GENERIC ENVIRONMENTAL ASSESSMENT OF STS PAYLOADS (1982-1991)

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ABSTRACT

This assessment presents the results of a comprehensive, generic analysis of the environmental effects of STS mission payloads and associated operations from 1982-1991. A traffic model, incorporating a mission data base, has provided the basis identifying the cumulative, regional, and interactive effects of these anticipated STS missions.

Because this assessment incorporates a broad spectrum mission payloads, the preparation of environmental assessments on future STS flights will not be necessary. An environmental assessment short form (Appendix A) will be completed for each mission on a given STS flight. The results of this environmental assessment will be integrated with the mission particular characteristics and summarized on this form.

From the perspective of payload ground and flight operations, no significant, long term, adverse impacts are anticipated under the Proposed Action. Hazards and risks associated with the Shuttle and/or payload operations are minimized to the maximum extent feasible through NASA's safety and design requirements. Accidents, therefore, are of low probability and would result in local and temporary effects. Of greater significance are the potential social (e.g. education and technology spinoffs) and customer (e.g. cost savings and research knowledge gains) benefits anticipated. Under the Expendable Launch Vehicle/Sounding Rocket and No-Action Alternatives many of these benefits would be markedly reduced or eliminated. The environmental consequences of STS, expendable launch vehicle, and sounding rocket launches have been incorporated into this assessment. The results of this generical environmental assessment of STS payloads support a Finding of No Significant Impact.

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1.0 SUMMARY AND CONCLUSIONS

This assessment identifies the potential environmental effects of the Space Shuttle launch and operation of payloads. Under the Proposed Action, the Space Shuttle would be utilized for the performance of 928 missions in space from 1982-1991. Two major alternatives to the Proposed Action were identified as reasonable approaches to achieving the payload mission objectives. These included the use of expendable launch vehicles/sounding rockets (Expendable Launch Vehicle/Sounding Rocket Alternative) and terrestrial systems (No-Action Alternative). Because of technical and operational constraints, many of the proposed missions could not be achieved under the two alternatives; in the case of the No-Action Alternative, for instance, about 40 percent of the unclassified missions (exclusive of National Security, Mid-deck experiments, and Get Away Specials) would have to forego anticipated benefits under the Proposed Action. Under the Expendable Launch Vehicle/Sounding Rocket Alternative, many of the automated payload missions, such as satellite deployment and small research missions, could be achieved.

1.1 Proposed Action

The Proposed Action addressed in this document is the utilization of the Space Transportation System (STS) for the performance of missions in space. Potential missions span a number of areas, including science and applications, technology development, commercial applications and National Security applications, and involve varying degrees of services and associated support systems.

An STS Traffic Model provided a basis for estimating the future STS impacts and includes 928 missions (exclusive of classified military missions), scheduled on 124 flights (exclusive of reflight opportunities and National Security flights) from 1982-1991.

The payload categorization is based on the potential space operations: launch vehicle (i.e. Orbiter) integrated missions, and free-flying missions. Launch vehicle integrated missions include payloads which remain attached to the Orbiter throughout its operation; are deployed and retrieved on a single flight or; are returned to Earth. Mid-deck experiments, Spacelab, Get Away Specials, and Landsat retrieval are examples of payloads within this mission class. Free-flying missions include payloads which are deployed from the cargo bay and remain detached permanently or are retrieved on a subsequent flight or; are retrieved, serviced, and redeployed on a single flight. The Long Duration Exposure Facility, Gamma Ray Observatory, communication satellites, and planetary spacecraft are exemplary of payloads in this latter class.

1.2 Alternatives to the Proposed Action

The two alternatives to the Proposed Action are: (1) continue the U.S. Space Program, but with the use of expendable launch vehicles (ELV); or (2) no-action, which would be to use terrestrial-based research, development, science and technology application, and communication systems. These two alternatives are described below.

1.2.1 Expendable Launch Vehicles

One alternative to the Proposed Action is the use of expendable launch vehicles (ELVs) and sounding rockets to achieve the payload mission objectives. The population of launch vehicles available encompasses both the U.S. and international countries; however, a subset of this population was selected as reasonable alternatives.

As an alternative to the Space Transportation System, ELVs and sounding rockets offer a wide but limited capability for orbital and suborbital missions. All missions are automated and include scientific, commercial, and DOD applications.

The ELVs provide orbital launch capability and include a variety of solid and liquid-staged vehicles; Titan, Atlas-Centaur, Delta, Scout, and Ariane. The Titan, Atlas-Centaur, Delta, and Scout are U.S. rockets primarily launched from the Eastern Test Range (ETR), Florida, and the Western Test Range (WTR), California (the Scout is launched from Wallops Flight Center, Virginia, WTR, California and San Marco, Africa). Ariane is a European vehicle launched from the Centre Spatial Guyanais-Guiana Space Center (CSG) in French Guiana, South America and is under the direction of the Centre National D'Etudes Spatiales (CNES) and the European Space Agency (ESA). For high energy missions, upper stages are coupled with the base vehicles. Typical upper stages include the Centaur, the Payload Assist Module (PAM), and the Inertial Upper Stage (IUS), among others. Sounding rockets provide a wide variety of suborbital and low-orbit mission capabilities. Both solid and liquid propellants are used for propulsion on these launch vehicles.

1.2.2 No-Action Alternative

The No-Action Alternative is defined as the fulfillment of the mission objectives through ground-based or terrestrial systems. This implies that the system characteristics and operations are substantially similar to the system that is being substituted. For many of the payloads, space applications represent a substitute for, extension of, or advancement of terrestrial systems. Communications and many environmental monitoring systems are examples of systems that, in most cases, have terrestrial equivalents.

Research and science and application payloads represent unique cases where terrestrial equivalents are virtually preempted. In these instances, the space environment characteristics are utilized for research, experiments, and testing and usually can not be duplicated on earth. Examples of payloads in this class are life science and physical science experiments requiring long duration exposure to microgravity, or Earth observational measurements requiring synoptic views. There are also payload-related activities that are, by definition, space operations. Satellite servicing, maintenance and retrieval, and search and rescue missions are exemplary of services that may be required for a payload. Based on these considerations, some payload characteristics and activities precluded the feasibility and practicality of a terrestrial equivalent. These include mission activities related to: (1) payload servicing and maintenance; and (2) payload retrieving. These also include those missions with the characteristics/requirements of: (1) long duration exposure to microgravity environment or other unique space environment parameters (e.g., ultra-high vacuum, high energy radiation, large volume of ionized gases); (2) viewing direction (e.g., synoptic views); and (3) other sampling and measurements and/or validation requirements (physical, chemical, spectroscopic, etc.) beyond terrestrial capabilities both technically and economically (e.g., highly accurate pointing and stability).

1.3 Environmental Consequences of the Proposed Action and Alternatives

The environmental analysis addresses seven environmental categories (socioeconomics; space quality; air, land, and water quality; noise; biotic resources; human health; and resource use) under a normal-operation scenario. An eighth category, accidents, was distinguished to address the possible environmental effects resulting from human error or mechanical/electrical failures of equipment and subsystems. The magnitude and type of impact, the duration, geographical context, and the potential for interactive and cumulative effects were considered for each of these aforementioned categories.

The process for analysis of the environmental effects from the launch vehicle and payload operations incorporated previous environmental assessments on launch vehicle related effects. Because of the tiering approach to this analysis, the launch vehicle and payload effects were evaluated on an independent basis initially, but then integrated to establish the total mission effects.

The results of this analysis are summarized in matrix form for both the launch vehicles and payloads and indicate that the launch vehicle impacts (documented in previous environmental studies) would essentially eclipse those associated with the payloads. From the perspective of payload ground and flight operations no significant, long-term, adverse impacts are anticipated under the Proposed Action. Specific findings of this analysis include:

Socioeconomics. Employment levels associated with payload manufacture, support, and servicing, would be relatively small and geographically dispersed in comparison with launch vehicle systems. Of greater significance are the potential social (e.g., education and technology spinoffs) and customer (e.g., cost savings, research knowledge gains) benefits anticipated under the Proposed Action.

The nation's support of and interest in the space program is clearly evinced by the high media exposure and presence of observers at each STS launch. This interest in the success of each mission contributes to and fosters pride in national space efforts.

The successful launch of the Shuttle and the completion of mission objectives provides a technical data base for continuous improvements in both the STS and the design and operation of payloads. The STS and future technology spinoffs are indispensable to performing future missions and maintaining leadership in space exploration.

International cooperation on research efforts allows exchange of technical data and collaboration of experts in scientific fields on topics ranging from basic theories of space phenomena to payload design optimization. The sharing and contribution of space hardware, experimental results, and research talents are strong technology drivers which could accelerate developments and knowledge in basic science and applications (e.g. atmospheric and space plasma physics) and potential commercial ventures and spinoffs (e.g. materials procesing, communications).

The Get Away Specials are exemplary of a payload class that encourages a positive and ambitious viewpoint of science, engineering, and technology by youth. This attitude is essential not only to encouragement of careers in science and engineering, but also to maintenance of the U.S. lead in technology and space.

The development and execution of commercialization opportunities is dependent on the fundamental research and development activities being initiated on the Shuttle over the next decade. Research and technology peformance tests in such areas as materials processing (e.g., glass fibers, pharmaceuticals); communications and Earth resource satellites and measurement systems; satellite servicing and; construction and assembly of subsystems in space are exemplary of the efforts being initiated that will affect the design, cost, and safety of spacecraft missions and operations.

Spinoff is the emergence of new products and processes which have origins in technology originally developed to fulfill the goals of NASA aerospace programs. There have been thousands of such spinoffs, each contributing some measure of benefit to the material economy, productivity, or lifestyle. In the aggregate, they represent a substantial dividend on material investment in aerospace research. The payload missions identified in this report produce direct public and user benefits while simultaneously contributing indirect benefits (spinoff) by generating new technology which may lead to secondary applications in the future.

The value of the benefits to the customers of the STS is inherently related to the nature of the payload mission - the technology, risk, system cost, and availability of equivalent systems. Consequently, the value of benefits for science and application, space processing, communications, and other free flying and integrated missions must be evaluated with respect to the mission requirements and compared to other alternatives. A partial listing of potential benefits is provided below:

- Lower transportation costs
- Reduced equipment cost, enhanced availability, and longer service life from STS maintenance and servicing capability
- Ability to react to unexpected or transient events
- Accelerated understanding and insights from real time involvement of payload specialists and crew in experiments
- Ability to construct, assemble, and checkout systems that may be difficult to alter or modify

- Ability to simplify designs that involve complex deployment mechanisms
- Production of higher quality/quantity products.

With the use of alternative launch vehicles or ground-based systems many of these benefits would be markedly reduced or eliminated.

Space Quality. The present and future orbital debris population in Low Earth Orbit (LEO) and Geostationary Orbit (GEO) was analyzed with respect to the Traffic Model for the Space Shuttle from 1982 to 1991 to determine the collision probability of orbital debris with operational payloads. Conservative estimates indicate that by 1991, well over 900 objects would have to be released per one week mission to achieve a collision probability of 10^{-5}.

The Traffic Model includes 175 upper stages that are projected to be used for space missions over the next decade. The macroparticle debris generated in various orbits as a result of these space missions under the Proposed Action would be 184 objects. Use of expendable launch vehicles would raise this number to over 340 objects. Most of this additional debris would be associated with LEO.

In both LEO and GEO, on-orbit collisions would adversely affect future space operations by increasing the likelihood of additional collisions and failures for operating spacecraft. While the threat to space operations from the debris population is not yet severe, continued use of space without regard to the consequences of populating the environment with additional objects may have a significant and adverse effect on space operations over the next 30 years. Programs to control the rate of debris deposition represent the most effective, near-term alternative to controlling the debris hazard.

Air, Land, and Water Quality. The environmental effects on air, land, and water quality from payload manufacture through post-flight processing are expected to be negligible. Sources of these effects include: payload manufacture (waste products from primary production and assembly operations); launch site processing and testing; and post-flight reprocessing (e.g., venting, purging, and cleaning operations). Adherence to regulatory and safety practices and procedures would limit the impact to air, land, and water quality from the storage, release, or use of materials and/or wastes.

Noise. Noise effects from payloads are expected to occur in association with payload manufacture and launch site pre- or post-processing activities (e.g., engine test firings of upper stages). Relative to other noise sources and levels, these sources should not cause a major disturbance or annoyance to the general public. Occupational safety and health regulations limit worker exposure over a period of 8 hours to a sound level of 90 dB_A. These regulatory limits, implemented through engineering controls and safe practices, serve to protect worker health. Consequently, no adverse noise impacts are anticipated from payload manufacture or launch site operations.

Biotic Resources. Based on the results of the analyses performed relative to the potential for waste steam generation from payload activities, no long-term or cumulative effects on flora or fauna are predicted. Most of these effects are traceable to the manufacturing process and, on a per payload basis, are negligible.

Direct impacts on endangered or threatened species and critical habitat are not anticipated because of the small quantities of waste or low risk associated with the payload manufacturing and operational cycle.

Health. Public and occupational health effects are anticipated to be significant. Payload ground and flight operations will not involve significant quantities of hazardous emissions or high risk operations which would affect the safety of crew or employees.

Resource Use. Natural and cultural resource commitments are insignificant when compared to national data bases. Shuttle-related energy and material demands are significantly larger than payload commitments. On a cumulative basis, generic estimating techniques indicate that total energy commitments will require less than 0.1 and 0.0016 percent for the Shuttle launches and satellite payloads, respectively. Material commitments also are negligible on a national scale and primarily involve steel, aluminum, composites, titanium, and solid and liquid propellants.

Accidents. Under worst-case scenarios, some payloads and payload operations could result in damage to the Space Transportation System equipment or personnel. The probability and severity of these events, however, are reduced or eliminated with appropriate hazard controls. NASA's Safety Policy and Requirements are directed at protecting flight and ground personnel, the STS, other payloads, the general public, and the environment from payload-related hazards.

In general, differences between the Proposed and Alternative Actions' environmental effects are not significant. The most noteworthy differences involve the reduced benefits to society and STS customers because of the more limited capabilities and services offered by alternative launch vehicles or ground-based systems. Reductions in environmental effects also would be commensurate with the number of missions that would have to be abandoned with the Expendable Launch Vehicle alternative, additional space debris would be generated over the Space Shuttle option for a given mission. The space debris issue is present regardless of the alternative examined and will require further monitoring and evaluation during the next decade.

1.4 Recommendation

The Shuttle launch of payloads is the currently preferred approach to achieving the goals of NASA and other agencies, organizations, private companies, and other nations in relation to the types, classes, and numbers of payloads described in this assessment. The alternatives do not offer the flexibility and capabilities of the Space Shuttle. The negative environmental effects of the Proposed Action are minimal while the potential benefits are very great. Because of this, a Finding of No Signifcant Impact for the Proposed Action of STS launch of payloads is recommended.

2.0 PURPOSE AND NEED

With the successful completion of the Space Shuttle Development tests (STS 1-4) and the first operational flights (STS 5-13), the United States has begun to achieve and measure the benefits of man's presence in space. Through the operation of the versatile, reusable Space Shuttle, continued achievement of national space goals can be expected as the launch rate increases through the 1980's. These goals are to (NASA/Hq, 1983g):

- Conduct an effective and productive space science program which expands human knowledge of the Earth's environment, the solar system, and the universe
- Conduct effective and productive space applications and technology programs which contribute materially toward U.S. leadership and security
- Expand opportunities for U.S. private sector investment and involvement in civil space and space-related activities
- Develop and apply advanced technology and management practices (under NASA leadership) which contribute signficantly to national productivity.

A broad range of direct and indirect environmental impacts was foreseen during the development and operational phases of the Space Transportation System (STS). To date environmental impact statements have been prepared for the overall Shuttle Program, launch site operations, and various development and test activities.

In addition, environmental assessments have been prepared on the potential environmental effects of the launch and operation of payloads by the STS on a per flight basis (NASA/Hq, 1982; 1983 (a), (b), (d), (e); 1984 (a), (b). The results of these environmental analyses indicate that the individual impacts from each Space Shuttle mission could combine or interact to create different, larger, or more complex types of environmental impacts than would generally be associated with any one mission. The geographic extent of these collective impacts also could reach beyond the locality into a larger region, whether it be the terrestrial or space environment.

This document presents the results of a comprehensive, generic analysis of the environmental effects of STS mission payloads and associated operations from 1982-1991. A traffic model, incorporating a mission data base, has provided the basis for identifying the cumulative, regional, and interactive effects of these anticipated STS missions.

Because this assessment incorporates a broad spectrum of mission payloads, the preparation of environmental assessments on future STS flights will not be necessary. An environmental assessment short form (Appendix A) will be completed for each mission on a given STS flight. The results of this will be integrated with the mission particular characteristics and summarized on this form.

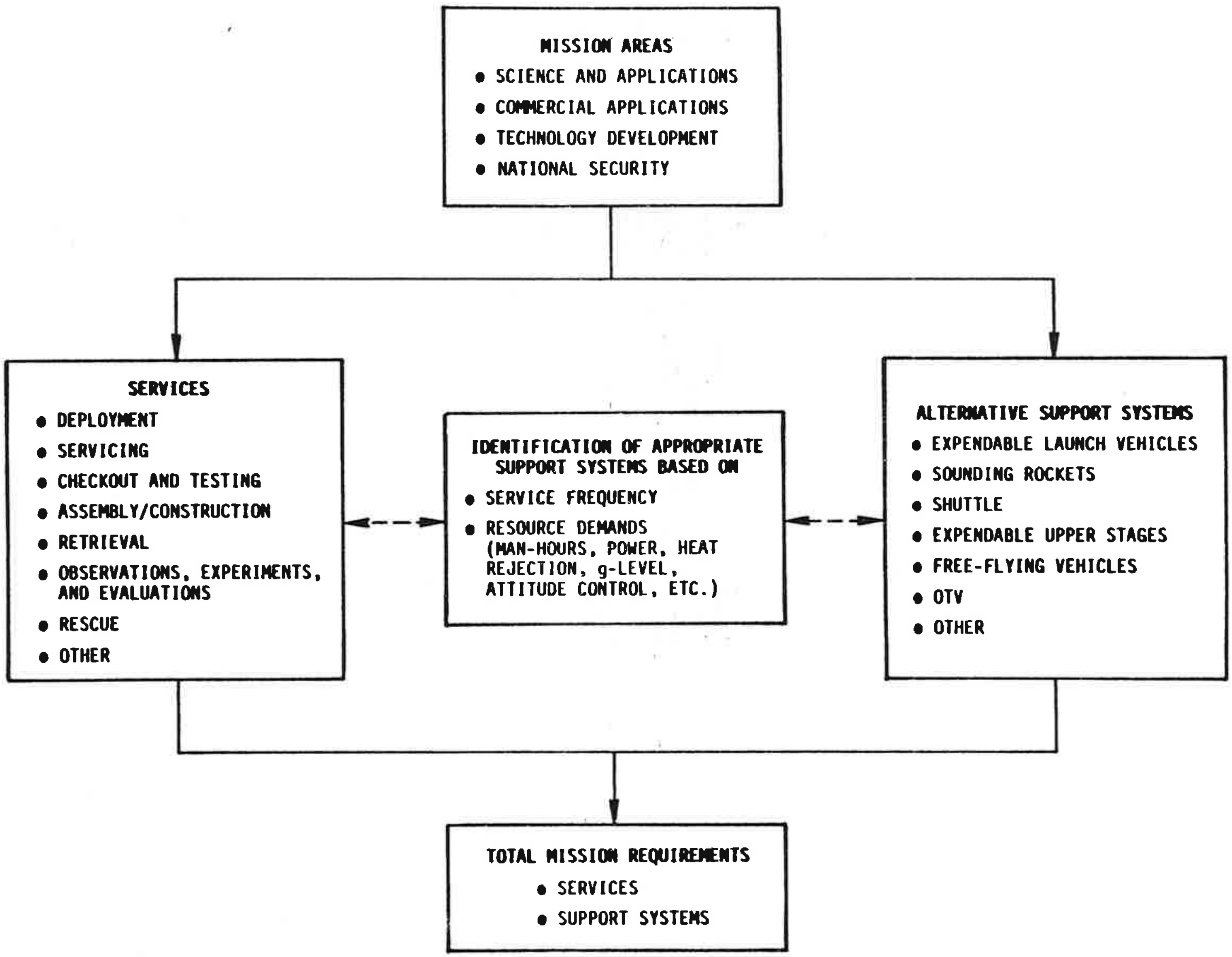

FIGURE 1. RELATIONSHIP OF MISSIONS, SERVICES, AND SUPPORT SYSTEMS

TABLE 1. SUMMARY OF PAYLOAD DESIGN AND OPERATIONAL REQUIREMENTS

Payload Operations	Shuttle	Atlas/ Delta/Titan	Scout/Sounding Rockets	Ariane
PRELAUNCH				
Design and Construction	User and launch agent coordinate regarding mission requirements and launch scheduling. Payload design process must include detailed payload descriptions/drawings; safety analyses; interface requirements; ground and flight services, operations and maintenance requirements; testing and check-out procedures.		Payload design and safety requirements are less stingent than those associated with the Shuttle.	Payload design and safety requirements are less stingent than those associated with the Shuttle.
Assembly and Testing	Build-up and assembly of spacecraft/payload components and systems; system integration, tests and verification; integration of cargo bay pallets and packages; installation of mid-deck experiments; cargo integration tests; environmental canister loading.	Build-up and assembly of components and systems; system integration, tests and verification.	Operations similar to Atlas/ Delta/Titan.	Operations similar to Atlas/Delta/Titan.
Hazardous Operations	Upper stage mating and spin test; monopropellant loading; gas charging; battery loading; ordnance loading; environmental canister loading cargo integration tests; system integration tests.	Operations similar to Shuttle (except cargo integration tests).	Operations similar to Shuttle (except cargo integration tests).	Operations similar to Shuttle (except cargo integration tests).
Payload-Vehicle Mating and Verification	Non-propellant payloads mating at OPF; propellant loading and upper stages mating at launch pad; final systems tests and verification; cargo bay and cabin close-out.	Payload mating with stage(s) and insertion in launch vehicle; propellant loading; subsystem check-out; interface verification and final tests; fairing installation and check-out.	Operations similar to Atlas/ Delta/Titan.	Operations similar to Atlas/Delta/Titan.
LAUNCH	ETR or WTR launch.	ETR or WTR launch.	Scout launches are from WFC, WTR or SM; Sounding Rocket launches are from WFC, WSMR, Ft. Churchill Rocket Range (Canada), or Poker Flat Rocket Range (Alaska).	CSG launch.
IN-FLIGHT				
Activation/Operation/ Deactivation	Crew activated: cargo bay payloads; launch platforms for upper stages; mid-deck experiments.; Spacelab and pallets. Crew operated: Mid-deck experiments; EVA; Spacelab; other.	Propellant stages activated, propellant burns, stages separate; payload separates from upper stage (if required); final orbit insertion provided by propellant system (e.g., apogee kick motor).	Orbital operations: Similar Atlas/Delta/Titan. Suborbital operations: payload activation and data collection.	Operations similar to Atlas/Delta/Titan.

