve as condensation nuclei for sulphate aerosols.

Section 4.1.2 of the draft EIS mischaracterizes the NAAQS and should be clarified to reflect the correct role these standards play in an RV operation. The NAAQS are set to protect public health and welfare. There are six pollutants for which EPA has set NAAQS. They are: ozone; carbon monoxide; lead; particulate matter; sulfur oxides and nitrogen oxides. As the title suggests, these standards are

Printed on Recycled Paper

ambient air standards which are monitored through the National Air Monitoring and State and Local Air Monitoring Networks. They apply nationwide. In order to protect the quality of the ambient air, EPA and the state and local air pollution organizations set emission limits, guidelines and control technologies for specific pollutants or processes. The NAAQS themselves are not emission limits and, therefore, RV operations could not fall below these levels. RV operations could contribute (or not contribute) to the failure of an area to attain one or more NAAQS. For example, if the vehicle were reentering in a NAAQS non-attainment area, the emissions from the RV operation could conceivably contribute to the area's failure to attain the applicable NAAQS. Each RV project should be addressed individually in an Environmental Assessment (EA) or EIS in order to determine whether or not its operation will contribute to the failure of an area to attain the NAAQS.

Volatile organic compounds from solvents should be addressed at the same time because these compounds help to form ozone in the presence of sunlight.

Hazardous air pollutants are now addressed through Title III of the Clean Air Act Amendments of 1990. EPA will be publishing the final list of the source categories for the hazardous air pollutants in the Federal Register in mid-1992. If any of the pollutants emitted by an RV operation fall under a category, EPA should be contacted for further information while preparing the tiered draft EA/EIS.

As stated in section 4.3.4, EPA would like to reinforce the importance of addressing the potential hazardous materials that may be created as part of the experiment in space in future tiered EAs/EISs. EPA may have specific comments at that time.

Additionally, EPA believes it is important that the developers of this technology recognize that the impacts of *both launch and reentry* will need to be reexamined in the near future as the ozone depletion crisis deepens (with implications for redefinition of criteria for acceptable impacts on the ozone layer), and as the fundamental processes responsible for stratospheric ozone depletion are better elucidated and quantified by the atmospheric research community.

We appreciate the opportunity to review this draft programmatic EIS. If you have any questions please call me at (202) 260-5053 or have your staff contact Patricia Haman of my staff at (202) 260-3358.

Sincerely,

for Richard E. Sanderson
Director
Office of Federal Activities

Enclosure

ambient air standards which are monitored through the National Air Monitoring and State and Local Air Monitoring Networks. They apply nationwide. In order to protect the quality of the ambient air, EPA and the state and local air pollution organizations set emission limits, guidelines and control technologies for specific pollutants or processes. The NAAQS themselves are not emission limits and, therefore, RV operations could not fall below these levels. RV operations could contribute (or not contribute) to the failure of an area to attain one or more NAAQS. For example, if the vehicle were reentering in a NAAQS non-attainment area, the emissions from the RV operation could conceivably contribute to the area's failure to attain the applicable NAAQS. Each RV project should be addressed individually in an Environmental Assessment (EA) or EIS in order to determine whether or not its operation will contribute to the failure of an area to attain the NAAQS.

Volatile organic compounds from solvents should be addressed at the same time because these compounds help to form ozone in the presence of sunlight.

Hazardous air pollutants are now addressed through Title III of the Clean Air Act Amendments of 1990. EPA will be publishing the final list of the source categories for the hazardous air pollutants in the Federal Register in mid-1992. If any of the pollutants emitted by an RV operation fall under a category, EPA should be contacted for further information while preparing the tiered draft EA/EIS.

As stated in section 4.3.4, EPA would like to reinforce the importance of addressing the potential hazardous materials that may be created as part of the experiment in space in future tiered EAs/EISs. EPA may have specific comments at that time.

Additionally, EPA believes it is important that the developers of this technology recognize that the impacts of *both launch and reentry* will need to be reexamined in the near future as the ozone depletion crisis deepens (with implications for redefinition of criteria for acceptable impacts on the ozone layer), and as the fundamental processes responsible for stratospheric ozone depletion are better elucidated and quantified by the atmospheric research community.