TABLE 1. (Continued)

Payload Operations	Shuttle	Atlas/ Delta/Titan	Scout/Sounding Rockets	Ariane
IN-FLIGHT (Cont.)				
Deployment	Payload and associated hardware checkout (see servicing/refueling) deployment and operation. Propellant may be used for attitude control and and station-keeping.	Pre-programmed deployment (e.g., solar panels, communication antennae) and operation. Propellant may be used for attitude control and station-keeping.	Operations similar to Atlas/ Delta/Titan.	Operations similar to Atlas/Delta/Titan.
Servicing/Refueling	Servicing of payloads (e.g., assembly and testing) prior to deployment; repair/refueling of on-orbit satellites and redeployment.	Not Applicable.	Not Applicable.	Not Applicable.
Retrieval	Rendezvous with non-functioning satellites; reload into cargo bay for Earth repair; retrieve deployed satellites.	Not Applicable.	Not Applicable.	Not Applicable.
LANDING	No on-board payloads in operation during landing of Orbiter.	Not Applicable.	Suborbital flights: Payload parachuted to Earth for ocean retrieval.	First and second stages can be parachuted for ocean retrieval.
POST-FLIGHT				
Retrieval	Primary and secondary landing facility operations similar; small and time-critical payloads off-loaded first.	Not Applicable.	Suborbital flights: Payload can be retrieved for possible reuse.	First and second stages can be retrieved for possible reuse.
Purge and Safety	Purging and gas-freeing of payload and Orbiter systems; safing of power systems.	Not Applicable.	Not Applicable.	Not Applicable.
Off-Loading and Transport to User	Payloads off-loaded at the OPF(ETR) or OMCF (VAFB) and returned to user; user responsible for post-flight (re)processing and transportation off-site.	Not Applicable.	Not Applicable.	Not Applicable.

*NA = Not Applicable

Sources: GDC, 1971; GDC 1977; GDC 1981; ESA 1981a; ESA 1981b; BCL, 1981; MDAC, 1973; MDAC 1980; Martin Marietta, 1974; Vought, 1980, Teeter and Reynolds, 1983; NASA/Hq, 1973b.

TABLE 2. SUMMARY OF PROJECTED PAYLOADS FOR STS OPERATIONS, 1982–1991[a]

Payload Mission Class	Scheduled STS Payloads[b]		Representative Payload(s)
	Number	Percent (Approximate)	
Launch Vehicle Integrated Payloads			
Mid-Deck Experiments[c]	248	27	Continuous Flow Electrophoresis
Get Away Specials (GAS)[d]	372	40	GAS (STS-7)
Spacelab	9	1	Spacelab-1 (Multidiscipline); Spacelab-4 (Life Sciences)
Other Integrated Science, Technology, and Application Missions	64	7	Materials Science Lab; Tethered Satellite System; Shuttle Infrared Telescope; Space Plasma Lab.
Free Flying Payloads			
Communication Satellites	130	14	Hughes HS-376
Environmental Satellites	23	3	Geostationary Operational Environmental Satellite; Advanced TIROS-N
Navigation Satellites	29	3	Navstar/GPS
Planetary Spacecraft	4	1	Venus Radar Mapper
Other Free Flying Science, Technology, and Application Payloads	49	5	Space Telescope; Long Duration Exposure Facility-1; German Shuttle Pallet Satellite; Origin of the Plasma in the Earth Neighborhood; Electrophoresis Operations in Space
TOTAL	928	100	

(a) Additional detail on the payloads is provided in Appendix B.
(b) Scheduled payloads shown in this table exclude 32 classified military missions.
(c) Mid-deck experiments are estimated at 2/flight.
(d) GAS are estimated at 3/flight.

3.0 DESCRIPTION OF THE PROPOSED ACTION AND IMPORTANT ALTERNATIVES

Under the Proposed Action, the Space Shuttle is projected to be utilized to accomplish 928 missions from 1982-1991. These missions would be flown on 124 STS flights with approximately 80 percent of the flights originating from Kennedy Space Center (KSC). In addition to these projected missions, which are the basis for analysis of cumulative and interactive effects of multiple missions, generic payloads also are defined to assess the effects of representative individual missions. The characteristics of the launch vehicles and payload ground and flight operations are provided below and serve as a baseline for establishing the environmental effects due to launching payloads. Two major alternatives to the Proposed Action are described. The Expendable Launch Vehicle/Sounding Rocket Alternative involves the use of expendable launch vehicles or sounding rockets to achieve payload mission objectives. The No-Action Alternative is defined as the fulfillment of missions through the use of ground-based systems.

3.1 Payload Descriptions

The projected Traffic Model includes 928 military and civilian payloads (exclusive of National Security Missions) scheduled on 124 flights (exclusive of reflight opportunities and National Security flights) from 1982-1991. The missions, as outlined in this section, encompass numerous disciplines and cross-cut all phases of the R&D cycle (i.e., from basic research to commercial operations).

Figure 1 illustrates the relationship between potential missions, services, and support systems. Table 1 summarizes the payload design and operational requirements for the STS and other launch vehicles.

In the context of this report, a mission is defined as the performance of investigations or operations in space to achieve the customer's goals. A single mission, therefore, could require more than one flight or more than one mission could be accomplished on a given STS flight. The payload refers to the total complement of instruments, equipment, support hardware, and consumables which would accomplish the mission objective.

The missions are summarized in Table 2. The Traffic Model generated is provided in Appendix B and details by flight, launch site, and year, the payloads and associated characteristics (orbit, mass, carrier, propellants). Alternatives to STS launches also are identified. The totals in Table 2 include delivery, servicing retrieval, and sortie operations. This mission count reflects the number of mass elements contained in the traffic model, not the number of mission steps involved in the disposition of a mass element. Each time a user payload is transported, handled and/or processed by an STS element it is counted as a mission. For example, placing a materials processing free-flyer into orbit initially is counted as a delivery mission. In the case of resupplying a free-flyer (exchange of finished product for new material), it is counted as a servicing mission.

The Traffic Model includes missions that were excluded from analysis in this assessment. These missions included those payloads which significantly modify the environment; contain or release radioactive material in excess of millicurie quantities; result in long-term impacts due to high probability, catastrophic events and; involve significant public controversy. By these criteria, Galileo, Chemical Release Radiation Effects Satellite (CRRES), International Solar Polar Mission (ISPM), and the Space Station-related payloads are excluded from detailed consideration in this report. For these latter missions, separate environmental impact statements must be prepared (NASA/Hq, 1981a). Missions involving national security also have been excluded from this study because unclassified descriptions were not available for the environmental analyses.

The missions have been placed into two general classes based on potential space operations: launch vehicle (i.e. Orbiter) integrated payloads and free-flying payloads. Launch vehicle integrated missions are defined as payloads which remain attached to the Orbiter throughout its operation; are deployed and retrieved on a single flight or; are returned to Earth. Mid-deck experiments, Spacelab, Get Away Specials, Landsat retrieval, and the Tethered Satellites System (TSS), are examples of payloads within this mission class. Free-flying payloads are those payloads which are deployed from the cargo bay and remain detached permanently or are retrieved on a subsequent flight or; are retrieved, serviced, and redeployed on a single flight. The Long Duration Exposure Facility (LDEF), Gamma Ray Observatory (GRO), communication satellites, and planetary spacecraft are examples of payloads in this latter class.

Separation of payloads into these mission classes is based on a consideration of the differences in the type and magnitude of associated environmental effects. Generic features of these missions are noted in the following subsections. Representative payloads also are identified within these mission classes.

3.1.1 Launch Vehicle Integrated Payloads

Launch vehicle integrated payloads described in this Section include Mid-deck experiments, Get Away Specials, Spacelab, and other science, technology, and application missions.

Mid-Deck Experiments. The Space Shuttle Orbiter Mid-deck not only provides a habitat and storage facility in space, but also the capability to carry a number of experiments. These experiments may be automated or involve human interaction in a laboratory environment similar to that of Spacelab. The utilities of the Mid-deck include crew accommodations, general storage provisions, and experiment utilities. Major crew accommodations include a waste collection system, sleeping station, food system, personal hygiene system, and a housekeeping system. The Mid-deck provides area for 42 storage lockers, with reusable trays in each locker. Two standard-sized trays, one large and one small, are available with egg crate-type dividers and appropriate equipment restraints. The lockers are limited by center of gravity constraints and a 27 kg maximum allowable locker mass (NASA/JSC, 1980a).

A wide variety of experiment payloads have been flown on the Mid-deck, including various student experiments such as the Night-Day Optical Sensor of Lightening, the Monodisperse Latex Reactor, and Continuous Flow Electrophoresis System. Generally, Mid-deck experiments are somewhat automated, but may require astronaut assistance. All Mid-deck experiments must conform to the safety requirements (NASA/Hq, 1980b).

Get Away Specials (GAS). On any given STS flight, the primary payloads generally will not occupy the total space available in the Orbiter's cargo bay or fully utilize the maximum weight available. Such a situation is the basis for a program to fly small experiments into space that will exploit extra space/weight opportunities. The effort is organized as the Small Self-Contained Payload or Get Away Special (GAS) Program (NASA/JSC, 1980b; NASA/GSFC, 1979; Lee, 1979).

GAS offers low-cost opportunity for individuals, commercial organizations, and educational institutions to conduct research and development experiments in space environment enountered by remaining on-board the Orbiter's open cargo bay. Structurally, the container is a pressure vessel constructed from aluminum and fiberglass and fitted with an outer layer of thermal insulation. As a housing for GAS experiments, it is ordinarily mounted on a sidewall of the Orbiter's cargo bay. It can, however, be used as a general purpose carrier, as for example during the OSTA-2 mission (STS-7) where three containers contained MAUS (MAUS is a German acronmy for Autonomous Materials Science Experiments in Weightlessness) materials processing experiments and be attached to the Mission Peculiar Equipment Support Structure (MPESS) platform. The experiment envelopes involve a diameter of 50.2 cm and a height of 35.9 to 71.8 cm. The mass capacity ranges from 27 to 91 kg (NASA/GSFC, 1979).

Spacelab. Spacelab, the European-developed and built contribution to the STS Program, is a versatile, general purpose orbiting laboratory for manned and automated activities in near-Earth orbit. The Spacelab is carried to and from orbit in the cargo bay of the Space Shuttle Orbiter. It remains in the open cargo bay during the mission. Orientation requirements are established by the Orbiter. Through the use of two launch sites (KSC and VAFB), complete world coverage is obtained and orbits of 20-104 degrees are possible. Multidisciplinary or single-purpose missions, which can involve on-orbit activities up to a week, span numerous scientific fields: materials processing, environmental observations, life sciences, astrophysics and solar astronomy, plasma physics, and technology testing and verification. NASA is currently considering extending the Shuttle orbital stay time to 30 days.

Spacelab consists of module and pallet sections used in various configurations to fulfill mission requirements: module only, pallet only, and module plus pallet. The pressurized module, accessible from the Orbiter cabin through a transfer tunnel, provides a shirt-sleeve working environment and supplies basic services such as power, thermal control and data management, together with basic support equipment. The module consists of one or two cylindrical segments, each 4.06 m in diameter and 2.69 m long, and two end cones. Subsystem equipment is located in the core segment, leaving about 60 percent of the volume available for experiments. The approximate mass available to a payload and mission dependent equipment (e.g., consumables, EVA equipment), ranges from 5790 kg for a short module and three-pallet system to 950 kg for a five-pallet system. When added to the mission independent mass (e.g., Spacelab subsystem and Orbiter support equipment), the total landing mass is about 13,000 to 13,500 kg (NASA/MSFC/ESA, 1976).

Other Science, Technology, and Application Missions. There is a variety of integrated Shuttle payloads which are not included in the previously discussed categories. They can be clustered in three distinct groups: (1) materials sciences related experiments; (2) observations of on/near-Earth environment; and (3) telescope facilities.

There are four integrated Shuttle payloads in the materials science group: (1) the Evaluation of Oxygen Interaction with Materials (EOIM) experiments that are to be mounted on the Development Flight Instruments (DFI) pallet; (2) the Materials Science Laboratory (MSL), which consists of experiments housed in containers that are mounted on a support structure and is scheduled for about 15 KSC launches during the 1982-1991 time frame; (3) a series of three KSC-launched materials processing studies coordinated by the Office of Space Sciences and Applications (OSTA); and (4) two KSC-launched flights of the Electrophoresis Operations in Space (EOS) prototype production hardware.

Five payloads are intended to perform observations of the Earth's on/near-space environment: (1) the Large Format Camera (LFC), which is mounted on the MPESS for one KSC launch (once proven flight-worthy, it will be integrated into OSTA-3, which is the Shuttle Radar Laboratory); (2) Earth Orbiting Measurements (EOM), which also is MPESS-mounted for two KSC launches; (3) the Tethered Satellite System (TSS), which will have its own unique support structure as an integral part of its deployer module and which is expected to be used in four KSC launches; (4) the Space Plasma Lab (SPL), which structurally consists of a Spacelab-type module and pallets and which is programmed for a single KSC launch; and (5) OSTA observation type missions, flown as the Shuttle Radar Laboratory (OSTA-3), two of which are scheduled for VAFB launches.

There are four telescope facilities considered: (1) the Shuttle Infrared Telescope Facility (SIRTF); (2) the Space Optical Telescope (SOT); (3) Starlab, and (4) Lidar Measurement of Air Quality. The differences between the facilities stem primarily from the spectral range covered by each telescope. For example, SIRTF, because of its dedicated infrared coverage, requires cryogenic equipment support. These facilities share many system features, such as the use of Spacelab structural modules (i.e., igloos, pallets), the ESA Instrument Pointing System, and the flexibility of various focal plane attachments (photographic and spectrometric).

3.1.2 Free-Flying Payloads

An overview of the potential missions of free-flying payloads detailed in this subsection include the following spacecraft: communications; environmental; navigation; space science and solar terrestrial; astronomy and astrophysics; planetary; and other science, technology and applications.

Communications Satellites. There are over 130 communications satellites projected to be launched from the Space Shuttle through 1991. These satellites provide a number of communications services (including voice and high speed data relay, as well as direct radio and television broadcasting) and operate in the C and Ku bands of the radio frequency spectrum, (4-6 Ghz and 14-12 Ghz, respectively).

The satellites receive (uplink) and retransmit (downlink) on different frequencies, with the uplink normally being the higher of the two frequencies. From its geostationary orbit position, 35,000 km directly above the Earth's equator, a communications satellite is able to cover a large portion of the Earth's surface. Because this is a single relay point, communications are improved due to reduced interference and signal distortion that can occur with Earth-bound relay systems.

Space Shuttle communications satellites consist of the communications satellite, an upper stage rocket motor, an apogee kick propulsion system [usually an apogee kick motor (AKM)], and an attitude control system (ACS). In most of the satellite designs, both the ACS and the AKM are integral parts of the satellite and, therefore, do not separate from the satellite. The upper stage motors, however, separate and are left in the elliptical transfer orbit to become part of the space debris population.

Although there are some differences based on satellite size or antenna shape, most of the communications satellites are similar in their construction and operation. The basic components of communications satellites are: (1) a power module; (2) a transponder module; (3) an antenna array, and (4) a propulsion or ACS module.

A variety of upper stages are used to boost the communications satellites into the elliptical transfer orbits (NASA/JSC, 1977). The upper stage used depends on the mass of the satellite and the assigned orbit station. Typical upper stages include the PAM-D, the IUS, the SSUS, and the Centaur. (See Appendix B for the types and quantities of propellants used with thses stages). These stages transfer the satellite from the low-Earth orbit of the Space Shuttle into an elliptical orbit with an apogee at geosynchronous orbit altitude where the upper stage is separated from the spacecraft/satellite. The AKM then fires to circularize the orbit. The ACS is then used for minor station-keeping and Earth-orientation maneuvering.

Ground transmitting and receiving stations are an integral part of communications satellite systems. These facilities, which serve as the initial signal processing sites for satellite communications, are located in or near all major cities on the North American continent. Worldwide ground-stations for existing or planned satellites are being built to accommodate the near-term demand for communication services. Recent technology advances, which include the development of portable two-way ground units and small satellite reception units for remote sites and general public use, are expected to expand the geographical range of communication services.

Environmental Satellites. Environmental satellite missions encompass numerous objectives, including global and regional monitoring and forecasting of weather and severe storms, assessment and prediction of climate and climate changes, assessment and monitoring of resources and geodynamic hazards, and monitoring and forecasting of ocean conditions and water quality. Among the types of proposed missions, the following are categorized as environmental satellites:

- Global Weather (e.g., NOAA/Tiros-N and GOES, ERBS)
- Ocean Observation (e.g., NOSS-Equiv, TOPEX)
- Resource Observations (e.g., Landsat, Magsat, GRM)
- Geodynamics/Earth Hazards (e.g., Lageos, GRM).

Typically, the spacecraft have launch masses of approximately 700 to 2400 kg, operate at a variety of orbits, and use a wide variety of instruments. The instruments include radiometers, cameras, multi-spectral scanners, microwave sounders, and imaging radars. Power supplies are solar cells and batteries. On-board solid and liquid propellants are used to transport the spacecraft to the desired final orbits; stages include the PAM-A, PAM-D, and the MMS. Other than the propellants and, to a lesser extent, batteries, there are no hazardous materials on board. Anticipated technology developments in the next decade include new instruments, multi-instrument measuring systems, and the use of large space platforms.

Navigation Satellites. The U.S. has one navigation satellite system and is in the process of procuring the replacement, which is to be operational by 1987. The current system provides worldwide, two-dimensional position location for the U.S. Navy and civil and commercial users. The Transit system consists of at least four active satellites in 1100 km polar orbits. The satellites broadcast information on 150 and 400 Mhz. The user's receiver measures the doppler frequency shift and determines the user's position. The Transit satellite mass is 265 kg and is currently launched by Scout ELVs from WTR. Transit satellites are not recovered when they fail, and become space debris with the Scout upper stage. Thirteen Transit satellites are in storage for launch before 1992 when the Transit system will be allowed to decay in favor of the follow-on NAVSTAR/GPS system.

The NAVSTAR/GPS (Global Positioning System) is a space-based radio navigation system, which will provide very highly accurate, three-dimensional position, velocity, and time information for DOD users. It also will provide the same navigational information to commercial users, but with intentionally degraded accuracy. The satellites will transmit navigation and time signals on 1575.4 and 1227.6 Mhz. In the model, the NAVSTAR/GPS is called the DOD-PAM.

Space Science and Solar Terrestrial Satellites. Space science and solar terrestrial missions have diverse scientific goals and concentrate on measuring the environment in the Earth's neighborhood, the Sun, and solar phenomena occurring in the space between the Earth and Sun. For organizational purposes, astronomical and astrophysical satellites are considered in a later subsection. The missions considered here concentrate on examining the Sun and its immediate neighborhood while astronomical/astrophysical satellites concentrate on other stars.

These missions use satellites launched into a broad variety of orbits, ranging from low Earth orbits (e.g., 400 km) to near-Earth heliocentric orbits. Initial launch inclinations range from 28.5 to 90 degrees and require launches from both ETR and WTR. Satellite masses typically range from 1000 to 4000 kg. Instrumentation on these satellites is usually passive and includes spectrometers covering the electromagnetic and particle energy spectra, telescopes, and other imaging devices. Power is supplied by solar cells and stored in nickel-cadmium batteries. Cooling/refrigeration required for some of the sensors is usually provided by liquified inert gases such as nitrogen and helium. Liquid and solid propellants are frequently used to place the spacecraft in the desired orbit and to provide attitude control and station-keeping. Currently planned spacecraft usually require a solid rocket motor, such as a PAM-D, for initial orbit insertion, but hydrazine-fueled carriers or internally carried hydrazine propellants also are used for primary propulsion. Attitude control and station-keeping functions typically use hydrazine. Other than the limited propellants and possibly the batteries, no large quantities of hazardous materials are carried by the spacecraft. Some of the spacecraft, e.g. Solar Maximum Mission (SMM), will be serviced or retrieved for refurbishment by the Shuttle, but most will be abandoned at completion of the mission or when they fail. Most of these missions will use single satellites; they typically last long enough that new or modified instrumentation would be desired for a follow-on spacecraft. The major difference between these spacecraft and most others is that they usually require highly eccentric final orbits, highly inclined orbits, or near-Earth heliocentric orbits.

Astronomy and Astrophysics Satellites. With the availability of the Space Shuttle, space astronomy and astrophysics missions are able to exploit the environment above the Earth's atmosphere on a routine basis with a broad range of instrumentation. The freedom from atmospheric extinction, emission, and scintillation and from variable seeing allows not only sampling cf nearly the entire wavelength range of electromagnetic radiation emitted by astronomical sources, but also imaging of sources to limiting magnitudes and with angular resolution unparalleled in ground-based astronomy. Research in high-energy astrophysics is expected to expand knowledge of energetic processes within or near compact objects (galaxies, quasars, pulsars, binary stellar systems) and in diffuse matter between objects.

The Space Shuttle is anticipated to be used for related missions in a variety of ways: (1) to carry automated satellites to near-Earth orbit, from which they will be launched to higher altitudes, (2) to launch major automated satellites into a near-Earth orbit and to provide revisit and maintenance opportunities, and (3) to carry observatory instruments into orbit, to provide basic facilities for use in orbit, and to return them to Earth after periods of one week. This last category of missions was addressed in Section 3.1.1.

These missions require a wide diversity of instrumentation ranging from the Space Telescope to small, rocket-class instruments. Astronomy and astrophysics research requires stabilization of the Shuttle to near one-arc-minute (by means of control moment gyros), control of pallet pointing direction throughout operation, and a contamination-free environment. Guidance and attitude control can be provided by sensors, gyros, star tracker, and hydrazine RCS. Average power requirements range from 700-2100 watts and are provided by solar arrays. NiCd batteries are commonly used for energy storage. Cryogens (e.g., liquid helium) are used for thermal control. Propulsion systems for these missions include reaction control system (for attitude control) and the Multimission Spacecraft (MMS) (for insertion of the payload into a higher orbit). The MMS uses hydrazine for propulsion.

Astronomy and astrophysics free-flying payloads scheduled over the next decade involve such missions as the Space Telescope, Cosmic Background Experiment, Gamma Ray Observatory, X-Ray Observatory, Advanced X-Ray Astrophysical Facility, and Cosmic Ray Observatory.

Planetary Spacecraft. Potential planetary missions involve exploration and intensive study missions to various solar system bodies. Exploration missions are directed at the discovery and understanding of processes, history, and evolution on a global scale and are best accomplished by using orbiting spacecraft in combination with entry bodies and landers. Intensive study missions focus on specific science issues and are typically accomplished using mobile vehicles, sample return or on-location analysis laboratories, and low-altitude polar orbiters.

Investigation of solar system bodies follows an evolution from initial exploration through intensive study missions. For Mars and the Moon, the exploration phase has been completed and the intensive study realm of investigation is being entered. The early investigation phase is nearly completed for Venus and Mercury, and has begun for Jupiter, Saturn, and their moons. Missions to primitive bodies (comets and asteriods), the outer planets, and more satellites of the giant planets are in the planning stages.

The ad hoc Solar System Exploration Committee (SSEC) of the NASA Advisory Council recommended recently (NASA/Hq, 1983f) a set of core missions for planetary exploration through the year 2000. These are:

(1) Venus Radar Mapper (VRM)
(2) Mars Geoscience/Climatology Orbiter
(3) Comet Rendezvous/Asteroid Flyby
(4) Titan Probe/Radar Mapper

These missions are in addition to the Galileo mission to Jupiter.

The primary goal of this Core Program is the scientific exploration of the solar system. The launch requirements of this program are expected to be satisfied by the ongoing joint NASA/USAF modification of the Centaur stage for use on the Shuttle. The SSEC also recommended a schedule for launching these missions in the period 1988-92.

The Galileo project* (NASA/JPL, 1981) will perform the first analysis of the atmosphere of an outer planet in 1988. The first mission in the Core Program, VRM, will complete the global characterization of the surfaces of the two most Earth-like planets: Venus and Mars. The Mars Geoscience/Climatology Orbiter is to be a program of low-cost, modestly scaled, inner solar system missions, using previously developed spacecraft and components. The third mission, Comet Rendezvous and Asteriod Flyby, requires the development of the Mariner Mark II spacecraft. This will be a modular spacecraft with multiple missions and applications. The Titan Probe/Radar Mapper mission uses a modified Galileo probe together with a fly-by or orbiter spacecraft equippped with a simple radar.

Other Free-Flying Science, Technology, and Application Missions.

There are five STS payloads included in this miscellaneous category of free-flyers:

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*NOTE: The Galileo project is not covered by this environmental assessment because it uses a nuclear power source. A separate environmental impact statement has been prepared for this project.

- Shuttle Pallet Satellite (SPAS)
- European Retrievable Carrier (EURECA)
- Shuttle Pointed Autonomous Research Tool for Astronomy (SPARTAN)
- Long Duration Exposure Facility (LDEF)
- Electrophoresis Operations in Space (EOS).

The five payloads can be grouped into two categories to highlight either mission function or mission duration. From a functional viewpoint, SPAS, EURECA, and LDEF are generalized carriers or platforms on which mission-specific equipment or experiment modules can be mounted, whereas SPARTAN and EOS designate equipment modules that are designed to perform specific operations.

SPAS and EURECA are related to the extent that they share the same basic support structural design, which is modular in concept. SPAS is scheduled for five flights, the first of which already has flown aboard STS-7 and has undergone successful deployment as a free-flyer. EURECA is nominally planned for three STS flights.

Eureca, which has a total mas of 3500 kg, would be deployed and retrieved (after a 6-9 month period in space) from an altitude of 300 km and would be placed in an operational circular orbit of 500 km. The addition of four propellant tanks and an associated monopropellant maneuvering system will enable Eureca to move to altitudes up to 800 km. The power sources include on-board batteries and solar array (which are retracted during launch and recovery operations).

LDEF can be viewed as a low-cost carrier offered to users for conducting relatively simple science and applications experiments in a free-flight space environment that is removed from the influence of the Orbiter. This carrier, which—in many respects—is a free-flying counterpart of the Get-Away Special (GAS), is scheduled for at least three flights.

SPARTAN, which is a science payload mounted on an MPESS carrier to obtain aeronomic data related to the upper atmosphere, is scheduled for three flights.

EOS, in its free-flying configuration, represents a continuation of an evolving effort leading to the use of electrophoretic processes in a space environment for the commercial production of biological materials. This development has already begun with the Mid-deck experiments flown aboard STS-7 and is expected to progress through two flights with cargo bay-mounted equipment before reaching the unmanned free-flying stage projected for six flights.

3.2 Proposed Action: Shuttle Launch of STS Payloads

The Proposed Action is the utilization of the Space Transportation System (STS) for the performance of missions in space. Potential missions span a number of areas, including science and applications, technology development, commercial applications and National Security applications, and involve varying degrees of services and associated support systems. Section 3.1 provided brief synopses on these potential missions. The STS Traffic Model (Appendix B) was based on the following guidelines:

- Payloads
  - Payloads and flight assignments from 1982-1988 are equivalent to those identified in NASA's payload flight assignments (May 1983)
  - Various data sources were to be used for projection of future payloads (i.e., Battelle-Columbus Laboratories (BCL) models, U.S. and foreign space agency documents, and periodicals) to span the range of potential Space Shuttle missions through 1991

- Time Frame
  - November 1982 (first operational flight) - December 1991

- Launch Sites
  - ETR, maximum launch rate 18 flights/year
  - WTR, maximum launch rate 6 flights/year

- Space Shuttle
  - Configuration and capability undergoes no major design changes (e.g. Extended Stay Orbiter in the fleet)
  - Launch build-up rate as indicated in May 1982 NASA flight assignments
  - Maximum launch rate begins in 1988 with 24 flights/year

- Payload Mix (1988-1991)
  - 4-7 dedicated DOD missions per year (a minimum of 2 ETR, 2 WTR launches per year)
  - 1 reflight opportunity per year
  - Get Away Specials and Mid-Deck experiments are assigned, but not detailed on each mission
  - Availability of payload by user (no delays)
  - Requirements for replacement spacecraft based on available information
  - Missions requiring more than one are flight scheduled as appropriate
  - Flight assignments not necessarily cost-optimized

The responsibility for the National Space Transportation System Program, which includes the Space Shuttle vehicle, any flight support hardware and software (e.g., upper stages, Spacelab, etc), and ground support systems, is shared jointly by NASA and the United States Air Force (USAF). Both programmatic and operational functions are shared. NASA is the launch agent responsible for operations at Kennedy Space Center (KSC), Florida, while the USAF is the counterpart at Vandenberg Air Force Base (VAFB), California. Operations at VAFB will commence in 1985.

3.2.1 Space Shuttle Characteristics

A complete Space Shuttle flight system consists of a piloted Orbiter vehicle, an External Tank (ET) for propellants, and two Solid Rocket Boosters (SRBs) (See Figure 2). Although the launch and landing mass of the Shuttle Orbiter will vary with the individual mission being flown, the gross empty mass of the Orbiter is about 68,000 kg. The 5 m diameter by 18 m long cargo bay is capable of carrying

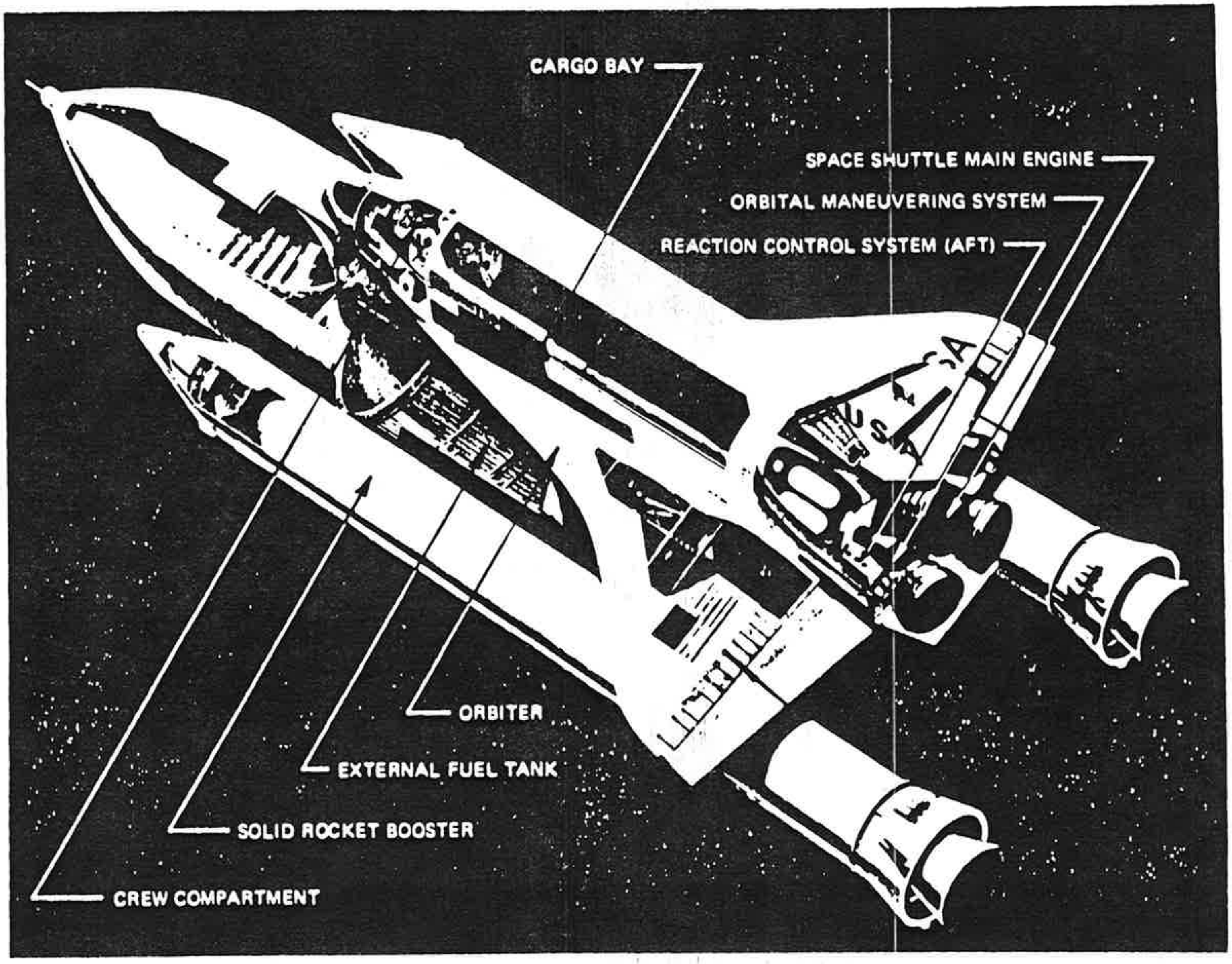


FIGURE 2. SPACE SHUTTLE VEHICLE AND SYSTEMS

up to 29,500 kg to easterly orbits from the ETR and up to 18,000 kg to polar orbits from the WTR. More detailed discussions of the Space Shuttle characteristics are found in the environmental impact statement for the Space Shuttle program (NASA/Hq, 1982) and other Shuttle documents (NASA/Hq, 1977; NASA/Hq, 1981b).

3.2.2 Payload Requirements and Operations

Use of the Space Shuttle for operating payloads, conducting experiments, and launching satellites requires prelaunch, flight, and post-flight activities of the STS customer, NASA, and Air Force personnel at the two launch sites (KSC, Florida, and VAFB, California). The generic activities are discussed in the following paragraphs.

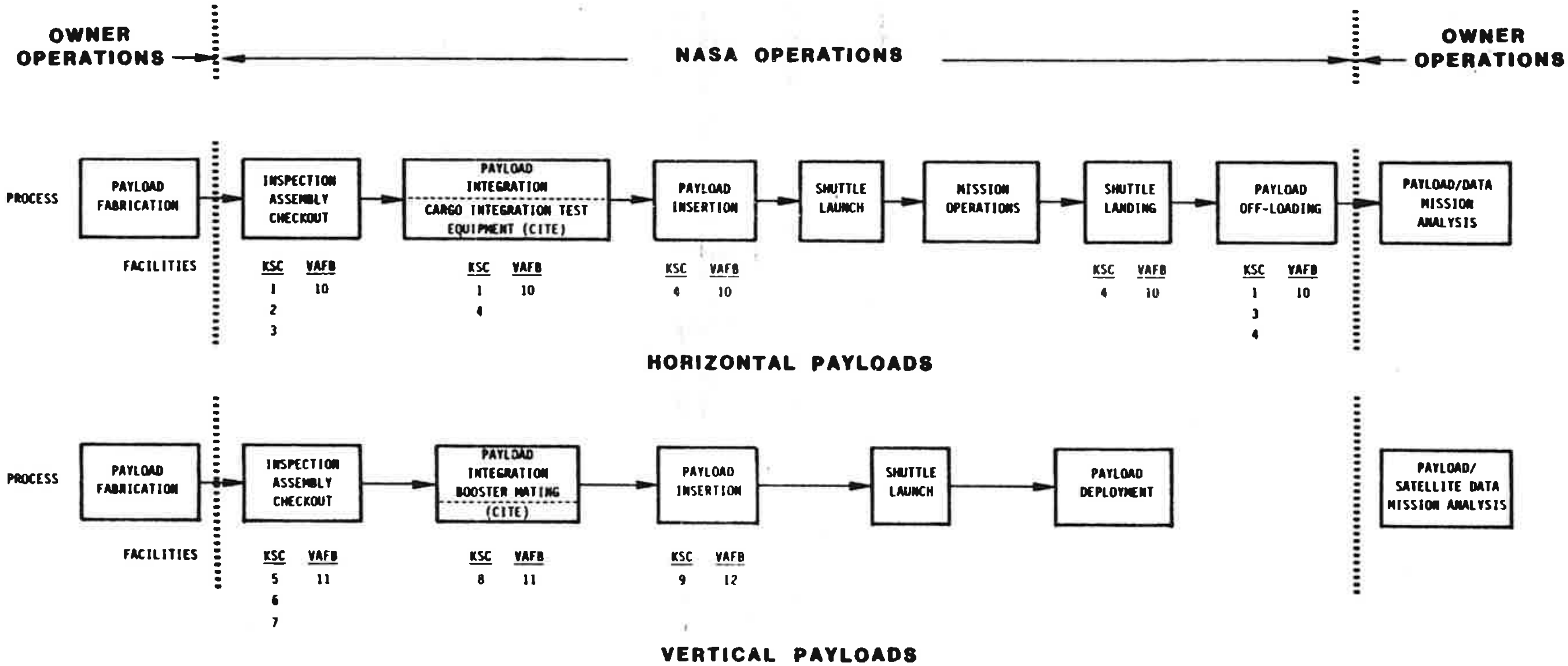
During the early payload design phases, the capabilities and requirements of the Orbiter are factored into the configuration and operational planning of a payload structure. Safety analyses are conducted throughout the design and building of the payloads (NASA/Hq, 1980b) to ensure their safe assembly and operation. The final design and selection of appropriate ground support equipment available at the launch site is coordinated with a NASA Launch Site Support Manager (LSSM).

All STS payloads and ground support equipment must comply with NASA Safety Policy and Requirements (NASA/Hq, 1980b) during both ground and flight operations. This policy requires that the basic design of the payload eliminate or control any hazard to the Orbiter, crew, and other payloads as well as the launch site environment. The payload owner/operator is responsible for assuring the safety of any hardware proposed for use in the STS while the STS Operator plans cargoes to minimize hazards created by interaction among payloads and between payloads and the Shuttle. In addition to flight requirements for payloads, the safety of ground operations during payload fabrication and integration into the Space Shuttle is monitored by the LSSM in accordance with standard operational guidelines (NASA/KSC, 1978; NASA/KSC, 1983b; NASA/JSC, 1983a).

STS user operations involve payload design, fabrication, and transportation to and from the launch/landing sites. Special shipping containers with shock and environmental controls are required for shipping payloads to the launch sites because of their delicate structural nature when on Earth. Payloads are processed by NASA/USAF personnel at the launch sites are shown in Figure 3. Although facilities are different at the two sites, the process flows are identical.

STS/Orbiter flight activities center on both the Orbiter and payload operations. Payload-related actions include: preparation and deployment of orbital payloads; activation of automatic payloads from the cargo bay control console; conduct of mid-deck experiments; Extra-Vehicular Activities (EVA) for experiments, payload operations, and satellite deployment and retrieval; and Spacelab operations. Orbiter operations can accommodate individual mission requirements, e.g., on-orbit pointing and stabilization.

The degree of satellite servicing operations depends largely on the type of payload and its operational configuration. Payload operation configurations include: (1) Shuttle-attached payloads, (2) short-duration exposure payloads, (3)



PAYLOAD PROCESSING FACILITIES (PPF)

KSC
1 - OPERATIONS & CHECKOUT (O&C)
2 - GAS FACILITY
3 - LIFE SCIENCE SUPPORT FACILITY (LSSF)
4 - ORBITER PROCESSING FACILITY (OPF)
5 - SOLID MOTOR ASSEMBLY BUILDING (SMAB)
6 - EXPLOSIVE SAFE AREA - 60 (ESA-60)
7 - DELTA SPIN TEST FACILITY (DSTF)
8 - VERTICAL PROCESSING FACILITY (VPF)
9 - PAYLOAD CHANGEOUT ROOM/ROTATING SERVICE STRUCTURE (PCR/RSS)

VAFB
10 - ORBITER MAINTENANCE AND CHECKOUT FACILITY (OMCF)
11 - PAYLOAD PREPARATION ROOM (PPR)
12 - PAYLOAD CHANGEOUT ROOM (MOBILE) (MPCR)

FIGURE 3. PAYLOAD PROCESSING FLOWS FOR SHUTTLE LAUNCHES

long-duration exposure payloads, (4) Low Earth Orbit (LEO) satellites, (5) Geostationary (GEO) satellites, and (6) planetary and other Earth-escape payloads. Shuttle-attached missions are generally not deployed or retrieved, but are operated on the Orbiter and Earth-returned. The short-duration exposure payloads are deployed, orbited near the Orbiter, retrieved, and returned to Earth in one mission. Because the entirety of payload operations is completed in one mission, both the Shuttle-attached and the short-duration exposure payloads are considered sortie missions. Long-duration exposure payloads are usually deployed during one flight, operated for an extended period of time on-orbit, possibly serviced during the operational period, and retrieved for Earth-return on a later flight. The LEO satellites are deployed and possibly retrieved for service or Earth-return. The GEO satellites are deployed and are not retrievable. (Development of an advanced retrieval system will be necessary to accommodate the retrieval option.) The planetary and other Earth-escape payloads are simply deployed and not retrieved or serviced.

The satellite servicing capability of the STS includes mission independent equipment and subsystems such as the Shuttle Orbiter, the Remote Manipulator System (RMS), the Extravehicular Mobility Unit (EMU), the Manned Maneuvering Unit (MMU), and support equipment (e.g., TV, lighting, and hand tool systems) (NASA/JSC, 1983b; Griswold, 1980). The Orbiter provides the utility base while the EMU and MMU provide environmental protection and life support and maneuvering capability during EVA.

Deployment operations are generally automated and can be achieved from the Aft Flight Deck (AFD) of the Orbiter. EVA may be required for contingency plans during failure of the auto-deployment. Both deployment and retrieval operations can be performed by the RMS. This capability is limited because of operational considerations: spinning or tumbling objects are not retrievable and the RMS performance is constrained to 15 m extensions and 0.61 m/s tracking speed and can be backdriven by forces exceeding 10.4 kg (Griswold, 1980). The SMM mission, however, will provide an early demonstration of the Shuttle's capability to rendezvous with and stabilize a spacecraft (via EVA) and capture it (via the RMS) for repair operations in the cargo bay. Service operations are supported primarily by the EMU and MMU for on-orbit inspection and checkout. Other service operations such as maintenance, reconfiguration, and resupply require tooling, refueling, and astronaut restraint systems.

The Orbiter has communications requirements with Earth stations while it is in orbit because of the extensive data collection needs of the payloads and the limited data processing capabilities of the Orbiter equipment and systems. Payloads use the Orbiter communications equipment and the Tracking and Data Relay Satellite System (TDRSS) to relay experimental results and other collected data to Earth stations for further analysis and processing.

Ground-support equipment operated during the Orbiter's flight includes the ground-tracking stations for both the Orbiter and payload operations, the Flight Control Center, the Mission Control Center, ground-relay stations, and other command and control facilities. Another aspect of ground control is the preparation of the landing facilities for Orbiter landing. Both a primary and secondary landing site are prepared for handling the Orbiter. Because STS customers are required to transport their own payloads from the landing facility, they must be notified of the facility to be used so that adequate transportation equipment from the facility to the payload post-flight processing facility can be arranged.

After the Orbiter has landed, the payloads are off-loaded from the Orbiter's cargo bay and returned to the STS customer. Related activities include the operations of the ground-support teams as well as the payload-support teams at the launch and landing sites.

Except for small, time-critical equipment that can be hand-carried through the Orbiter's cabin immediately after landing, payloads are off-loaded at the OPF (KSC) or the OMCF (VAFB). At these facilities, fluid systems are drained and vented and fuel systems are purged of fuel and fumes to ensure the safe transfer of the payloads. Flight kits are removed and returned to the customer as are the mid-deck experiment modules. Larger payloads are removed and transported to post-flight processing facilities. Payloads are (1) moved off-site for experimental analysis; (2) analyzed at the landing/launch site and reconfigured and reprocessed for future flights; or (3) analyzed and processed for storage for future flights (NASA/KSC, 1983a).