We appreciate the opportunity to review this draft programmatic EIS. If you have any questions please call me at (202) 260-5053 or have your staff contact Patricia Haman of my staff at (202) 260-3358.

Sincerely,

for Richard E. Sanderson
Director
Office of Federal Activities

Enclosure

Environmental Impact of the Action

LO—Lack of Objections
The EPA review has not identified any potential environmental impacts requiring substantive changes to the proposal. The review may have disclosed opportunities for application of mitigation measures that could be accomplished with no more than minor changes to the proposal.

EC—Environmental Concerns
The EPA review has identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require changes to the preferred alternative or application of mitigation measures that can reduce the environmental impact. EPA would like to work with the lead agency to reduce these impacts.

EO—Environmental Objections
The EPA review has identified significant environmental impacts that must be avoided in order to provide adequate protection for the environment. Corrective measures may require substantial changes to the preferred alternative or consideration of some other project alternative (including the no action alternative or a new alternative). EPA intends to work with the lead agency to reduce these impacts.

EU—Environmentally Unsatisfactory
The EPA review has identified adverse environmental impacts that are of sufficient magnitude that they are unsatisfactory from the standpoint of environmental quality, public health or welfare. EPA intends to work with the lead agency to reduce these impacts. If the potential unsatisfactory impacts are not corrected at the final EIS stage, this proposal will be recommended for referral to the Council on Environmental Quality (CEQ).

Adequacy of the Impact Statement

Category 1—Adequate
EPA believes the draft EIS adequately sets forth the environmental impact(s) of the preferred alternative and those of the alternatives reasonably available to the project or action. No further analysis or data collection is necessary, but the reviewer may suggest the addition of clarifying language or information.

Category 2—Insufficient Information

The draft EIS does not contain sufficient information for EPA to fully assess environmental impacts that should be avoided in order to fully protect the environment, or the EPA reviewer has identified new reasonably available alternatives that are within the spectrum of alternatives analyzed in the draft EIS, which could reduce the environmental impacts of the action. The identified additional information, data, analyses, or discussion should be included in the final EIS.

Category 3—Inadequate
EPA does not believe that the draft EIS adequately assesses potentially significant environmental impacts of the action, or the EPA reviewer has identified new, reasonably available alternatives that are outside of the spectrum of alternatives analyzed in the draft EIS, which should be analyzed in order to reduce the potentially significant environmental impacts. EPA believes that the identified additional information, data, analyses, or discussions are of such a magnitude that they should have full public review at a draft stage. EPA does not believe that the draft EIS is adequate for the purposes of the NEPA and/or Section 309 review, and thus should be formally revised and made available for public comment in a supplemental or revised draft EIS. On the basis of the potential significant impacts involved, this proposal could be a candidate for referral to the CEQ.

*From: EPA Manual 1640, "Policy and Procedures for the Review of Federal Actions Impacting the Environment."

Comment 1:
Section 4.1.1.2 of the draft EIS attempts to address the possible effects of ablation. The issue of seeding the atmosphere with particulates, which may catalyze stratospheric ozone depletion, is not mentioned. Much of the increase in particulate loading of the lower stratosphere has been identified as aluminum oxide particles thought to emanate from ablating spacecraft materials.

Response:
There are no known effects due to ablation and particulates. Specifically, aluminum oxide particles would not be produced in reentry operations by ablation. (See discussion on ablation in section 4.1.1, pp. 4-3 to 4-5, 4-8).

Comment 2: The current state of atmospheric research is evolving.

Response:
DOT has examined the most recent literature available. The discussion of atmospheric research has been revised to reflect studies conducted since 1986. There was no change in our findings, however. See page 4-7.

Comment 3:
The EIS should be clarified to reflect the role the NAAQS play in protecting public health.

Response:
The text has been revised for clarity (p. 4-9). Project specific environmental assessments will address local air quality impacts, including emissions of volatile organic compounds (VOCs).

Comment 4:
Hazardous air pollutants will need to be evaluated during Project specific environmental assessments.

Response:
The revised text on page 4-13 reflects the hazardous air pollutants provisions of Title III of the Clean Air Act amendments and acknowledges the need for more detailed project specific review.