3.3 Alternative Action: Expendable Launch Vehicle/ Sounding Rocket Launch of Payloads

This section defines potential alternatives to the Proposed Action and provides background information relevant to the environmental analyses. The alternative to the Proposed Action is the use of expendable launch vehicles (ELVs) and sounding rockets (SR) to achieve the payload mission objectives. The population of launch vehicles encompasses both the U.S. and foreign countries; however, a subset of this population was selected as a reasonable alternative. This screening process was appropriate in view of the numerous launch vehicles and stages available or planned. The launch vehicles considered representative of the technology available to practically implement the mission objectives included the Atlas, Delta, Scout, Titan, and Ariane as well as the currently available series of sounding rockets. Upper stages utilized were PAM-A, PAM-D, PAM D-2, IUS, Centaur, MMS, and TMV (currently referred to as OMV).

The two major criteria utilized in determining whether a reasonable alternative to Shuttle utilization existed were that: (1) the mission objectives would not be degraded; and (2) that any requirements to redesign the payload would be within the technical and economic constraints of the customer. The assumptions used included: (1) ELV/SR vehicles would be available as needed with no delays; (2) one payload per vehicle launch; and (3) no major redesigns for adaptions to ELVs. This revised mission model did not seek to optimize costs and only considered the operational-mission accomplishment aspect of payload operations. In many instances, the use of alternative launch capabilities was clearly precluded. Payloads falling within this category included manned (non-automated) payloads, payloads exceeding size and weight constraints of vehicles, and payloads necessitating long duration exposure to space environment conditions.

Based on these criteria, alternatives to the Proposed Action, i.e., the payload mission model and the generic payloads (Section 3.1), were identified. For the generic payloads, additional discussion on the basis for flight vehicle assignments is provided where appropriate. Appendix B identifies the alternative to Space Shuttle launch and operations for all missions scheduled in the STS mission model.

3.3.1 Vehicle Characteristics

As an alternative to the Space Transportation System, ELVs and sounding rockets offer a wide, but limited, capability for orbital and suborbital missions. All missions are automated and include scientific, commercial, and DOD applications.

Expendable Launch Vehicles. The ELVs provide orbital launch capability and include a variety of solid and liquid-staged vehicles; Titan, Atlas Centaur, Delta, Scout, and Ariane (NASA/Hq, 1981c; BCL, 1983b). The Titan, Atlas-Centaur, Delta, and Scout are U.S. rockets primarily launched from ETR, Florida, and Western Test Range (WTR), California (the Scout is launched from Wallops Flight Center (WFC), Virginia, and San Marco, Africa). Ariane is a European vehicle launched from the Centre Spatial Guyanais-Guiana Space Center (CSG) in French Guiana, South America and is under the direction of the Centre National D'Etudes Spatiales (CNES) and the European Space Agency (ESA). For high energy missions, upper stages are coupled with the base vehicles. Typical upper stages include the Centaur, the Payload Assist Module (PAM), and the Inertial Upper Stage (IUS), among others. (AWST, 1983).

Sounding Rockets (SR). The SRs (e.g. Aries, Nike-Malemute, Castor I, and Talos-Castor) provide a wide variety of suborbital and low-orbit mission capabilities (AWST, 1983). Both solid and liquid propellants are used for propulsion. These rockets are small and easily launched, but have a relatively small payload size and provide only short-duration exposure (up to 10 minutes) to a low-gravity environment.

Combining both the ELV and SR capabilities would provide a viable alternative to the Space Transportation System. However, the capabilities of this alternative are limited and could not accomplish 100 percent of the STS traffic model. Generally, use of ELVs and SRs to complete (as best possible) the STS traffic model would increase the number of vehicle flights and costs would be expected to be much higher.

3.3.2 Payload Requirements and Operations

The use of expendable launch vehicles and sounding rockets for launching satellites and conducting experiments involves prelaunch, launch, flight, and post-flight activities. The following paragraphs generically describe the payload requirements/operations throughout a mission including prelaunch, launch, flight, and post-flight activities. Differences among these activities for the various launch vehicles are cited in Table 1. Although the payload processing details of the Scout and sounding rockets vary, the general process flows are similar and are presented together.

Prelaunch activities include payload design and construction, assembly and testing, and finally, payload-vehicle mating. Potential hazardous operations also are specified. Proper design and construction of the payload for a specific vehicle is the responsibility of the customer. Once the spacecraft goals and experimental concepts have been established by the customer, a proposal to NASA/USAF/ESA must identify mission requirements, spacecraft characteristics, hazardous operations, launch vehicle requirements, and ground support requirements. After approval of the mission, budget and vehicle allocations are made. The mission planning is provided through interactive participation of the customer, the sponsor (NASA/USAF), and the vehicle contractor. This preparation includes extensive interface and safety documentation. The required interface documentation, mission data, and payload characteristic data for each vehicle are summarized in Table 1.

Assembly and testing activities include the final assembly of the payload upon receipt at the launch processing facilities and preliminary testing of the payload mechanical, electrical, power communication, and data subsystems. These tests are generally defined by the user and performed by NASA and/or the USAF at the ETR and WTR facilities or CNES at the CSG facilities. Potential hazardous operations include propellant loading of satellite attitude control system (ACS), installation of the separation bolts and ordnance attaching the payload to an upper stage (if necessary), handling of radioactive and chemically hazardous products and pressurizing fluids, and spin testing the payload and/or upper stage. Once a payload is mated with an upper stage or other ordnance, the assembly is considered hazardous material and is handled accordingly. Hazardous operations are limited to explosive-safe areas (NASA/KSC, 1983a). Special training, equipment, and handling procedures are guidelined in the KSC Safety Practices Handbook (NASA/KSC, 1978) for ETR launches. Similar safety procedures are used for other launch sites.

Payload vehicle mating of the ELVs and sounding rockets generally occurs at the launch pad in a method similar to the vertically-integrated Shuttle payloads. Once the mating is completed, interface verification tests and general electric power systems tests are completed. Upon final testing and closeout of the payload, fairings are attached and checked. The vehicle is then ready for launch.

Payload operations for unmanned flights are automated for the ELVs and sounding rockets. For in-flight activities or orbital flights (Titan, Atlas-Centaur, Delta, Scout, Ariane), the propellant stages burn, separate, and reenter the atmosphere or stay in orbit and become debris. Payloads destined for LEO utilize on-board propellants for final orbit insertion, deploy applicable systems (solar panels), and begin pre-programmed functions. For higher orbit payloads, the attached upper stage burns and separates. Final orbit insertion is achieved by on-board satellite propulsion system (e.g., kick motors). Control systems provide proper attitude and guidance of the spacecraft after system intitialization.

On-orbit servicing/retrieval, landing, and post-flight payload operations are not generally applicable to ELVs. However, Ariane does propose retrieval of the first stages of the vehicle. For suborbital flights (mostly sounding rockets), the experiment or sensing device is activated, data collected, and payload returned to Earth (usually by parachute). The payload can then be retrieved for later use and/or research.

3.4 No-Action Alternative: Terrestrial Equivalents

The No-Action Alternative is defined as the achievement of the payload mission objectives through ground-based or terrestrial systems. Equivalency to the Proposed Action in terms of mission objectives is required for a mission to have a terrestrial equivalent. This requirement, therefore, precludes degradation of any mission objectives or substantial revisions to the mission requirements unless economic and technical factors enhance the attractiveness of a terrestrial equivalent.

The fulfillment of a mission objective by a terrestrial equivalent implies that the system characteristics and operations be substantially similar to the system that is being substituted. For many of the payloads, space applications represent a substitute for, extension of, or advancement of terrestrial systems. Communications and many environmental monitoring systems are examples of systems that, in most cases, have terrestrial equivalents.

Research and science and application payloads represent unique cases where terrestrial equivalents are virtually preempted. In these instances, the space environment characteristics are utilized for research, experiments, and testing and usually can not be duplicated on Earth. Examples of payloads in this class are life science and physical science experiments requiring long duration exposure to microgravity or Earth observational measurements requiring synoptic views.

Finally, there are payload-related activities that are, by definition, space operations. Satellite servicing, maintenance and retrieval, and search and rescue missions are exemplary of services that may be required for a payload.

Based on these considerations, the following payload activities and characteristics precluded the feasibility and practicality of a terrestrial equivalent:

(1) Activities
- payload servicing and maintenance
- payload retrieval

(2) Characteristics/Requirements
- long duration exposure to microgravity environment or other unique space environment parameters (e.g., ultra-high vacuum, high energy radiation, large volume of ionized gases)
- viewing direction (e.g., synoptic views)
- other sampling and measurements and/or validation requirements (physical, chemical, spectroscopic, etc.) beyond terrestrial capabilities both technically and economically (e.g., highly accurate pointing and stability).

4.0 ENVIRONMENTAL EFFECTS OF THE PROPOSED AND IMPORTANT ALTERNATIVE ACTIONS

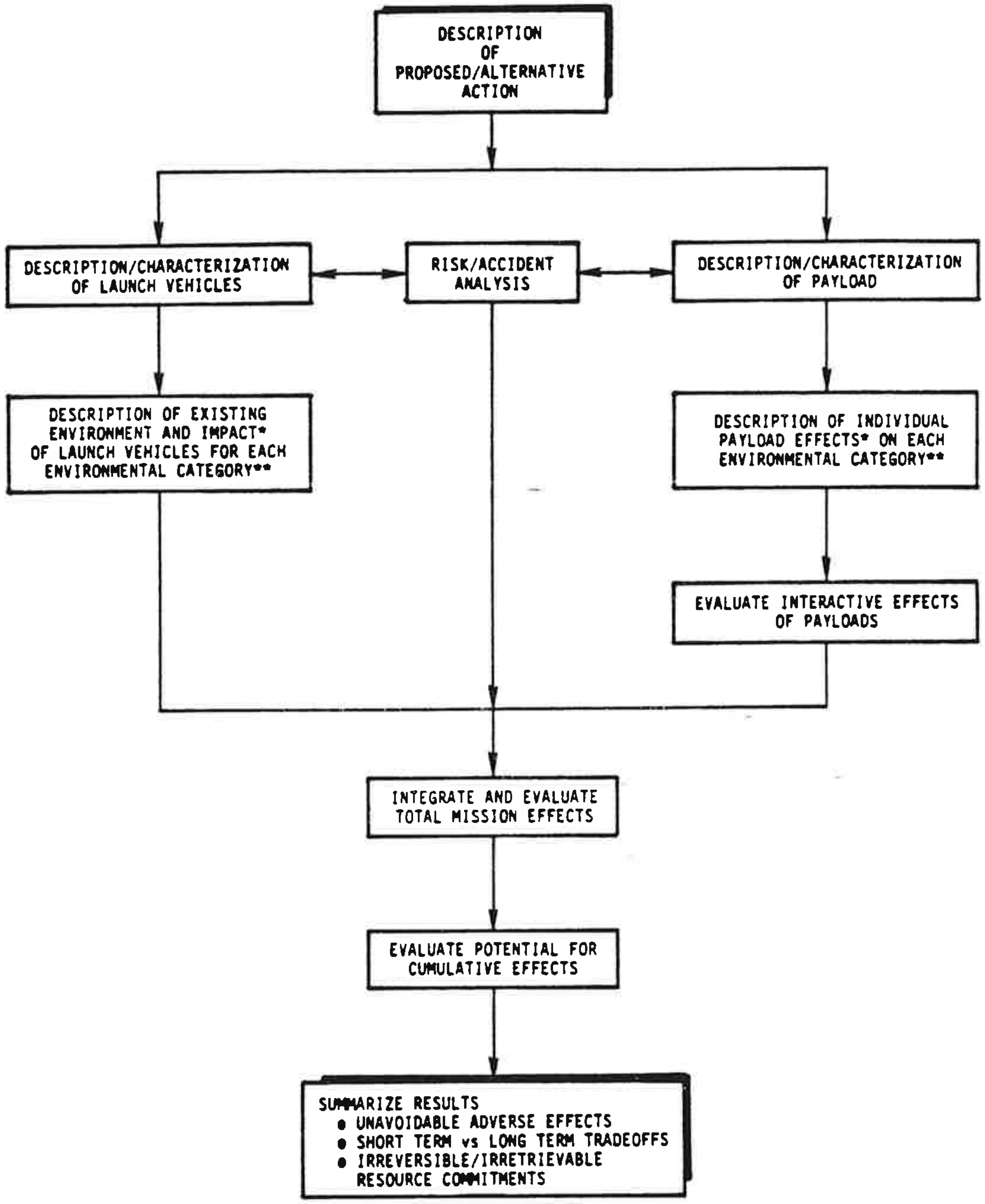
This environmental assessment addresses seven environmental categories (socioeconomics; space quality; air, land and water quality; noise; biotic resources, human health; and resource use) under a normal operation scenario. An eighth category, accidents, has been distinguished to address the possible environmental effects resulting from human error and/or mechanical/electrical failure(s) of equipment/subsystems. The magnitude and type of impact, the duration, geographical context, and the potential for interactive and cumulative effects are considered for each of these aforementioned environmental categories.

The process for the analysis of the environmental effects from the launch vehicle and payload operations is depicted in Figure 4. As the Figure indicates, the Proposed/Alternative Action is subdivided into two subcategories, launch vehicle (irrelevant for the No-Action Alternative) and payload. The characterization process (Section 3.0) is a key input to the environmental analysis for each subcategory. Because of the tiering approach to this analysis, the launch vehicle and payload effects are evaluated on an independent basis initially, but then integrated to establish total mission effects. Finally, the potential for cumulative effects is addressed.

As Figure 4 illustrates, a normal and an accident scenario are considered. The risk/accident scenario and associated impacts, as previously indicated, are addressed as a separate environmental category. Figure 5 illustrates how hazards and risks to the crew and launch vehicle are minimized to the maximum extent feasible through an iterative design process. NASA's safety policy and the requirements (NASA/Hq, 1980b) for payloads formalize this process to reduce the probability and severity of potential accidents (see Section 3.2.2). From this perspective, the generic environmental analysis presumes launch vehicle and payload conformance to established design and operational guidelines.

Table 3 summarizes the environmental effects for all payloads under the Proposed Action, and the Expendable Launch Vehicle/Sounding Rockets, and No-Action Alternatives. These effects are described in the balance of the section. In instances where payload environmental effects are similar, the results of previous analyses are incorporated by reference. Differences in the impacts are noted where appropriate. Cumulative effects, which center on (1) accrued socioeconomic benefits and (2) changes in space quality from accumulated space debris, also are addressed. The table briefly describes the nature of the vehicle and payload impacts and also indicates the magnitude of the impacts for both the launch vehicles and the payloads.

Based on the payload analyses, long-term, regional, socioeconomic benefits are anticipated under the Proposed Action. With the Expendable Launch Vehicle/Sounding Rocket Alternatives, the magnitude of these benefits would be less, and in the case of the No-Action Alternative, the socioeconomic impact from foregone opportunities would be negative. The second area where payload environmental effects are potentially large involves the changes to the space environment due to the contribution of abandoned spacecraft and spent upper stages to the space debris population. Interaction of payloads during launch and orbital



* FOR EACH ENVIRONMENTAL CATEGORY, IDENTIFY

- MAGNITUDE - SIGNIFICANT vs NONSIGNIFICANT
- TYPE - BENEFICIAL vs ADVERSE
- DURATION - SHORT-TERM vs LONG-TERM
- CONTEXT - LOCAL vs REGIONAL vs GLOBAL
- CAUSALTY LINK - DIRECT vs INDIRECT
- CONJUNCTIVE RELATIONSHIPS - INTERACTIVE; CUMULATIVE

** ENVIRONMENTAL CATEGORY

- SOCIOECONOMIC
- SPACE QUALITY
- AIR, LAND & WATER QUALITY
- NOISE
- BIOTIC RESOURCES
- HUMAN HEALTH
- RESOURCE USE
- ACCIDENTS

FIGURE 4. ENVIRONMENTAL ASSESSMENT PROCESS

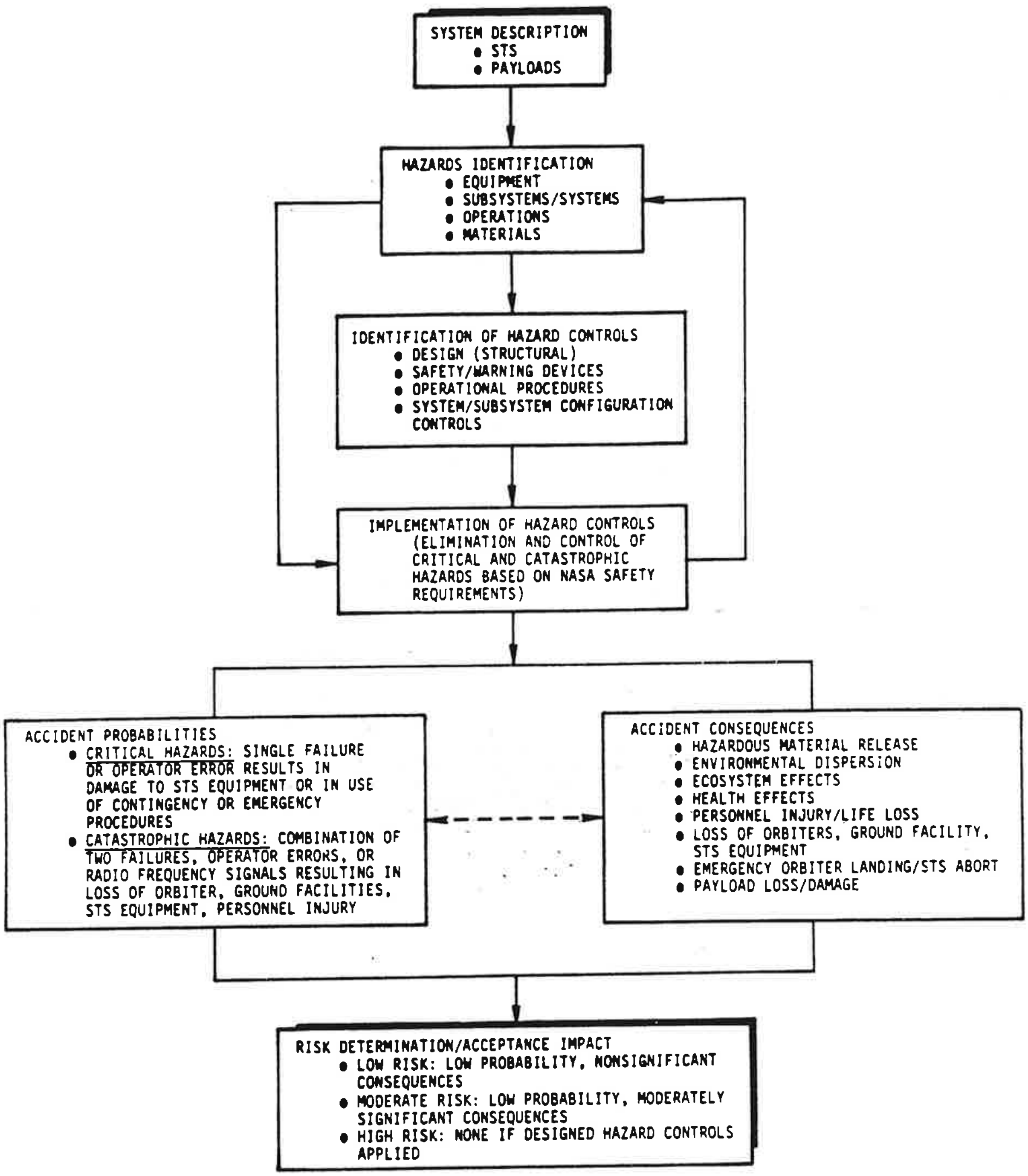


FIGURE 5. RISK/ACCIDENT ANALYSIS PROCEDURE

TABLE 3. SUMMARY OF SHUTTLE AND PAYLOAD ENVIRONMENTAL IMPACTS FOR THE PROPOSED AND ALTERNATIVE ACTIONS

Environmental Category	Nature of Payload Impacts/Magnitude (for Launch Vehicle/Payload)*		
	Proposed Action	Expendable Launch Vehicle Alternative	No-Action Alternative
Socioeconomics	Infrastructure and public services in KSC vicinity capable of supporting Shuttle related needs.	Labor shifts are expected; however, employment impacts would be insignificant on a national scale.	Small employment reductions anticipated if research opportunities forgone and Shuttle activities were not undertaken.
	Mildly stimulating affect on local economics from launch vehicle production and payload development activities. Technical, commercial, and scientific advances in space research and applications.	Impacts are similar, but less significant than the Proposed Action because of launch vehicle constraints and payload requirements.	Benefits of research in space would be forgone. Terrestrial communication service costs may rise.
	(2)/(3)	(2)/(2)	2
Space Quality	Space debris generated includes spent upper stages, abandoned spacecraft, and miscellaneous hardware. Debris contributions will not significantly increase collision hazards to operational spacecraft in LEO and GEO through 1992.	Payload debris contributions would be similar to those anticipated under the Proposed Action. Relative to the Shuttle, ELVs would contribute additional debris over that anticipated with a Shuttle/PAM. The additional debris depends on the ELV used and the payload mission.	There would be no space debris generated with equivalent ground-based systems.
	2/2	2/2	0
Air, Land, and Water Quality	Emissions from the Shuttle ground and flight operations will be within regulatory limits. HCl will cause temporary, localized effects due to acidic rain or ground cloud fall out. Shuttle activities occur on government land dedicated to similar uses. Water quality impacts due to controlled reentry of hardware, residual propellant, and cooling and acoustic damping water are temporary and localized. (Cont.)	Ground and launch air, land, and water quality effects are similar to, but less than, the Shuttle on a per launch basis.	Launch related effects would be eliminated under the No-Action Alternative. (Cont.)

*The rating scale relates the magnitude (i.e., degree, extensiveness, scale, probability of occurrence) of the impact to its significance. The assessment of an impact is with respect to the existing environment and presumes the implementation of appropriate mitigative controls. Parenthetical ratings refer to positive (beneficial) impacts.

Rating	Definition
0	No or minimal impact
1	Small (measurable), temporary, localized impact
2	Large, short/long-term, local/regional/global scale impact
3	Significant (includes, but not necessarily limited to, impacts associated with irreversible/irretrievable commitments of resources; adverse effects which can't be avoided; and benefits which may be of national/international scale), short/long-term, regional/global scale impact.

TABLE 3. (Continued)

Environmental Category	Nature of Payload Impacts/Magnitude (for Launch Vehicle/Payload)*		
	Proposed Action	Expendable Launch Vehicle Alternative	No-Action Alternative
Air, Land, and Water Quality (Continued)	Air, land, and water quality impacts throughout the payload operational cycle would be negligible and temporary in nature. The payload manufacturing phase will release small quantities of pollutants.	Payload related impacts would be equivalent to those anticipated under the Proposed Action.	Relative to the Proposed Action, impacts would be slightly less due to the abandonment of many missions. With the rise in ground-based communications systems, associated impacts would tend to be localized and nonsignificant.
	2/0	2/0	1.5
Noise	Major noise sources include Shuttle launch and reentry of the SRB, ET, and Orbiter. Ascent and descent sonic booms are temporary and infrequent.	ELV launch noise is less than that for a Shuttle launch. ELVs create no landing noise, since expended stages fall into remote ocean areas.	Launch related effects would be eliminated under the No-Action Alternative.
	Noise generation by virtually all payload missions would be insignificant. Noise generated during verification testing (during the prelaunch phase) and experiment activation (during on-orbit operations) would be within existing guidelines and standards.	With launched payloads, noise generation would be insignificant.	Noise generated in research laboratories or by facility operations (e.g., receiving station of a communications system) would be with regulatory limits and would not affect worker safety or health.
	1.5	1/0	0
Biotic Resources	Noise, acidic rain events, and aluminum oxide dust from Shuttle launches will result in local damage to flora and fauna. These effects will, in most cases, be temporary.	Combustion products and propellant releases will not produce significant toxic effects on plant or animal communities. Effects will be less than those anticipated under the Proposed Action.	Launch related effects would be eliminated under the No-Action Alternative.
	2/0	1/0	0-1

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TABLE 3. (Continued)

Environmental Category	Proposed Action	Expendable Launch Vehicle Alternative	No-Action Alternative
	Nature of Payload Impacts/Magnitude (for Launch Vehicle/Payload)*		
Biotic Resources (Continued)	Biotic impacts are localized and temporary and attributable to payload manufacturing processes.	Impacts are essentially equivalent to those anticipated under the Proposed Action.	Terrestrial equivalent systems will have an insignificant impact on plants, fish, or wildlife. Research activities, navigation, and communication systems would not generate large quantities of waste or disturb/destroy large land areas.
Health	Surface concentrations of exhaust products are less than recommended human exposure limits. No physiological damage expected due to use of exclusion zone.	Effects are similar to but less than Shuttle.	Launch related effects would be eliminated under the No-Action Alternative.
	Public and occupational health effects are insignificant. Payload ground and on-orbit operations will not involve hazardous emissions or operations that would threaten crew or worker health and safety.	Impacts are similar to those anticipated under the Proposed Action. Risks to crew during on-orbit operations would be eliminated since all ELV payloads would be automated.	Terrestrial equivalent systems would not significantly affect occupational or public health.
	0/0	0/0	0

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TABLE 3. (Continued)

Environmental Category	Nature of Payload Impacts/Magnitude (for Launch Vehicle/Payload)* — Proposed Action	Expendable Launch Vehicle Alternative	No-Action Alternative
Resource Use	Natural and cultural resource commitments do not involve significant quantites of scarce resources. Total energy requirements per Shuttle launch are estimated at 750 x 10^9 kJ assuming 24 launches per year.	Resource requirements are similar to but less than those for a Shuttle launch. About 180 x 10^9 kJ of energy per ELV launch is required (Delta launch rate of 5 per year).	Launch vehicle resource commitments would be eliminated under the No-Action Alternative.
	Relative to the Shuttle energy and material use, payloads will not require or deplete significant quantities of natural or cultural resources.	Payload resource commitments are similar to those anticipated under the Proposed Action.	Resource requirements for Earth-based systems, such as research laboratories or receiving/transmitting stations, would be moderate.
	1/0	1/0	2
Accidents	Potential accidents during Shuttle launch include explosions, fire, release of toxic gases, crash or mission aborts. These events could be catastrophic; but are of extremely low probability.	Accident related events with ELVs are similar but less severe than those anticipated for the Shuttle. No loss of flight crew would be possible.	Launch vehicle related effects from accidents would be eliminated under the No-Action Alternative.
	Under worst-case scenarios, some payloads and payload operations could result in damage to the STS equipment or personnel injury. The probability and severity of these events are reduced or eliminated with appropriate hazard controls.	The probability and severity of accident events is lower because of the automated nature of payloads.	Accident probabilities and consequences for Earth-based systems are low. A worst-case scenario for communications systems, for example, would involve an aircraft collision with an electronics tower. The probability of this event is extremely low.
	2/1	2/0	1

*The rating scale relates the magnitude (i.e., degree, extensiveness, scale, probability of occurrence) of the impact to its significance. The assessment of an impact is with respect to the existing environment and presumes the implementation of appropriate mitigative controls. Parenthetical ratings refer to positive (beneficial) impacts.

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orbital operations from the standpoint of potential accidents is not an issue of concern. Extensive safety and design requirements (Figure 5) minimize these risks. The payload impacts on air, land, and water quality; noise, biotic resources; human health; and resource use are small and localized. Potential accident effects, when compared to those occurring from a Shuttle-related malfunction also are negligible.

4.1 Space Quality and Projected Hazard Levels

The greatest impact from either the Proposed Action or the ELV/SR Alternative Action will be growth in the space debris population. The primary concern is the growth in the number of uncontrollable-debris (non-maneuverable) objects. The reason for this concern is that large, uncontrollable-debris growth will be introduced with the onset of collisions. Evolutionary calculations generally show that a catastrophic collision should be expected to occur in LEO by 1995 (Reynolds and Fischer, 1980 and 1983).

Table 4 summarizes the upper stage use projected by the Traffic Model. Between 1982 and 1991, 175 upper stages are anticipated to be used for space missions. The macroparticle debris generated in various orbits as a result of space missions under the Proposed and Expendable Launch Vehicle Alternative are identified in Table 5. In the aggregate, ELVs involve over 50 percent more debris deposition. When compared by orbit location, the most striking difference appears in LEO—about 172 objects are projected to be deposited by ELVs. Most of these objects, however, are expected to reenter the atmosphere and burn-up in a relatively short time.

TABLE 5. MACROPARTICLE DEBRIS GENERATED BY LAUNCH VEHICLES AND UPPER STAGES UNDER THE PROPOSED ACTION AND EXPENDABLE LAUNCH VEHICLE ALTERNATIVE

		Deposition Orbit					
Action	Launch Vehicle	LEO	GTO	GEO	Planetary	Other	Total
Proposed Action	STS	8	136	3	2	35	184
Alternative Action	ELV	172	135	1	4	29	341

The following discussion centers on the impact nominal STS operations might make to the population densities in the 1984-1991 time frame. The contribution of these objects to a large, non-linear growth (collisions) is not addressed.

TABLE 4. UPPER STAGE USE PROJECTED BY STS TRAFFIC MODEL

Upper Stage Type	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Total
PAM-A	0	0	0	0	0	0	0	8	8	12	28
PAM-D	2	5	7	10	12	8	6	7	7	2	66
PAM-DII	0	0	0	3	11	13	12	4	3	8	54
IUS/SRM1	0	0	0	0	2	3	2	1	4	2	14
IUS/SRM2	0	2	1	0	0	0	0	0	0	0	3
IUS Twin	0	0	0	0	0	0	0	1	0	0	1
Centaur	0	0	0	0	2	0	0	0	0	0	2
Unique Stages	0	0	2	2	0	2	0	0	0	0	6
TOTAL	2	7	10	15	27	26	20	21	22	24	175

Microparticle Objects in LEO. The contributors to microparticle debris in LEO will be collisions and SRM exhaust particulates. In the time frame to 1991, the dominant source will be SRMs. Table 7 shows the projections for SRM particulate fluxes. These fluxes (impacts/m^2/year) represent an upper limit, since some percentage of the SRM particulates will be injected into low-perigee rapid decay orbits.

The threat which these exhaust particulates present to functioning spacecraft depends on the vulnerability of spacecraft components, primarily the solar panels. Although the characteristic size for the particulates will be in the 1-10 microgram mass regime, they carry enough kinetic energy on collision to produce cratering and small fractures. The effect on solar panels most likely will be a slow degradation of performance as surface cratering builds up, but no experimental evidence is available as to how rapidly this will occur.

Macroparticles in LEO. The marginal threat from large objects introduced into LEO by Shuttle-initiated activity is complicated by the difficulty in properly accounting for the anticipated source terms. Besides functioning spacecraft and spent stages, other objects (more numerous and, therefore, more threatening) may be released during staging, deployment, or at the start-up of operational activity. The largest source of tracked debris to date has been accidental explosions occurring in LEO. Testing of schrapnel-producing antisatellite weapons such as the Soviets use promises to be a major non-NASA source in the future (Kessler, 1981; Chobotov, 1982).

Another issue to address in discussing large LEO debris is the preferential buildup of objects released at Shuttle operating altitude as a result of the relatively high level of activity. These objects will include fragments left unattached in the bay before ascent or shaken loose in the bay during ascent, objects released during payload deployment or experiment activation, and objects accidentally released. Retrieval operations will pose a special problem since the Shuttle will not be able to accommodate such objects as deployed antennae and solar panels; if these objects are left in orbit, they will become large, long-lived debris. The objects being threatened by this debris will, of course, be the Orbiter and any of a number of deployed free flyers such as LDEF which remain at Shuttle operating altitude. The Shuttle operating altitude is about 290-320 km.

The Traffic Model for Shuttle-initiated activity in LEO will involve over 70 payloads with minimal propulsive capability. A significant percentage of the deployments in LEO (38 percent) are into high-inclination, highly-eccentric "Molniya" orbits. Table 7 shows the average number of objects which must be released per mission to present collision probabilities of 10^{-4} and 10^{-5}.

Macroparticles in GEO. The mission model calls for 134 Shuttle payloads destined for GEO; this will be the total NASA user traffic to GEO during this period. A variety of carriers will be used to perform the transfer. The IUS will leave a stage in GEO separate from the delivered satellite; special carriers are called for in some cases and represent an unknown contribution. The PAM-D and PAM-D2 carriers will have a self-contained AKM and leave no extra vehicles in GEO. The

TABLE 6. TRAFFIC MODEL PROJECTIONS FOR SRM PARTICULATE FLUXES

Year	Number of Bound Orbit Transfers (A)	80% * A	Mean Time Between Firings (days)	Number of Firings Contributing Particulates At Any Given Instant	Expected Impacts (m^2/yr)
1984	9	7.2	50	1	1.2
1985	15	12	30	1+	2.0
1986	26	20.8	17.5	3	3.4
1987	25	20	18	3	3.4
1988	20	16	22.5	2	2.7
1889	19	15.2	24	2	2.5
1990	23	18.4	19.8	2+	3.0
1991	21	16.8	21.8	2+	2.8

TABLE 7. THE AVERAGE NUMBER OF OBJECTS (NS) WHICH MUST BE RELEASED PER SHUTTLE MISSION TO PRESENT COLLISION PROBABILITIES (P_{cs}) OF 10^{-4} AND 10^{-5} PER 7 DAY MISSION

Year	Number of Debris Contributing Flights	$N_s(P_{cs} = 0.0001)$	$N_s(P_{cs} = 0.00001)$
1984	14	714	71
1985	18	556	56
1986	25	400	40
1987	32	313	31
1988	83	435	44
1989	12	733	23
1990	5	1667	167
1991	2	5000	500

deposition of these objects will provide additional targets for collision with the current population, elevate the probability of collision between drifting GEO objects; eventually, all of the objects placed in orbit in this mission model will join the drifting population, unless procedures are instituted to remove them.

4.2 Proposed Action: Shuttle Launch of Payloads

Use of the Space Shuttle to launch and/or operate the payloads described in the previous section will result in a number of environmental impacts. Most of these will be relatively minor and most are negligible when compared to the launch of the Shuttle. This section and the accompanying tables describe the impacts that are to be expected from the payloads.

4.2.1 Shuttle Integrated Payloads

The environmental effects of the Shuttle launch and operation of the integrated payloads which were described in Section 3.1.1 are summarized in Table 8. Both individual mission and cumulative effects for these integrated payloads are the same: There are very few negative impacts on the environments of either Earth or space. The payloads are designed and manufactured under very stringent guidelines. In addition, operational requirements have been developed to reduce or eliminate the hazards and negative impacts on either of these environments. At the same time, the potential for very positive effects from these experiments and operations are very great and could have global, long-term benefits for all mankind. As is shown in the table, any negative impacts would result only from accidents which have very low probabilities of occurrence.

4.2.2 Free-Flying Payloads

The environmental impacts resulting from the launch and operations of the free-flying payloads are summarized in Table 9. These payloads, described in Section 3.1.2, will have very minor impacts on Earth's and space environments under normal operating conditions. These payloads are designed and fabricated under the same stringent safety guidelines that apply to the Shuttle-integrated payloads. Negative impacts are primarily due to accidents and space debris contributions. The benefits that would accrue from the operation of these payloads and spacecraft have large potentials for global, long-term benefits, particularly in the areas of human health, safety, communications, and resources management.

Of the payloads considered in this assessment, satellites will require the most intensive material and energy use. Materials for satellite manufacture include steel, aluminum, copper, titanium, beryllium, composites, and miscellaneous plastics and propellant. Generic estimating techniques indicate that material requirements for the 209 satellites scheduled for Shuttle launch over the next decade would be insignificant compared to the U.S. production of related materials. Steel requirements, for instance, would total 0.170 MT, which is 1.25 E-5 percent of the U.S. steel production. Energy requirements for these satellites include those for propellant and fluids, manufacture and support, materials and ground support. These requirements would total 6.13 billion kilojoules or 0.0016 percent of the national energy demand.

TABLE 8. SUMMARY OF ENVIRONMENTAL IMPACTS FROM SHUTTLE LAUNCH OF GENERIC INTEGRATED PAYLOADS[(a)]

Environmental Category	Nature of Payload Impacts/Magnitude: Mid-Deck	Get Away Specials (GAS)	Spacelab	Other Integrated Payloads
Socioeconomics	Very minor, localized benefits during payload manufacture. (1)	Minor, localized effects during payload manufacture. (1)	Large, measurable, localized benefits during design and fabrication. (2)	Large, measurable, localized benefits for payload fabricators. (2)
	Far-reaching, large benefit from investigations and product development. (3)	Long-term benefits from application of of research encouragement of scientific/aeronautical research and careers. 3	Long-term benefits from experimental results and continued development and applications. (3)	Long-term general benefits to humans resulting from space research. Possibilities for commercialization of processes. (3)

(a) The rating scale relates the magnitude (i.e., degree, extensiveness, scale, probability of occurrence) of the impact to its significance. The assessment of an impact is with respect to the existing environment and presumes the implementation of appropriate mitigative controls. Parenthetical ratings refer to positive (beneficial) impacts.

Rating	Definition
0	No or minimal impact
1	Small (measurable), temporary, localized impact
2	Large, short/long-term, local/regional/global scale impact
3	Significant (includes, but not necessarily limited to, impacts associated with irreversible/irretrievable commitments of resources; adverse effects which can't be avoided; and benefits which may be of national/international scale), short/long-term, regional/global scale impact.

TABLE 8. CONTINUED

Environmental Category	Nature of Payload Impacts/Magnitude: Mid-Deck	Get Away Specials (GAS)	Spacelab	Other Integrated Payloads
Space Quality	No space debris generated.	Negligable impacts. Present if experimental release of material occurs.	No space debris generated; Intentional releases are of short duration and minor impact.	No space debris generated; Intentional releases have short term, minor, and localized impacts.
	0	0	1	1
Air, Land, & Water Quality	Self-contained experiments in highly controlled environments will minimize effects.	Releases are minor and not discernable in context of total environment.	Negligable, local, and temporary confined to manufacture and fabrication of spacelab modules.	Negligable, local, and temporary, confined to manufacturer and fabrication of payload modules.
	0	0	0	0
Noise	Insignificant impacts.	Insignificant impacts.	Insignificant impacts.	Noise from processing machinery would be very slight.
	0	0	0	1

(a) The rating scale relates the magnitude (i.e., degree, extensiveness, scale, probability of occurrence) of the impact to its significance. The assessment of an impact is with respect to the existing environment and presumes the implementation of appropriate mitigative controls. Parenthetical ratings refer to positive (beneficial) impacts.

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TABLE 8. CONTINUED

Environmental Category	Nature of Payload Impacts/Magnitude: Mid-Deck	Get Away Specials (GAS)	Spacelab	Other Integrated Payloads
Biotic Resources	Controlled, self-containd packages reduce or prevent contact with environment. 0	Insignificant Impacts. Controlled, self-contained canisters prevent or reduce contact with environment. 0	Insignificant impacts. Controlled, self-contained packages and experiments prevent or reduce contact with environment. 0	Insignificant impacts. No direct contact with environment under normal operations. 0
Human Health	No impacts to general public. Crew exposure and risks are negligable. 0	Activities and function take place away from humans - no impact expected. 0	Negligable impacts. Low-risk activities for spacelab crew. 0	Negligable impacts. Operational procedures reduce or eliminate human contact/exposure. 1
Resource Use	Insignificant use of resources due to small size of packages. 0	Insignificant use of resources due to small size of packages. 0	Insignificant use of resources due to relative size of spacelab modules and experimental equipment. 0	Insignificant use of resources. Long-term potential for materials processing will be beneficial. 0/(2)

(a) The rating scale relates the magnitude (i.e., degree, extensiveness, scale, probability of occurrence) of the impact to its significance. The assessment of an impact is with respect to the existing environment and presumes the implementation of appropriate mitigative controls. Parenthetical ratings refer to positive (beneficial) impacts.

Rating	Definition
0	No or minimal impact
1	Small (measurable), temporary, localized impact
2	Large, short/long-term, local/regional/global scale impact
3	Significant (includes, but not necessarily limited to, impacts associated with irreversible/irretrievable commitments of resources; adverse effects which can't be avoided; and benefits which may be of national/international scale), short/long-term, regional/global scale impact.

TABLE 8. CONTINUED

Environmental Category	Nature of Payload Impacts/Magnitude			
	Mid-Deck	Get Away Specials (GAS)	Spacelab	Other Integrated Payloads
Accidents[(b)]	No impact on general public and ground crews from on-orbit operations.	No impact on general public from on-orbit operations.	No impact on general public from on-orbit operations.	No impact on general public from on-orbit operations.
	0	0	0	0
	Negligable impact on Shuttle crew with on-board release.	Ground and Shuttle crews may be exposed to hazards from pressurized containers.	Ground and Shuttle crews may be exposed to hazardous materials and pressurized containers subject to rupture.	Ground and Shuttle crews may be exposed to hazardous materials and pressurized containers subject to rupture. Some mechanical equipment may be subject to failure.
	1	1	2	2

(a) The rating scale relates the magnitude (i.e., degree, extensiveness, scale, probability of occurrence) of the impact to its significance. The assessment of an impact is with respect to the existing environment and presumes the implementation of appropriate mitigative controls. Parenthetical ratings refer to positive (beneficial) impacts.

Rating	Definition
0	No or minimal impact
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(b) Low probability events.