8.3 Final EIS Distribution List

FEDERAL AND STATE GOVERNMENT

Advisory Council on Historic Preservation

Department of Agriculture
  Ecological Sciences Division
  F~rest Service

Department of the Air Force
  Air Force (Space Plans and Policy) SAF/SX
  Hill Air Force Base
    6501 Range Squadron/CX
    6545th Test Group/XRP
  Space Systems Division

Department of Energy

Department of Health & Human Services

Department of the Interior

Environmental Protection Agency, Office of Federal Activities

Federal Aviation Administration, Office of Environment and Energy
Federal ~Communications Commission

House Committee on Space Science and Technology (Subcommittee on the Environment)

Lt. Governor of Colorado

National Science Foundation

Ecology Conservation Office

Department of Commerce
  National Oceanic and Atmospheric Administration
  National Environmental Satellite, Data and Information Service
  Office of Space Commerce

NASA
  Unmanned Launch Vehicle and Upper Stages Code ML
  Environmental Management Branch Code JXG
  Office of Commercial Programs Code C
  Environmental Management Office, Marshall Space Flight Center

Strategic Defense Initiative Office - Test and Evaluation

State Science Advisor Utah State Capitol Building

White Sands Missile Range
National Range Operations Directorate - STEWS-NR

NON-GOVERNMENT

Aerospace Daily

American Rocket Company

Arent Fox

AT&T
-Satellite Communications

Bechtel National, Inc.

Boeing Defense and Space Group
Aerospace & Electronics Division

British Embassy
Transport Policy Section

Conatec

EER Systems

Federation of American Scientists

General Dynamics Corporation
Commercial Launch Services

General Electric Company
Astro-Space Division
Reentry Systems Department

The Gleason Agency, Inc.

Hughes Aircraft Company

Instrumentation Technology Associates, Inc.

International Finance Corp.

International Technology Underwriters, Inc.

Lockheed Missiles & Space Co.

Martin Marietta Corporation

McDonnell Douglas Astronautics

Microgravity Research Associates

Mr. John Geddie of Albuquerque, New Mexico

Olsen, Marlene of Mancos, Colorado

Orbital Sciences Corporation

Propulsion Systems
Rocketdyne Division

QW Communications

Reynolds, Smith and Hills

Scott Science & Technology

Spaceport Florida Authority (Ed O'Connor)

Space Industries, Inc.

Space Services, Inc. of America

Space Systems Loral

TRW Space Launch Services

University of Tennessee - Calspan
Center for Aerospace Research
Center for Advanced Space Propulsion

United Technologies

Westinghouse Electric Corporation

9.0 LIST OF PREPARERS

Department of Transportation

Sharon D.W. Boddie (Project Manager)
EIS Experience - 1.5 years
Total Experience - 8 years
Education - B.S. Chemical Engineering (1984)

Ronald Gress
Total Experience - 21 years
Education - B.A. Physics (1967)
M.B.A. Operations Research (1970)

Derek Lang
Total Experience - 3.5 years
Education - M.S. Aerospace Engineering (1989)

Camille Mittelholtz (Environmental Division)
EIS Experience - 19 years
Total Experience - 24 years
Education - B.A. Political Science (1968)

Advanced Engineering & Planning Corp., Inc. (AEPCO)

Edward T. Cremmins
EIS Experience - 11 years
Total Experience - 24 years
Education - B.S. Economics (1958)
M.A. Russian Studies (1970)

John D. Duke
EIS Experience - 5 years
Total Experience - 13 years
Education - A.A. Fine Arts (1976)

Bradley Hilton (Project Manager)
EIS Experience - 18 years
Total Experience - 19 years
Education - B.S. Civil Engineering (1972)

Wei Lin
EIS Experience - 5 years
Total Experience - 10 years
Education - M.S. Chemical Engineering (1985)

F. Scott Truesdale
EIS Experience -
Total Experience
Education - B.S.

Kerming Tsaur
EIS Experience -
Total Experience
Education - M.S.
M.S.

4 years
- 6 years
Environmental Science/Geology (1984)

6 years
- 14 years
Chemistry (1975)
Petroleum Engineering (1978)

James S. Whang
EIS Experience - 20 years
Total Experience - 20 years
Education - Ph.D. Environmental Engineering (1974)

9-2

REFERENCES

1) Cohen, L.S., H.T. Couch, and T.A. Murrin, "Performance of Ablative Materials in Ramjet Environments." In Heat Transfer with Thermal Control Applications, The MIT Press, Cambridge, Massachusetts, 1975.