TABLE 9. SUMMARY OF ENVIRONMENTAL EFFECTS FROM SHUTTLE LAUNCH OF GENERIC FREE-FLYING PAYLOADS

Environmental Category	Nature of Payload Impacts/Magnitude (for Type of Payload) Communications Satellites	Environmental Satellites	Navigation Satellites	Space Science and Solar-Terrestrial Satellites	Astronomy and Astrophysics Satellites	Planetary Spacecraft	Other Free-Flying Science, Technology, and Applications Missions
Socioeconomics	Localized long-term stability as demand for communications satellites rises. (3) Long-term global benefits from increased and improved communications (3)	Localized long-term stability for satellite manufacturers (3) Long-term, global benefits from improved resource management, more complete data gathering, and better analysis (3)	Localized long-term stability for satellite manufacturers (3) Long-term, global benefits from enhanced navigation of oceans and air. Reduced operating costs and increased safety for users (3)	Local short-term benefits for fabricators and experimenters (2) Data will expand scientific knowledge. Potential for some economic benefits (2)	Minor benefits to involved organizations and satellite fabricators (1) Data will contribute to scientific knowledge base (2)	Minor benefits to involved organizations and spacecraft fabricators (1) Potential benefits for general public are more cultural than economic (2)	Minor benefits from fabrication of spacecraft and platforms, limited to localized short-term benefits (1) Long-term global benefits are potentially substantial. Improved medical technologies, materials production methods, and new applicants would be substantial social, cultural, and economic benefits (3)
Space Quality	Addition of upper stages to space debris population. Addition of spent spacecraft to space debris population. Reduction in numbers of upper stages relative to ELV alternative 2	Spent satellites, booster motors, etc. will add to space debris population. Reduction in numbers relative to ELV alternative 2	Spent satellites, booster motors, etc. will add to space debris population. Reduction in numbers relative to ELV alternative 2	Spent satellites, booster motors, etc. will add to space debris population. Reduction in numbers relative to ELV alternative 2	Spacecraft will be large, but number of spacecraft will be small and many are designed for retrieval. Impacts will be minor and temporary 1	Will not contribute to space debris population as spacecraft leave Earth's gravitational field 0	Non-maneuvering nature of platforms, etc. are potential space debris problems. Unrecoverable craft would add to debris population 1
Air, Land, Water Quality	Negligible impacts from fabrication and operations 0 Global, long-term improvement of data and analysis of environmental quality (2)	Insignificant impacts from fabrication 0 Long-term, global benefits from satellite data and analysis. See also Socioeconomics (3)	Insignificant impacts from fabrication 0 Few impacts from operations, all are insignificant (3)	Insignificant impacts from fabrication 0 Insignificant impacts from operations 0	Insignificant impacts 0	Insignificant impacts. No interaction with environment 0	Negligible impacts. Returned cultures and experiments may have very minor, localized impacts 1
Noise	Insignificant impacts 0	Insignificant impacts 0	Insignificant impacts 0	Insignificant impacts 0	Insignificant impacts 0	Insignificant impacts 0	Insignificant impacts 0
Biotic Resources	Insignificant impacts. No contact with terrestrial environment 0 Indirect effects. See Air, Land, and Water Quality (2)	Direct effects are insignificant 0 Indirect effects. See Socioeconomics (2)	Insignificant impacts 0	Insignificant impacts. No contact with environment 0	Insignificant impacts. No direct contact with environment 0	Insignificant impacts. No interaction with environment 0	Negligible impacts. Returned materials and cultures would be widely dispersed, not subject to concentrations 1
Human Health	Direct effects are insignificant 0 Indirect effects. See Air, Land, and Water Quality (2)	Insignificant direct effects 0 Indirect effects, see Socioeconomics (2)	Direct/indirect effects include improved safety for ocean vessels and aircraft, reduced loss of life resulting from storms and other hazards, greater potential for rescues from improved positioning capability (3)	Potentials for data use could result in long-term benefits through weather forecasting, etc. (1)	Insignificant impacts 0	Insignificant impacts 0	Operational impacts are insignificant 0 Products, long-term benefits from improved medicines and other medical technologies would enhance human health (3)
Resource Use	Growing use of satellites for communications reduces radio frequency spectrum and orbit stations available for satellite use. Possible saturation of usable locations. 2 Satellite fabrication uses insignificant amounts of resources 0	Insignificant use of resources. 0 Long-term, global benefits from discovery of new resource deposits and better management of older deposits (2)	Insignificant use of resources 0 Long-term benefits to navigation sector from improved operations (1)	Direct effects are insignificant 0 Potential long-term benefits from better resource management (1)	Insignificant use of resources 0	Insignificant use of resources 0	Spacecraft, etc., insignificant use of resources. 0 Processes and operations, new technologies for more efficient and effective use of existing resources. Potential for new materials and new uses for old resources. (2)
Accidents[b]	System failures could mean economic loss of satellite 1 Premature firing or explosion of rocket motors could damage or destroy Shuttle and/or satellite 3 Misdirected electromagnetic radiation could cause injuries to workers 1	System failures could mean economic loss of satellite 1 Premature firing or explosion could damage or destroy satellite and/or Shuttle 3 Insignificant hazard to general public 0	System failures could mean economic loss of satellite 1 Premature firing or explosion of rocket motors could damage or destroy satellite and/or Shuttle 3 Insignificant hazard to general public 0	System failures could mean economic loss of satellite 1 Premature firing or explosion of rocket motors could damage or destroy satellite and/or Shuttle 3 Insignificant hazard to general public 0	Systems failure could mean economic and operational loss of spacecraft 2 Large size of spacecraft could result in physical injuries to ground crew in handling mishap 2 Servicing/retrieval operations accidents could result in loss of life and/or damage or destruction of spacecraft and/or Shuttle 3	Systems failure could mean economic and operational loss of spacecraft 2 Premature firing or explosion of rocket motors could damage or destroy the spacecraft and/or Shuttle 3	Systems failure could mean economic and operational loss of spacecraft 2 Ground crew handling mishap could result in physical injuries 2 Servicing/retrieval operations accidents could result in loss of life and/or damage or destruction of spacecraft and/or Shuttle 3

(a) The rating scale relates the magnitude (i.e., degree, extensiveness, scale, probability of occurrence) of the impact to its significance. The assessment of an impact is with respect to the existing environment and presumes the implementation of appropriate mitigative controls. Parenthetical ratings refer to positive (beneficial) impacts.

Rating	Definition
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3	Significant (includes, but not necessarily limited to, impacts associated with irreversible/irretrievable commitments of resources, adverse effects which can't be avoided, and benefits which may be of national/international scale), short/long-term, regional/global-scale impact

(b) Low-probability events

4.3 Alternative Action: Expendable Launch Vehicle/Sounding Rocket Launch Payloads

This section highlights the differences between the Proposed Action, the Shuttle launch of the payloads, and the Alternative Action, the use of Expendable Launch Vehicles and/or Sounding Rockets. With the ELV/SR alternative, several options exist; from total abandonment of the operation and experiment to no, or very little, change from the Proposed Action. The differences in the environmental impacts as shown in Tables 6 and 7, are discussed in the following paragraphs.

A number of integrated and free-flying payload missions could not be initiated if expendable launch vehicles or sounding rockets were used as an alternative to Shuttle launch of payloads. Non-automated payloads requiring human intervention, payloads exceeding the size and mass constraints of launch vehicles, and payloads necessitating long duration exposure to space environment conditions would be precluded from utilizing the space environment for research or commercial applications. There are a number of missions for which the Expendable Launch Vehicle/Sounding Rocket Alternative is technically or economically infeasible. Of the 306 unclassified missions (exclusive of GAS and Mid-deck experiments), about 40 percent would have to forego the benefits from the proposed shuttle activities. For the generic payloads described in Section 3.0, the Expendable Launch Vehicle/Sounding Rocket Alternative for CFES, GAS, Spacelab, MSL, TSS, SIRTF, SPL, Eureca, SPARTAN, LDEF, SPAS, and EOS would not be appropriate.

The Atlas-Centaur and Delta launch vehicles were found to be reasonable options for 57 and 113 missions, respectively. The remaining 19 missions were assigned to the T34D/IUS, Ariane, or Scout. Appendix B provides further detail on whether or not an expendable launch vehicle or sounding rocket would be a reasonable alternative to the use of the Shuttle.

Although sounding rockets have not been identified as reasonable alternatives to other generic payloads (Section 3.0) it is possible that small, automated research payloads (e.g., GAS) could be flown on a sounding rocket if the experiment requirements could be fulfilled. Environmental impacts of sounding rockets would be considerably less than the Shuttle launch. However, this alternative would be available to very few of the payloads because of experimental requirements (e.g., long duration exposure to zero-g) or size/mass constraints.

Environmental impacts of communication, environmental, navigation, and planetary spacecraft missions would not be significantly different from those associated with the Proposed Action. Abandonment of research and commercial opportunities would: (1) severely limit the near-term realization of potential benefits to man from space exploration and (2) eliminate environmental impacts associated with payload development, manufacture, and operation.

4.3.1 Launch Vehicle Integrated Payloads

The Expendable Launch Vehicle or Sounding Rocket Alternative would not technically nor economically feasible for any of the integrated Shuttle payloads described in Section 3.1 In most cases, a combination of several research requirements, e.g., long duration exposure and Earth-return of payload, precluded these from further consideration for alternative launch vehicle actions. Table 8 is therefore not applicable to this alternative action.

4.3.2 Free-Flying Payloads

Free-flying payloads capable of being launched by ELVs include communication, environmental, navigation, and planetary spacecraft. The environmental impacts of the vehicles are shown in Table 3. The environmental effects associated with the generic missions and payloads are essentially the same as for Shuttle launch of these payloads as shown in Table 9. This section will describe the major differences that ELV/SR use would have on those impacts.

Communication Satellites. Of the 130 communication satellites to be launched betwen 1982-1991, only the TDRS satellites could not be launched by ELVs. The TDRS series exceeds the mass capability of the current launch vehicle fleet. Environmental effects are not significantly different from those anticipated by the Proposed Action, although the type and quantity of space debris generation will differ with the use of expendable vehicles.

The socioeconomic impacts center on different labor requirements and may result in a variation in transportation and launch costs to the customer, depending on location of the ELV launch site. Changes in the demand for domestic or foreign vehicles may occur depending on the ELV capabilities and associated costs.

The effects on space quality resulting from the use of ELVs would not be significantly different from the effects that result from the use of the Shuttle to launch the satellites. The most pronounced effects on space quality would be the placement of a greater number of objects in space that would represent an increased collision hazard to other spacecraft. These would consist of launch vehicles stages in low Earth and elliptical transfer orbits.

Accident consequences for unmanned ELV launches include the loss of payloads and temporary damage to the immediate environment. The accident consequences for ground-stations are identical to those projected under the Proposed Action. The potential for loss of Shuttle crew would be eliminated.

Environmental Satellites. Environmental satellites are currently being launched to low sun-synchronous orbits by the USAF's Atlas F vehicles and high geosynchronous orbits by NASA Delta vehicles. If the Shuttle were not used, this practice would continue, the only limitation being the stock of Atlas F vehicles available for this purpose. The effects on the use of geosynchronous orbit are equivalent to those for Shuttle launch of the payloads.

Accident consequences for unmanned ELVs include the loss of the payload and temporary damage to the environment near the accident site. The accident consequences for the ground-based facilities are the same as those projected under the Proposed Action, and these consist of normal work-place types of accidents.

Navigation Satellites. The current Transit and Nova navigation satellites have been launched by Scout ELVs. The NAVSTAR Global Positioning System (GPS) is being designed for launch from the Space Shuttle with a PAM-D2 solid rocket motor. The Delta ELV with a solid rocket third stage is the existing ELV which would be most appropriate for this mission; minor modifications would be required to both the spacecraft and vehicle. A single spacecraft launch on an Atlas/Centaur would be to expensive, but multiple launches on a Titan 34D/IUS could be undertaken with costs which approximate those for a Delta launch. Since 24 to 26 launches are projected, the costs of modifying the vehicle or spacecraft to accomplish this mission would be amortized, and either Delta or Titan vehicles could be selected to optimize cost and program requirements.

The use of the Shuttle and PAM-D2 to accomplish the mission will cause both the PAM-D2 and spacecraft to become part of the space debris population. If the Delta were used the Delta's second stage as well as the solid rocket motor third stage and NAVSTAR spacecraft will join the space debris population. If the Titan 34D/IUS were selected, the Titan second stage and the two IUS stages would join the debris population, but at least two spacecraft could be placed for each launch. Thus, a Shuttle launch results in the addition of two major space debris objects while Delta and Titan 34D/IUS launches result in an average of three and two-and-a-half debris objects, respectively. The Proposed Action would place 24 to 26 NAVSTAR satellites in 20,000 km orbits with 63 degree inclination. This would result in 48 to 50 major items of debris if the Shuttle were used; about 72 to 78 items would be added to the space debris if Deltas were used.

Accident consequences for the navigation satellite launches by ELVs include the loss of payloads and their services and temporary damage to the environment near a crash site.

Planetary Spacecraft. Planetary missions are the most demanding of launch vehicle performance capabilities. Flyby and orbital missions to Mars and Venus can be accomplished by existing Atlas/Centaur and Tital 34D/IUS vehicles. Most planetary missions envisioned for the rest of this century are directed at such outer planets as Jupiter. These missions would require a Titan/Centaur vehicle, and these are no longer in production. Non-recurring expenditures of several missions of dollars would be needed to restore the capability to produce and launch these vehicles. The Titan vehicles, however, are not considered to have as much capability growth as the Shuttle.

The use of the Atlas or Titan ELVs will result in disposal of a lower stage in Earth orbit. The upper stage escapes the Earth's gravitational influence and remains in regions where the space debris problem is not a current concern.

Accident consequences for ELV launches include loss of the payload and temporary damage to the environment near the accident site. Since the ELVs are unmanned, the risk to the Shuttle now is eliminated. Ground-station operations and accidents are the same as for the Proposed Action, the Shuttle launch of these missions.

4.4 No-Action Alternative: Terrestrial Equivalents

A substantial number of the integrated and free-flying missions could not be achieved through ground-based systems. About 40 percent of the unclassified missions (exclusive of National Security, GAS, and Mid-deck experiments) would have to forego the anticipated benefits under the Proposed Action. For these missions and the generic payloads (as described in Section 3.0), terrestrial equivalent systems would be feasible for communication, environmental, and navigational systems. Most of these ground-based systems are primarily radio communication-type systems with networks of broadcast and relay towers as well as undersea and land line cables. Because of this, only the ground-based communications systems are detailed in the following paragraphs. The environmental impacts are also shown in Table 3.

4.4.1 Ground-based Systems

Environmental impacts of ground-based communication systems are detailed in this Section and provide a worst case envelope for ground-based navigational and environmental systems. The direct and indirect Shuttle-related impacts would be replaced by localized and dispersed impacts from the construction and operation of those aforementioned systems.

4.4.2 Communications Systems

Terrestrial equivalents of space-based communications systems exist for virtually all of the proposed communications payloads (except for technology verification and servicing operations). The feasibility of ground-based systems is a function of several variables, including the service type, user requirements (e.g., reliability and speed of data transmission), location or remoteness of the user community, and the technology status and associated capital and operating costs of the ground-based systems. Large population centers, for instance, might be able to rely on microwave relay towers, land lines, or undersea cables. Remote and mobile facilities (e.g., oil rigs, aircraft, vessels at sea, small isolated communities), on the other hand, might have to rely on atmospheric propagation of radio waves if this were applicable. Other ground-based techniques rely on innovative concepts such as laser transmissions, fiber optics, and utilization of meteor trails for radio wave relay. These latter alternatives, while technically feasible, might not be economically feasible nor practical for operational implementation. Terrestrial equivalents to the Proposed Action explored in this Section therefore include only those technologies that would be cost competitive with space-based communications systems.

Socioeconomics. Short and medium range (e.g., less than 1000 km) transmission of moderate and high volumes communications traffic is likely to be more cost-effective when transmitted via ground microwave systems than satellite systems. For long distances (e.g., greater than 1000 km), and in sparsely populated areas where the traffic volume does not support a large investment in ground facilities, satellite relay systems are more cost-effective than ground relay systems.

Thus, the No-Action Alternative would tend to raise the cost of some long-distance communications, while reducing some short and intermediate distance communication costs. The full economic trade-off between ground and space-linked communications systems is complex, and depends upon a number of factors including the density of the active user population (e.g., TV reception); projections of market growth for all types of communications services; and technology. Studies of a relatively underdeveloped country, such as India, indicate that for uniform population density and a low technology base, the economic cross-over distance for satellite stations with VHF radio-telephone links to the Earth-stations ranges from 200 km to 400 km (Pelton, 1982). Thus, while the terrestrial alternative would raise costs, it is a reasonable alternative technology. Selection of ground-microwave technology, however, would delay the spread of the communications networks to remote, low-density areas until the high volume user traffic would materialize and require servicing. While U.S. companies would probably compete to supply some of the equipment for these systems, it is likely that a lower percentage of the systems would be of U.S. origin than is the case for the satellite systems. This should have a small, but measurable, impact on U.S. exports and employment. The operations and maintenance costs associated with ground-based systems also would tend to be higher than for space-based systems. This is particularly true when undersea, above ground, and buried cables are used. Land systems using hardwire cables require reduced vegetation zones along the rights-of-ways which require forestry crews as well as line repair crews to continually inspect and maintain the rights-of-ways and the transmission lines. Undersea cables operate in a very demanding environment. The corrosiveness of sea water and the high pressures on the ocean bottom result in a continuing maintenance requirement of cable inspection renewal and relaying and can only be accomplished by a cable laying vessel. Based on these considerations undersea cables would be expensive systems to operate and maintain.

If the No-Action Alternative were to be interpreted as leading to the abandonment of all future U.S. space activity, there would be a corresponding reduction of employment in the aerospace industry. The impact would be the greatest on the labor force involved in the (1) design and fabrication of spacecraft and supporting ground stations and (2) launch vehicles equipment. The U.S. balance of payments also would be adversely affected due to the use of the launch services of other space-oriented countries such as the Soviet Union, France, and Japan. The effects on society of reducing both commercial and research use of space are not easily predicted, but would be significant and adverse.

Space Quality. The No-Action Alternative would not add to the space debris population and would, therefore high a slightly positive effect on space quality. However, if the launch services of other nations were used to launch the communications satellites, there would be no net space quality changes over the Expendable Launch Vehicle/Sounding Rocket Alternative required.

Air, Land, and Water Quality. The No-Action Alternative would avoid the direct near-term and temporary effects on air, land, and water quality associated with the Shuttle launches. It would also avoid the minor effects generated by the fabrication and assembly of the communications satellites. The short-term effects of the Shuttle launches would be replaced by temporary air, water, and land quality effects from the construction, operation, and maintenance of greatly expanded ground-based systems. These would include the construction of microwave towers, laying of undersea cables, and erecting radio frequency broadcast towers. Some of these facilities would be located in remote areas where there is no other development of man-made origins. For these particular locations, there would be a potential for short-term adverse effects, associated with construction disturbances. Facility operations would include negligible and temporary effects on the air, land, and water quality in the immediate vicinity.

Noise. The No-Action Alternative would substitute the temporary noise levels generated by the launching of the Space Shuttle with the relatively minor, local, and temporary noise associated with microwave tower construction, undersea cable laying, and radio frequency broadcast tower erection. The normal operations and maintenance of these systems do not generate measurable nosie levels that would affect local environments.

Biotic Resources. The reliance upon ground-based communications sytems would necessitate the construction, operation, and maintenance of a large number of microwave towers, undersea cables, broadcast towers, land lines, and associated buildings and other facilities. Taken individually, no one single facility or system network would lead to any significant impacts on the biotic environment. Facilities and access road construction would result in minor adverse effects on specific local areas, especially in remote, isolated, and/or ecologically delicate areas. Restricted development along the access roads and in the vicinity of the facilities would help mitigate the potential adverse effects, but would not eliminate them entirely as routine operations and maintenance would continue to exert a disturbing influence of these areas. The cumulative effects of using ground-based communications systms would be adverse but of minor significance. The number of locations that would be disturbed would increase siginficiantly, especially with the use of undersea cables and below or above ground transmission lines. In addition, electrical power would be required for many of the repeater stations which would result in power transmission lines being erected to the facilities. In remote locations, particularly where vegetation is diverse and fast-growing, continual maintenance of the rights-of-way would be required. This would establish a permanent disruption of ecological resources. Undersea cables require more constant routine maintenance than land-based wire systems due to the corrosiveness and dynamic pressures of the water in which they function. The cables have to be pulled up from the ocean floor, inspected, renewed, and relaid; all these activities would disturb the local ocean ecology. In all likelihood, however, the use of totally ground-based systems would not result in any significant adverse effects to the biotic environment.

Human Health. Normal operations of ground-based communications systems would have no significant effects on human health. Any impacts that would be present would be the result of construction and maintenance activities and would be more directly related to accidents than normal activities.

Resource Use. The No-Action Alternative would require the construction of a large number of microwave towers, the erection of broadcast towers and above-ground cables, and the construction of the associated repeater, relay, and other equipment facility structures. No one single facility or structure would use a significant amount of resources either for construction or operation. There is, however, a potential for some minor effects if all of the proposed communications satellites were to be replaced by ground-based systems. All of the structures and facilities would use metals (such as steel and aluminum) and other building materials (such as concrete and bricks) that are, for the most part, non-renewable. The quantities used would be a very small and almost insignificant amount and therefore would represent a very small potential for any significant impact on the total market for building materials. The basic manufacturing of the construction materials and the building and fabrication of the systems, as well as the operation of the systems, require the use of various forms of energy. A brief investigation of the materials and energy requirements associated with the construction and operations of one microwave tower indicates that this process consumes about 25 kilowatts (thermal) of energy. (Rice, 1974; 1978; Battison, 1982). The total number of towers that would be required is very hard to determine at this time. But for comparison purposes, a typical microwave relay system would consist of approximately 2100 towers. This represents a total estimated energy consumption of about 1.7 x 10^{13} kJ for the equivalent 10 year operational life of a communications satellite. Although this is about ten times the energy required for one Space Shuttle launch of a communications satellite, the tower life of a microwave tower is more likely to be 20 years or more with the greatest portion of the energy expended during the construction phase. The energy use for the additional 10 year operational period would be a small incremental increase over the preceeding 10 year period. Submarine cables would represent an energy cost of about three to five times that of a space-borne communications system. Investment costs of any substitute system are very difficult to determine at the present time.

Accidents. High risk activities associated with the No-Action Alternative include construction and maintenance of towers, installation of submarine cables at sea, communications facility operations, and aircraft operations in the vicinity of towers. Any of these accidents could lead to either deaths or injuries. Accidents associated with operations of the facilities include electrical shock associated with high voltage or high capacity electronic equipment. This particular industry has a relatively good safety record; the probability of a major incident is therefore very small. (BLS, 1982). Construction accidents are more common and more prevalent than in other industrial sectors. The accident risk factor to be expected during the construction of new towers and relay stations would be about 19.5 incidents per 100 workers, which is about twice the average of the private sector. Both natural and man-induced accidents at sea can be significant. Mitigating actions, such as life lines and flotation devices, fend to reduce the severity of human accidents, but little can be done to mitigate the effects of storms at sea. Increasing the number of microwave towers and other broadcast towers would tend to increase the number of aircraft-related accidents. In the U.S., in particular, with its large number of private pilots and aircraft, this presents an increased risk to life. From 1974 to 1978, there were an average of 4.8 collisions per year with electronics towers of all types, of which 2.8 per year were fatal accidents (NTSB, 1975-79). Statistics are not available to calculate the equivalent aircraft accident rates for other countries in the world, but considering relative populations, numbers of private pilots and aircraft, and projected increase in the number of electronics towers, the implementation of tower networks would result in at least one additional fatality per country per year. If an accident of any kind were to remove a tower from operation, a major disruption to a total communications network would not be anticipated. This would be especially true for any microwave system or boadcast tower, where signals could be rerouted through adjacent or other near-by towers. Submarine cables present somewhat of a different problem in that when a cable fails, or is accidentally cut underwater; the approximate location of the failure must first be determined and then a vessel dispatched to locate the actual failure. This is a time-consuming process because the cable has to be retrieved from the ocean bottom, inspected for damage or other failure indication, repaired, and then relayed on the ocean bottom. If the failure location is not evident the cable must be searched along its entire length until the failed portion is found. Unless alternate cable systems are available for use, the entire communications system associated with that cable is not usable. Cable technology has progressed so that internal diagnostics can generally indicate failures before they occur and can pinpoint their locations, which reduces the potential for complete disruption of the communications network.

5.0 LIST OF CONTRIBUTORS

A summary listing of contributors to this document is presented in Table 10. The Table identifies the contributor, organization, area of expertise, and major area of contribution to this report.

TABLE 10. MAJOR CONTRIBUTORS TO THE GENERIC ENVIRONMENT ASSESSMENT REPORT

Name	Organization	Area of Expertise	Major Area of Contribution
Lew Andrews	NASA/HQ	Environmental Compliance	Review/NEPA
Donald Turner	NASA/HQ	STS Flight Assignments	Review
Corinne Buoni	BCL	Life Sciences	Project Management, Payload Assessment, and Mission Model Development
Eric Rice	BCL	Systems, Management and Safety	Technical Review
Robert Reynolds	BCL	Astronomy and Astrophysics	On-Orbit Debris Hazards
Al Buoni	BCL	Environmental and Health Sciences	Space Shuttle Environmental Effects
Hank Collis	BCL	Space Logistics	STS Requirements/Capabilities; Payload Assesments
Thomas Crabb	BCL	Launch Vehicle and Life Support Systems	ELV/SR Requirements/Capabilities; Payload Assessment
Richard Earhart	BCL	Economics and Physics	Payload Assessment and Benefit Analysis
Rudolfo Vegara	BCL	Aerospace Vehicles/Operations	Payload Assessment
Mary Ann Zanetos	BCL	Environmental and Health Sciences	ELV Environmental Effects
Robert Conlon	BCL	Payload Analysis and Requirements	Mission Model
William Weber	BCL	Launch Vehicle Performance	Payload Launch Vehicle Assignments
George Mourad	BCL	Remote Sensing and Geodesy	Payload Characterization

6.0 REFERENCES

Aviation Week and Space Technology. Survey of Launch Vehicles. (March 14) 1983.

Battison, J. (September) 1982. Telephone Conversation Memorandum: John Battison, Chief Engineer of WOSU-AM-FM-TV, R. W. Earhart, BCL, Columbus, OH.

BCL. (February) 1981. Foreign Space Launch Vehicle Performance Document Report. Prepared for NASA by Battelle Columbus Laboratories, Columbus, OH.

BCL. (June) 1983a. Outside Users Payload Model. Prepared for NASA/Hq by Battelle Columbus Laboratories, Columbus, OH.

BCL. (December) 1983b. Foreign Space Launch Vehicle Performance Document. BCL-NLVP-DD-4(83). Prepared for NASA/Hq by Battelle Columbus Laboratories, Columbus, OH.

BLS. (April) 1982. Occupational Injuries and Illnesses in the United States by Industry, 1980. Bulletin 2130. U.S. Department of Labor, Bureau of Labor Statistics, Washington, DC.

Chobotov, V. A. (February 25) 1978. "Collision Hazards in Space", TR-0081(6790)-1, The Aerospace Corp., El Segundo, CA.

Chobotov, V. A. (August 3-5) 1981. "The Probability of Collision in Space", AAS/AISS Astro-Specialist Conf., pp. 81-148.

Chobotov, V. A. 1982. "Assessment of Satellite Collision Hazards by Simulated Sampling in Space", presented at the Johnson Space Center Orbital Debris Workshop, Houston, TX.

ESA. (February) 1981a. The Ariane-3 Programme. ESA Bulletin.

ESA. (September) 1981b. Specific Data on L03; General Information on Ariane; The Launch Facilities. Prepared for ESA by Ariane L03. Centre National d'Etude Spatiales (CNES).

GDC. (August 2) 1971. Centaur Mission Planner's Guide. Launch Vehicle Program, Aerospace Division, General Dynamics Corporation, San Diego, CA.

GDC. (December) 1977. Standardized Atlas Launch Vehicle System for Orbital Missions. Launch Vehicle Program, Convair Aerospace Division, General Dynamics Corporation, San Diego, CA.

GDC. 1981. Atlas/Centaur/Comstar Launch Operations and Flight Plan. No. GDC-BNZ (69)-007, Launch Vehicle Program, Convair Aerospace Division, General Dynamics Corporation, San Diego, CA.

Griswold, H. R., and R. C. Wilde. 1980. EVA Equipment for Satellite Service. United Technologies Corporation, Hamilton Standard Division, Windsor Locks, CT.

Hughes Aircraft Company. (March) 1982. SBS Phase III Safety Analyses. Hughes Aircraft Company, El Segundo, CA.

Kessler, D. J. and Cour-Palais, B. G. 1978. "Collision Frequency of Artificial Satellites: Creation of a Debris Belt", in Space Systems and Their Interactions With Earth's Space Environment. Vol. 71 of Astronautics and Aeronautics.

Kessler, D. J. (July-August) 1981. "Sources of Orbital Debris and the Projected Environment for Future Spacecraft", Journal of Spacecraft and Rockets, Vol. 18, No. 4, pp. 357-360.

Koller, Jr., A. (June) 1981. Summary of STS-1 Launch Environmental Effects and Follow-on Corrective Actions. NASA/KSC, KSC, FL.

Lee, C. M. (May) 1979. "Get Away Specials," Spaceflight, Vol. 21, No. 5, pp. 197-202.

Martin Marietta. (February) 1974. Mission Planning Guide, Titan IIIC. No. IR-73-1. Martin Marietta Corporation, Denver Division, Denver, CO.

MDAC. (November) 1973. Delta Payload Planner's Guide. Delta Programs, McDonnell Douglas Astronautics Company, Huntington Beach, CA.

MDAC. (June) 1980. Delta Spacecraft Design Restraints. L. C. Raburn, Delta Program, McDonnell Douglas Astronautics Company, Huntington Beach, CA.

NASA/GSFC. (October) 1979. Get Away Special (GAS) Small Self-Contained Payloads Experimenter Handbook. NASA/GSFC, Greenbelt, MD.

NASA/Hq. (July) 1973a. Environmental Statement for the National Aeronautics and Space Administration, Office of Space Science, Launch Vehicle and Propulsion Programs Final Statement. NASA/Hq, Washington, DC.

NASA/Hq. (July) 1973b. Final Environmental Impact Statement for National Aeronautics and Space Administration, Office of Space Science, Sounding Rocket Program. NASA/Hq, Washington, DC.

NASA/Hq. (June) 1977. Space Transportation System User Handbook. NASA/Hq, Washington, DC.

NASA/Hq. (April) 1978. Environmental Impact Statement, Space Shuttle Program Final Statement. NASA/Hq, Washington, DC.

NASA/KSC. (October) 1979. Environmental Impact Statement for the Kennedy Space Center (Final). NASA/KSC, KSC, FL.

NASA/Hq. (June) 1980a. Environmental Assessment on the Chemical Release Module Program. NASA/Hq, Washington, DC.

NASA/Hq. 1980b. Safety Policy and Requirements for Payloads Using the Space Transportation System. NHB 1700.7A. NASA/Hq, Washington, DC.

NASA/Hq. 1980c. Beyond the Atmosphere—Early Years of Space Science. NASA SP 4211. NASA/Hq, Washington, DC.

NASA/Hq. 1981a. Implementing the Provisions of the National Enviromental Policy Act, NHB-8800.11, Change 1. NASA/Hq, Washington, DC.

NASA/Hq. (January) 1981b. Space Shuttle News Reference. 1981-341-570/3256. WSGPO, Washington, DC.

NASA/Hq. (May) 1981c. Expendable Launch Vehicles Program (Code OL). NASA/Hq, OSTA, Washington, DC.

NASA/Hq. (October) 1982. Environmental Assessment of Space Shuttle Payloads and Payload Operations for the Fifth Space Shuttle Launch (STS-5). NASA/Hq, Office of Space Transportation Operations, Washington, DC.

NASA/Hq. (January) 1983a. Environmental Assessment, Space Shuttle Payloads and Payload Operations for the Sixth Space Shuttle Launch (STS-6). NASA/Hq, Office of Space Transportation Operations, Washington, DC.

NASA/Hq. (May) 1983b. Environmental Assessment of Space Shuttle Paylaods and Payload Operations for the Seventh Space Shuttle Launch (STS-7). NASA/Hq, Office of Space Transportation Operations, Washignton, DC.

NASA/Hq. (May) 1983c. Space Transportation System Space Shuttle Payload Flight Assignments. NASA/Hq, STS Customer Services, Washington, DC.

NASA/Hq. (August) 1983d. Environmental Assessment, Space Shuttle Payloads and Payload Operations for the Eighth Space Shuttle Launch (STS-8). NASA/HQ, Office of Space Transportation Operations, Washington, DC.

NASA/Hq. (September) 1983e. Environmental Assessment of Space Shuttle Paylaods and Payload Operations for the Ninth Space Shuttle Launch (STS-9). NASA/Hq, Office of Space Transportation Operations, Washington, DC.

NASA/Hq. 1983f. Planetary Exploration Through the Year 2000. Executive Summary Solar System Exploration Committee of the NASA Advisory Council, Washington, DC.

NASA/Hq. 1983g. Space Station: Support for NASA Goals. NASA/Hq MF 83-2264(1). Washington, DC.

NASA/Hq. (January) 1984a. Environmental Assessment of Space Shuttle Payloads and Payload Operations for the Eleventh Space Shuttle Launch (STS-11). NASA/Hq, Office of Space Transportation Operations, Washington, DC.

NASA/Hq. (March) 1984b. Environmental Assessment of Space Shuttle Operations for STS-41-C. NASA/Hq, Office of Space Transportation Operations, Washingon, DC.

NASA/JPL. (July) 1981. Environmental Impact Statement for Project Galileo—A Review Draft. NASA/NPL, Washington, DC.

NASA/JSC. (July) 1977. Space Transportation System User Handbook. NASA/JSC, Houston, TX.

NASA/JSC. (September) 1980a. Orbiter Mid-deck Payload Provisions Handbook. Revision A. JSC-105. NASA/JSC, Spacecraft Design Division, Crew Station Branch, Houston, TX.

NASA/JSC. (May 15) 1980b. STS and Get Away Special (GAS) Payload Integration Plan. JSC-14021 Revision A. NASA/JSC, Houston, TX.

NASA/JSC. (May) 1983a. Space Shuttle Program Level II Program Definition and Requirements. Space Shuttle System Payload Accommodations. JSC-07700. Volume XIV. Revision H. NASA/JSC, Houston, TX.

NASA/JSC. (May) 1983b. Space Transportation System—EVA Description and Design Criteria. JSC-10615. JSC, Houston, TX.

NASA/KSC. 1978. KSC Safety Practices Handbook. Volumes 1 and 2. KHB 1719.2A. NASA/KSC, KSC, FL.

NASA/KSC. (October) 1979. Environmental Impact Statement for the Kennedy Space Center (Final). NASA/KSC, KSC, FL.

NASA/KSC. 1983a. Launch Site Accommodations Handbook for STS Payloads - K-STSM-14.1, Revision B. NASA/KSC, KSC, FL.

NASA/KSC. 1983b. Payload Accommodations at the Rotating Service Structure. K-STSM-14.10, NASA/KSC, KSC, FL.

NASA/MSFC. (October) 1972. Environmental Statement for George C. Marshall Space Flight Center and Mississippi Test Facility (now National Space Technology Laboratory). Final Statement. NASA/MSFC, Huntsville, AL.

NASA/MSFC. (August) 1973. Final Environmental Impact Statement for the Space Shuttle Main Engine Component and Subsystem Testing. NASA/MSFC, Santa Susana, CA.

NASA/MSFC. (January) 1977. Final Environmental Statement for the Space Shuttle Solid Rocket Motor DDT&E Program at Thiokol Wasatch Division, Promontory, Utah. NASA/MSFC, Washington, DC.

NASA/MSFC/ESA. (May) 1976. Spacelab Payload Accommodation Handbook. NASA/MSFC/ESA, Huntsville, AL.

National Academy of Sciences. 1975. Practical Applications of Space Systems. NASA, Panel on Materials Processing Space. Paper 9 Materials Processing in Space. National Academy of Science, Washignton, DC.

NTSB. 1975-1979. Brief Format Supplemental Issue for 1974-1978 Series Accident Report. National Transportation Safety Board, Washington, DC.

APPENDIX A

SUGGESTED FORMAT FOR SHUTTLE PAYLOAD ENVIRONMENTAL ASSESSMENTS

APPENDIX A

SUGGESTED FORMAT FOR SHUTTLE PAYLOAD ENVIRONMENTAL ASSESSMENTS

The payloads that have been or will be scheduled on the Space Shuttle can be generically described according to the characteristics specified in Section 3.0 of this assessment. Once categorized, the environmental impacts of the paylaods can be determined from the information contained in Section 4.0.

The payload impact assessment process would be assisted by use of the suggested form presented in this appendix. Essential information concerning the type, operation, physical characteristics, crew requirement, safety reviews, and upper stage use for the payload are included on the front of the form. When this information has been recorded, the impacts for the type of payload can be abstracted from Section 4.0 of the Generic Environmental Assessment and entered on the back of the form in the appropriate box in the matrix. Special or unique operations, configurations, and/or requirements can be addressed as well as synergistic effects of the payload on other payloads for a particular flight. The bottom portion of the form includes a certification section and a FONSI approval section. This form could reduce the paperwork flow involved in pre-flight administration, yet it also contains the information that is essential for the environmental assessment decision-making process.

PAYLOAD NAME:

Mission Duration, dy ______

Service Life, yr ______

APPLICATION:

☐ Commercial* ______ ☐ Technology Development* ______

☐ Science* ______ ☐ National Security ☐ Other* ______

ORBITAL OPERATIONS:

☐ Deployment ☐ Service ☐ Deployment, Operation, Retrieval (Single Mission)

☐ Attached ☐ Retrieval

OBJECTIVE:

DESCRIPTION:

PAYLOAD ORBIT CHARACTERISTICS:

Apogee, km ______ Perigee, km ______ Inclination, deg ______

LAUNCH SITE: ☐ ETR ☐ WTR

LAUNCH DATE:

UPPER-STAGE TYPE:

☐ MMS ☐ PAM-A ☐ TOS

☐ IUS ☐ PAM-D ☐ None

☐ CENTAUR ☐ PAM D-II ☐ Other ______

Propellant (Type/Quantity, kg) ______

EQUIPMENT PHYSICAL CHARACTERISTICS:

Location ☐ Middeck ☐ Cargo (Pressurized) ☐ Cargo (Unpressurized)

Overall Dimensions

L, m ______ W, m ______ H, m ______ Stowed

L, M ______ W, m ______ H, m ______ Deployed

Mass, kg** ______

Propellants, Type/Quantity, kg (Except Upper Stages) ______

Hazardous Materials, Type/Quantity, kg (Except Propellants) ______

CREW REQUIREMENTS:

Crew Participation ☐ Yes ☐ No

Major Activity (ies) ______

Extravehicular Activity (EVA) ☐ Yes ☐ No

Purpose ______

HRS/EVA ______

SYSTEM SAFTY CONCERNS: (Major hazards, type of accident; probability of occurrence)

______

______

ALTERNATIVES:

Alternate Launch Vehicle/Launch Site ______

Terrestrial Equivalent ______

DEBRIS GENERATION: (Quantity/Type/Location)

SPECIAL CONSIDERATIONS:

*Specify Particular Application

APPENDIX B

STS MISSION PROFILE AND ALTERNATIVES, 1982-1991
(Excludes Mid-Deck Experiments and Get-Awav-Specials)

FLT LS YR(a)	Payload (Code)(b)	Payload Orbit(a) (km/deg)	Service Life(d) (Y or D)	Mass(e) (kg)	Payload Carrier(f)	Payload Carrier Propellant Type, Quantity(g) (kg)	Alternate Launch Vehicle(h)	Terrestrial Equivalent(i) (Yes/No)
5 K 82	SBS-C(10)	GEO	8-10 Y	4106(1); 1055(3); 560(4)	PAM-D	Solid, 2000	Delta	Yes
	TELESAT-E(10)	GEO	8-10 Y	4106(1); 1055(3); 560(4)	PAM-D	Solid, 2000	Delta	Yes
6 K 83	TDRS-A(10)	GEO	10 Y	21092(1); 17010(3); 2268(4)	IUS-2	Solid, 14742	None	Yes
7 K 83	SPAS-01(9)	Shuttle Orbit (Deploy/Retrieve)	7 D	1800(1)	Free Flyer	Nitrogen, 60(j)	None	No
	OSTA-2(4)	Shuttle Orbit (Attached)	5 D	1800(1)	MPESS	None	None	No
	TELESAT-F(10)	GEO	7-10 Y	4557(1); 567(4)	PAM-D	Solid, 2000	Delta	Yes
	PALAPA B-1(10)	GEO	7-10 Y	4501(1); 638(4)	PAM-D	Solid, 2000	Delta	Yes
8 K 83	PDRS/PFTA(5)	Shuttle Orbit (Attached)	7 D	3856(1)	MPESS	None	None	No
	EOIM(4)	Shuttle Orbit (Attached)	7 D	2427(1)	Pallet	None	None	No
	INSAT 1-B(10)	GEO	7 Y	4423(1); 500(4)	PAM-D	Solid, 2000	Delta	Yes
9 K 83	SPACELAB-1(3)	Shuttle Orbit (Attached)	9 D	14970(1)	LM + IP	None	None	No
10 K 83	DOD 83-1(8)							
11 K 83	PALAPA B-2(10)	GEO	8-10 Y	4502(1); 638(4)	PAM-D	Solid, 2000	Delta	Yes
	WESTAR-VI(10)	GEO	8-10 Y	4482(1); 550(4)	PAM-D	Solid, 2000	Delta	Yes
12 K 83	MSL-1(4)	Shuttle Orbit (Attached)	6 D	2427(1)	MPESS	None	None	No
	TDRS-B(10)	GEO	10 Y	21092(1); 17010(3); 2268(4)	IUS-2	Solid, 14742	T34D/IUS	Yes
13 K 83	LDEF-1(6)	556, 28.5 (Deploy)	1 Y	9979(1)	Free Flyer	None	None	No
	SMM(5)	575, 28.5 (Service)	7 D	4762(1)			None	No
14 K 84	OAST-1(9)	Shuttle Orbit (Deploy/Retrieve)	6 D	1368(1)	MPESS	None	None	No
	LFC-1(4)	Shuttle Orbit (Attached)	7 D	1814(1); 511 (LFC only)	MPESS	None	None	No
	TELESAT-K(10)	GEO	7-10 Y	4345(1); 600(4)	PAM-D	Solid, 2000	Delta	Yes
	SYNCOM IV-1(10)	GEO	10 Y	7829(1); 6849(2); 1311(4)	Unique Stage	Solid, 3300	A/C	Yes

STS MISSION PROFILE AND ALTERNATIVES, 1982-1991
(Excludes Mid-Deck Experiments and Get-Away-Specials)
(Continued)

FLT LS YR(a)	Payload (Code)(b)	Payload Orbit(c) (km/deg)	Service Life(d) (Y or D)	Mass(e) (kg)	Payload Carrier(f)	Payload Carrier Propellant Type, Quantity(g) (kg)	Alternate Launch Vehicle(h)	Terrestrial Equivalent(i) (Yes/No)
15 K 84	GSTAR-A(10)	GEO	10 Y	6123(1); 670(4)	PAM-D	Solid, 2800	Delta	Yes
	TDRS-C(10)	GEO	10 Y	21092(1); 17010(3); 2268(4)	IUS-2	Solid, 14742	None	Yes
16 K 84	SPARTAN-1(9)	Shuttle Orbit (Deploy/Retrieve)	7 D	1445(1)	MPESS	None	None	No
	TELSTAR 3-C(10)	GEO	10 Y	4535(1); 653(4)	PAM-D	Solid, 2000	Delta	Yes
	SBS-D(10)	GEO	8-10 Y	4539(1); 550(4)	PAM-D	Solid, 2000	Delta	Yes
	SYNCOM IV-2(10)	GEO	10 Y	7829(1); 1311(4)	Unique Stage	Solid, 3300	A/C	Yes
17 K 84	OSTA-3 (Shuttle Radar Lab)(4)	Shuttle Orbit (Attached)	7 D	3628(1)	1P-MPESS	None	None	No
	ERBS(9)	600, 40	2 Y	2112(1)	PAM-D(j)	Solid, 2000	Delta	No
18 K 84	SPACELAB-3(3)	Shuttle Orbit (Attached)	7 D	5174(1)	LM + MPESS	None	None	No
19 K 84	MSL-2(4)	Shuttle Orbit (Attached)	7 D	1894(1)	MPESS	None	None	No
	TELESAT-H(10)	GEO	8-10 Y	4559(1); 600(4)	PAM-D	Solid, 2000	Delta	Yes
	ARABSAT(10)	GEO	7-10 Y	4608(1); 1260(3); 678(4)	PAM-D	Solid, 2000	Delta	Yes
20 K 84	REFLIGHT OPPORTUNITY							
21 K 84	DOD 84-1(8)							
22 K 85	SYNCOM IV-3(10)	GEO	10 Y	7829(1); 1311(4)	Unique Stage	Solid, 3300	A/C	Yes
23 K 85	SPACELAB-2(3)	Shuttle Orbit (Attached)	7 D	15245(1)	IG + 3P	None	None	No
24 K 85	LDEF-1(5)	Shuttle Orbit (Retrieve)	3 D	0(1)	FSS	None	None	No

STS MISSION PROFILE AND ALTERNATIVES, 1982-1991
(Excludes Mid-Deck Experiments and Get-Away-Specials)
(Continued)