2) Council on Environmental Quality, Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act, 40 CFR Parts 1500 - 1508, and 1515 - 1517, July 1, 1990.

3) DOT, Environmental Impact Statement Guidelines for the Development of Commercial Space Launch Facilities (including Appendix A: "Master Checklist for the Preparation and Review of Environmental Impact Statements" and Appendix B: "Detailed Checklist for the Preparation and Review of Environmental Impact Statements."), July 1989.

4) DOT, The Future of the Commercial Space Launch Market: 1993 - 2005, May 1991.

5) M.A. Faget, B.J. Garland, J.J. Buglia, NACA Research Memorandum L58E07a, "Preliminary Studies of Manned Satellites, Wingless Configuration: Non-Lifting", May 18, 1958.

6) DOT, Order 5610.1C, Procedures for Considering Environmental Impacts, as modified through July 30, 1985.

7) DOT, Programmatic Environmental Assessment of Commercial Expendable Launch Vehicle Programs, February 1986.

8) Goetz, P.W (Ed.), The New Encyclopedia Britannica: Macropaedia, 15th Edition, Encyclopedia Britannica, Chicago, 1985.

9) Gomez, A.V., C.G. Johnson, and D.M. Curry, "Radiative, Ablative, and Active Cooling Thermal Protection Studies for the Leading Edge of a Fixed-Straight Wing Space Shuttle." In Fundamentals of Spacecraft Thermal Design, Lucas, J.W. (Ed.), The MIT Press, Cambridge, Massachusetts, 1972.

10) Harr, M., and R. Kohli, Commercial Utilization of Space: An International Comparison of Framework Conditions, Battelle Press, Columbus, Ohio, 1989.

11) Hicks, R.M., J.P. Mendoza, and F. Garcia, Jr., "A Wind Tunnel-Flight Correlation of Apollo 15 Sonic Boom."

12) Hildago, C.J., C.J. Casey, et al., "Toxicity of Pyrolysis Gases from Silicone Polymers", Journal of Combustion Toxicology, Vol. 5, May 1978.

13) Ladacki, M., "Chemical Aspects of Ablation". In Chemistry of Space Research, Landel, R.F and A. Rembaum (Eds.), American Elsevier Publishing Company, Inc., New York, New York, 1972.

14) Lee, Burton, "Concerning Re-entry Capsules," Space, May-June 1990.

15) McKnight, D., et al., "The Orbital Debris Issue: A Status Report," Space Technology, Vol. 10, No.3, 1990.

16) Molina, M.J., "Heterogeneous Chemical Processes in Ozone Depletion". In Ozone Depletion, Greenhouse Gases, and Climate Change, Proceedings of a Joint Symposium by the Board on Atmospheric Sciences and Climate, National Academy Press, Washington, D.C., 1989.

17) NASA, "A Conceptual Design Study of the Reusable Reentry Satellite," Technical Memorandum 101043, Swenson, B.L., et al., October 1988.

18) NASA, Environmental Impact Statement for the Space Shuttle Program, April 1978.

19) NASA, Present State of Knowledge of the Upper Atmosphere 1990: An Assessment Report, Watson, R.T., M.J. Kurylo, M.J. Prather, September 1990.

20) NASA, Tier 1 Environmental Impact Statement for Space Station Freedom (Draft), February 1990.

21) Office of Technology Assessment, Congress of the United States, "Orbiting Debris: A Space Environmental Problem," Background Paper, 1990.

22) Oral Statement of Mr. Joe Pawlick, Program Manager of the COMET Program.

23) Public Law 98-575, "Commercial Space Launch Act," October 30, 1984; as amended by P.L. 100-657, "Commercial Space Launch Act Amendments of 1988," November 15, 1988.

24) Rees, M.H., Physics and Chemistry of the Upper Atmosphere, Cambridge University Press, 1989.

25) R.S. Harwood, C.H. Jackman, I.L. Karol, and L.X. Qiu, Predicted Rocket and Shuttle Effects on Stratospheric Ozone, Chapter 10: Scientific Assessment of Stratospheric Ozone, 1992.