FLT LS YR(a)	Payload (Code)(b)	Payload Orbit(c) (km/deg)	Service Life(d) (Y or D)	Mass(e) (kg)	Payload Carrier(f)	Payload Carrier Propellant Type, Quantity(g) (kg)	Alternate Launch Vehicle(h)	Terrestrial Equivalent(i) (Yes/No)
25 K 85	OAST-2(9)	Shuttle Orbit (Deploy/Retrieve)	6 D	3629(1)	Pallet	None	None	No
	RCA-H(10)	GEO	8-10 Y	7212(1); 1500(3); 800(4)	PAM-D2	Solid, 3250	A/C	Yes
	TELSTAR 3-D(10)	GEO	10 Y	4535(1); 653(4)	PAM-D	Solid, 2000	Delta	Yes
	MEXSAT-A(10)	GEO	9-10 Y	4627(1); 560(4)	PAM-D	Solid, 2000	Delta	Yes
26 K 85	SPACELAB D-1(3)	Shuttle Orbit (Attached)	7 D	15599(1)	LM	None	None	No
27 K 85	EOS-1(4)	Shuttle Orbit	7 D	2268(1)	Free Flyer	None	None	No
	AUSSAT-1(10)	GEO	7-10 Y	4539(1); 600(4)	PAM-D	Solid, 2000	Delta	Yes
	GSTAR-C(10)	GEO	10 Y	6092(1); 670(4)	PAM-D2	Solid, 3250	A/C	Yes
	SYNCOM IV-4(10)	GEO	10 Y	7829(1); 1311(4)	Unique Stage	Solid, 3300	A/C	Yes
28 K 85	DOD 85-1(8)							
29 K 85	SPACENET-C(10)	GEO	8-10 Y	4567(1); 1142(8); 500(4)	PAM-D	Solid, 2000	Delta	Yes
	RCA-M(10)	GEO	10 Y	7212(1); 1500(3); 800(4)	PAM-D2	Solid, 3250	A/C	Yes
	GALAXY(10)	GEO	9-10 Y	4536(1); 476(4)	PAM-D	Solid, 2000	Delta	Yes
30 K 85	AMERSAT-A(10)	GEO	10 Y	4566(1); 667(4)	PAM-D	Solid, 2000	Delta	Yes
	MEXSAT-B(10)	GEO	9-10 Y	4627(1); 560(4)	PAM-D	Solid, 2000	Delta	Yes
	WESTAR-VII(10)	GEO	10 Y	4585(1); 550(4)	PAM-D	Solid, 2000	Delta	Yes
31 K 85	MSL-3(4)	Shuttle Orbit (Attached)	7 D	2427(1)	MPESS	None	None	No
	SPARTAN-2(9)	Shuttle Orbit (Deploy/Retrieve)	7 D	1445(1)	MPESS	None	None	No
	AUSSAT-2(10)	GEO	7-10 Y	4536(1); 600(4)	PAM-D	Solid, 2000	Delta	Yes
	DOD PAM-1(12)	20000, 63	10 Y	5443(1)	PAM-D	Solid, 2000	Delta	Yes
1 V 85	DOD 85-2(8)							
32 K 85	SPACELAB-4(3)	Shuttle Orbit (Attached)	7 D	12675(1)	LM	None	None	No

STS MISSION PROFILE AND ALTERNATIVES, 1982-1991
(Excludes Mid-Deck Experiments and Get-Away-Specials)
(Continued)

FLT LS YR[(a)]	Payload (Code)[(b)]	Payload Orbit[(c)] (km/deg)	Service Life[(d)] (Y or D)	Mass[(e)] (kg)	Payload Carrier[(f)]	Payload Carrier Propellant Type, Quantity[(g)] (kg)	Alternate Launch Vehicle[(h)]	Terrestrial Equivalent[(i)] (Yes/No)
33	EOS-2(4)	Shuttle Orbit	7 D	3856(1)	Free Flyer	None	None	No
K	INSAT 1-C(10)	GEO	8-10 Y	4423(1); 635(4)	PAM-D	Solid, 2000	Delta	Yes
86	STC DBS-A(10)	GEO	7-10 Y	5443(1); 650(4)	PAM-D	Solid, 2000	Delta	Yes
	SPACENET-D(10)	GEO	8-10 Y[(j)]	4567(1); 1142(3); 500(4)	PAM-D	Solid, 2000	Delta	Yes
34 K 86	SPACE TELESCOPE(9)	600, 28.8	15 Y	12565(1)	Free Flyer (OMS Kit)	Shuttle, Biprop.	None	No
35	ASTRO-1(4)	Shuttle Orbit (Attached)	7 D	6804(1); 1500 (expts.)	IG + 2P	None	None	No
K 86	CRRES(9)	250-1200, 57	0.5 Y	5061(1)	Free Flyer + KM	Solid, 245	Delta	No
36	USAT-1(10)	GEO	-	6033(1); 750(4)	PAM-D2	Solid, 3250	A/C	Yes
K 86	INTELSAT VI-1(10)	GEO	10 Y	15967(1); 2000(4)	IUS/SRM-1	Solid, 9707	T34D/IUS/SRM-1; Ar-4	Yes
37 K 86	ISPM(7)	Heliocentric Orbit	4.5 Y	450(4)	Centaur	LO_2/LH_2, 13600	None	No
38 K 86	GALILEO(7)	Jupiter Orbit	5 Y	21484(1); 900(4)	Centaur	LO_2/LH_2,13600	A/C	No
39	RCA-K(10)	GEO	10 Y	4038(1); 500(4)	PAM-D	Solid, 2000	Delta	Yes
K	STC DBS-B(10)	GEO	7 Y	5443(1); 650(4)	PAM-D	Solid, 2000	Delta	Yes
86	DOD PAM-2(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
	RCA DBS-1(10)	GEO	10 Y	7756(1); 700(4)	PAM-D2[(j)]	Solid, 3250	A/C	Yes
40 K 86	DOD 86-1(8)							
41	MSL-4(4)	Shuttle Orbit (Attached)	6 D	1894(1)	MPESS	None	None	No
K	UNISAT-1(10)	GEO	8-10 Y[(j)]	6600(1); 850(4)	PAM-D2	Solid, 3250	A/C	Yes
86	INTELSAT VI-2(10)	GEO	10 Y	15967(1); 2000(4)	IUS/SRM-1	Solid, 9707	T34D/IUS/SRM-1; Ar-4	Yes

STS MISSION PROFILE AND ALTERNATIVES, 1982-1991
(Excludes Mid-Deck Experiments and Get-Away-Specials)
(Continued)

FLT LS YR(a)	Payload (Code)(b)	Payload Orbit(c) (km/deg)	Service Life(d) (Y or D)	Mass(e) (kg)	Payload Carrier(f)	Payload Carrier Propellant Type, Quantity(g) (kg)	Alternate Launch Vehicle(h)	Terrestrial Equivalent(i) (Yes/No)
42 K 86	DOD 86-2(8)							
43 K 86	AMERSAT-B(10)	GEO	8-10 Y(j)	4567(1); 667(4)	PAM-D	Solid, 2000	Delta	Yes
	UNISAT-2(10)	GEO	8-10 Y(j)	6600(1); 850(4)	PAM-D2	Solid, 3250	A/C	Yes
	WESTAR VIII(10)	GEO	10 Y	4585(1); 550(4)	PAM-D	Solid, 2000	Delta	Yes
	DOD PAM-3(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
44 K 86	STC DBS-C(10)	GEO	7-10 Y	5443(1); 650(4)	PAM-D	Solid, 2000	Delta	Yes
	USAT-2(10)	GEO	8-10 Y(j)	6033(1); 750(4)	PAM-D2	Solid, 3250	A/C	Yes
	RCA DBS-2(10)	GEO	10 Y	7756(1); 700(4)	PAM-D2(j)	Solid, 3250	A/C	Yes
45 K 86	ASTRO-2(4)	Shuttle Orbit (Attached)	7 D	6804(1)	IG + 2P	None	None	No
	IRIS(9)	160,28.5	1 D	1633(1)	None	None	Delta	No
	ORION-A(10)	GEO	8-10 Y(j)	4627(1); 550(4)	PAM-D	Solid, 2000	Delta	Yes
46 K 86	EOM-1(4)	Shuttle Orbit (Attached)	7 D	3856(1)	IG + 1P	None	None	No
	STC DBS-D(10)	GEO	7-10 Y	5443(1); 650(4)	PAM-D	Solid, 2000	Delta	Yes
	DOD PAM-4(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
47 K 86	UNISAT-3(10)	GEO	8-10 Y(j)	6577(1); 850(4)	PAM-D2	Solid, 3250	A/C	Yes
	DBS LUX-A(10)	GEO	7-10 Y	5058(1); 600(4)	PAM-D	Solid, 2000	Delta	Yes
	ORION-B(10)	GEO	8-10 Y(j)	4627(1); 550(4)	PAM-D	Solid, 2000	Delta	Yes
	DOD PAM-5(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
2 V 86	OSTA-5(4)	Shuttle Orbit (Attached)	6 D	1905(1)	Pallet	None	None	No
	LANDSAT(5)	578,98.2	1 D	5040(1)	MMS	Hydrazine, 75	None	No
3 V 86	DOD 86-3(8)							
48 K 87	MSL-5(4)	Shuttle Orbit (Attached)	6 D	1894(1)	MPESS	None	None	No
	AMERSAT-C(10)	GEO	8-10 Y(j)	4567(1); 667(4)	PAM-D	Solid, 2000	Delta	Yes
	INTELSAT VI-3(10)	GEO	10 Y	15967(1); 2000(4)	IUS/SRM-1	Solid, 9707	T34D/IUS/SRM-1; Ar-4	Yes

STS MISSION PROFILE AND ALTERNATIVES, 1982-1991
(Excludes Mid-Deck Experiments and Get-Away-Specials)
(Continued)

FLT LS YR(a)	Payload (Code)(b)	Payload Orbit(c) (km/deg)	Service Life(d) (Y or D)	Mass(e) (kg)	Payload Carrier(f)	Payload Carrier Propellant Type, Quantity(g) (kg)	Alternate Launch Vehicle(h)	Terrestrial Equivalent(i) (Yes/No)
49 K 87	REFLIGHT OPPORTUNITY							
50	TELESAT-J(10)	GEO	10 Y	6237(1); 800(4)	PAM-D2	Solid, 3250	A/C	Yes
K	STC DBS-E(10)	GEO	7-10 Y	5443(1); 650(4)	PAM-D	Solid, 2000	Delta	Yes
87	ORION-C(10)	GEO	8-10 Y(j)	4626(1); 550(4)	PAM-D	Solid, 2000	Delta	Yes
	SBS-E(10)	GEO	8-10 Y(j)	4359(1); 550(4)	PAM-D	Solid, 2000	Delta	Yes
51	TSS-1(4)	Shuttle Orbit (Attached)	1-6 D	3628(1)	Pallet	None	None	No
K	USAT-3(10)	GEO	8-10 Y(j)	6033(1); 750(4)	PAM-D2	Solid, 3250	A/C	Yes
87	DOD PAM-6(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
	SATCOL-1(10)	GEO	7-10 Y	4589(1); 550(4)	PAM-D	Solid, 2000	Delta	Yes
52 K 87	SPACELAB D-4(3)	Shuttle Orbit (Attached)	7 D	14969(1)	IG + 4P	None	None	No
53	MSL-6(4)	Shuttle Orbit (Attached)	6 D	1894(1)	MPESS	None	None	No
K	SPARTAN-3(9)	Shuttle Orbit (Deploy/Retrieve)	7 D	1447(1)	MPESS	None	None	No
87	EURECA-1(9)	Shuttle Orbit (Deploy)	1 Y	3500(1)	Free Flyer	None	None	No
	DOD PAM-7(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
	RCA DBS-3(10)	GEO	8-10 Y(j)	7756(1); 700(4)	PAM-D2(j)	Solid, 3250	A/C	Yes
54 K 87	SPACELAB 8(3)	Shuttle Orbit (Attached)	7 D	14969(1)	LM + 1P	None	None	No
55	DOD PAM-8(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
K 87	LDEF-2(6)	556, 28.5 (Deploy)	1 Y	9979(1)	Free Flyer	None	None	No
56	RCA-I(10)	GEO	1 Y	7212(1); 1500(3); 800(4)	PAM-D2	Solid, 3250	A/C	Yes
K	STC DBS-F(10)	GEO	8-10 Y(j)	5443(1); 650(4)	PAM-D	Solid, 2000	Delta	Yes
87	INTELSAT VI-4(10)	GEO	10 Y	15967(1); 2000(4)	IUS/SRM-1	Solid, 9707	T34D/IUS/SRM-1; Ar-4	Yes
57	ASTRO-3(4)	Shuttle Orbit (Attached)		15967(1)	IG + 2P	None	None	No
K	ORION-D(10)	GEO	8-10 Y(j)	4627(1); 550(4)	PAM-D2	Solid, 3250	Delta	Yes
87	DOD PAM-9(12)	20000, 63	10 Y	4553(1)	PAM-D	Solid, 2000	Delta	Yes

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FLT LS YR(a)	Payload (Code)(b)	Payload Orbit(c) (km/deg)	Service Life(d) (Y or D)	Mass(e) (kg)	Payload Carrier(f)	Payload Carrier Propellant Type, Quantity(g) (kg)	Alternate Launch Vehicle(h)	Terrestrial Equivalent(i) (Yes/No)
58 K 87	ROSAT(12)	450, 57	8-10 Y(j)	2300(1)	Unique Stage	Solid, 2000(j)	Delta	No
59 K 87	DOD 87-1 (8)							
60 K 87	DOD 87-2 (8)							
61 K 87	OAST-3(9)	Shuttle Orbit (Deploy/Retrieve)	6 D	2263(1)	MPESS	None	None	No
	EUVE(9)	550, 28.5 (Deploy)	1 Y	2498(1)	Small Propul. Sys.	Hydrazine	Delta	No
	DOD PAM-10(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
	EURECA-1(5)	Shuttle Orbit (Retrieve)	1 D	45(4)	Free Flyer	None	None	No
62 K 87	MSL-7(4)	Shuttle Orbit (Attached)	6 D	1898(1)	MPESS	None	None	No
	GSTAR-1X(10)	GEO	10 Y	6092(1); 670(4)	PAM-D2	Solid, 3250	A/C	Yes
	INTELSAT VI-5(10)	GEO	10 Y	15967(1); 2000(4)	IUS/SRM-1	Solid, 9707	T34D/IUS/SRM-1; Ar-4	Yes
63 K 87	EOM-2(4)	Shuttle Orbit (Attached)	7 D	3855(1)	IG + 1P	None	None	No
	TSS-2(4)	Shuttle Orbit	2-7 D	3628(1)	Pallet	None	None	No
	DOD PAM-11(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
	RCA DBS-4(10)	GEO	10 Y	7756(1); 700(4)	PAM-D2(j)	Solid, 3250	A/C	Yes
64 K 87	DOD PAM-12(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
	SATCOL-2(10)	GEO	7-10 Y	4589(1); 550(4)	PAM-D	Solid, 2000	Delta	Yes
65 K 87	DOD 87-3(8)							
66 K 87	REFLIGHT OPPORTUNITY							

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FLT LS YR[a]	Payload (Code)[b]	Payload Orbit[c] (km/deg)	Service Life[d] (Y or D)	Mass[e] (kg)	Payload Carrier[f]	Payload Carrier Propellant Type, Quantity[g] (kg)	Alternate Launch Vehicle[h]	Terrestrial Equivalent[i] (Yes/No)
4 V 87	DOD 87-4(8)							
5 V 87	OSTA-7(4) Commercial Landsat(11)	Shuttle Orbit (Attached) Sun Synchronous	7 D 5 Y	1905(1) 7258(1)	Pallet Unique Stage	None Solid, 2000[j]	None Delta	No No
6 V 87	DOD 87-5(8)							
7 V 87	DOD 87-6(8)							
8 V 87	REFLIGHT OPPORTUNITY							
67 K 88	DOD PAM-13(12) INTELSAT VI-6(10)	20000, 63 GEO	10 Y 10 Y	5443(1) 15967(1); 2000(4)	PAM-D2 IUS/SRM-1	Solid, 3250 Solid, 9707	Delta T34D/IUS/SRM-1; Ar-4	Yes Yes
68 K 88	SPACELAB-J(3)	Shuttle Orbit (Attached)	7 D	15970(1)	LM + 1P	None	None	No
69 K 88	OSTA-9(4) DOD PAM-14(12) ABCI-1(10)(j)	Shuttle Orbit (Attached) 20000, 63 GEO	7 D 10 Y 10 Y	1905(1) 5443(1) 5000(1); 550(4)[j]	Pallet PAM-D2 PAM-D	None Solid, 3250 Solid, 2000	None Delta Delta	No Yes Yes
70 K 88	DOD 88-1(8)							
71 K 88	OSS-2(4) GRO(9)	Shuttle Orbit (Attached) 400, 28.5 (Deploy)	7 D[j] 2 Y	6804(1) 14093(1)	1G + 2P TMS	None Hydrazine[j], 2275	None None	No No

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(Continued)

FLT LS YR[a]	Payload (Code)[b]	Payload Orbit[c] (km/deg)	Service Life[d] (Y or D)	Mass[e] (kg)	Payload Carrier[f]	Payload Carrier Propellant Type, Quantity[g] (kg)	Alternate Launch Vehicle[h]	Terrestrial Equivalent[i] (Yes/No)
72	MSL-8(4)	Shuttle Orbit (Attached)	6 D	1893(1)	MPESS	None	None	No
K	TSS-3(4)	Shuttle Orbit (Attached)	7 D	363(1)	Pallet	None	None	No
88	DOD PAM-15(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
	RCA DBS-5(10)	GEO	10 Y	7756(1); 700(4)	PAM-D2	Solid, 3250	A/C	Yes
73	DBS LUX-B(10)	GEO	7-10 Y	5057(1); 600(4)	PAM-D	Solid, 2000	Delta	Yes
K	TELESAT-K(10)	GEO	8-10 Y	6237(1); 800(4)	PAM-D2	Solid, 3250	A/C	Yes
88	LDEF-2(5)	Shuttle Orbit (Retrieve)	1 D	0(1)	Free Flyer	None	None	No
74	SPACELAB-10(3)	Shuttle Orbit (Attached)	7 D	14968(1)	LM + 1P	None	None	No
K								
88								
75	Space Plasma Lab(4)	Shuttle Orbit (Attached)	7-9 D	3856(1)	IG + 1P	None	None	No
K	ACTS(9)	GEO	8-10	650(4)(j)	PAM-D	Solid, 2000	Delta	No
88	DOD PAM-16(12)	20000, 63	10	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
76	DOD 88-2(8)							
K								
88								
77	REFLIGHT OPPORTUNITY							
K								
88								
78	SBTS-A3(10)	GEO	8-10 Y(j)	4627(1); 650(4)	PAM-D	Solid, 2000	Delta	Yes
K	AUSSAT-3(10)	GEO	7-10 Y	4536(1); 600(4)	PAM-D	Solid, 2000	Delta	Yes
88	DOD PAM-17(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
79	DOD PAM-18(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
K	INTELSAT VI-7(10)	GEO	10 Y	15967(1); 2000(4)	IUS/SRM-1	Solid, 9707	T34D/IUS/SRM-1; Ar-4	Yes
88								
80	DOD 88-3(8)							
K								
88								
81	TSS-4(4)	Shuttle Orbit (Attached)	7 D	3629(1)	Pallet	None	None	No
K	DOD PAM-19(12)	20000, 63	10 Y	5443(1)	PAM-D2	Solid, 3250	Delta	Yes
88	RAINBOW-1(10)	GEO	10 Y	5000(1)(j); 650(4)	PAM-D	Solid, 2000	Delta	Yes

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FLT IS YR[a]	Payload (Code)[b]	Payload Orbit[c] (km/deg)	Service Life[d] (Y or D)	Mass[e] (kg)	Payload Carrier[f]	Payload Carrier Propellant Type, Quantity[g] (kg)	Alternate Launch Vehicle[h]	Terrestrial Equivalent[i] (Yes/No)
9 V 88	DOD 88-4(8)							
10 V 88	DOD 88-5(8)							
11 V 88	DOD 88-6(8)							
12 V 88	NOSS-1(Equiv)(11)	700, 87 (Deploy)	3 Y	3816(4)	TMS	Hydrazine, 2275	Delta	No
	MAPSAT(11)	919, 60	10 Y	1400(4)	MMS(j)	Hydrazine, 75	Delta	Yes
13 V 88	NOSS-2(Equiv)(11)	700, 87 (Deploy)	3 Y	3814(4)	TMS	Hydrazine, 2275	Delta	No
	BRAZIL ERS(11)	Sun Synchronous	2 Y	1300(4)(j)	MMS(j)	Hydrazine, 75	Scout	Yes
14 V 88	SOT-1(4)	Shuttle Orbit (Attached)	7-10 D	3100(4)	IPS	None	None	No
	Lower Atm. Res. Sat(9)	780, 60-92	2 Y	2000(4)	MMS(j)	Hydrazine, 75	Delta	No
82 K 88	DOD PAM-20(12)	20000, 63	10 Y	4553(1)	PAM-D2	Solid, 3250	Delta	Yes
	SPAS-02(9)	Shuttle Orbit (Deploy/Retrieve)	7 D	4800(1)	Free Flyer	Nitrogen, 60(j)	None	No
83 K 88	DOD PAM-21(12)	20000, 63	10 Y	4553(1)	PAM-D2	Solid, 3250	Delta	Yes
	ITALSAT-3(10)	GEO	5 Y	690(4)	PAM-D2	Solid, 3250	Delta	Yes
	EURECA-2(9)	Shuttle Orbit (Deploy)	7 D	1497(4)	Free Flyer	None	None	No
84 K 89	TELESAT-L(10)	GEO	10 Y	6237(1); 800(4)	PAM-D2	Solid, 3250	A/C	Yes
	LSAT-1(10)	GEO	7 Y	2415(3)	PAM-D2	Solid, 3250	Ar-3	Yes
	Solar Probe(7)	Heliocentric Orbit with Perihelion at 4R Sun	5 Y	1500(4)	IUS-Twin	Solid, 19404	None	No
85 K 89	REFLIGHT OPPORTUNITY							

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(Continued)

FLT LS YR(a)	Payload (Code)(b)	Payload Orbit(c) (km/deg)	Service Life(d) (Y or D)	Mass(e) (kg)	Payload Carrier(f)	Payload Carrier Propellant Type, Quantity(g) (kg)	Alternate Launch Vehicle(h)	Terrestrial Equivalent(i) (Yes/No)
86 K 89	DOD 89-1(8)							
87 K 89	DOD 89-2(8)							
88 K 89	SPAS-03(9)	Shuttle Orbit (Deploy/Retrieve)	7 D	1814(1)	Free Flyer	Nitrogen, 60(j)	None	No
	DBS-B-1(10)	GEO	7-10 Y	1050(4)	PAM-A	Solid, 3450	A/C	Yes
	HITCHHIKER-1(4)	Shuttle Orbit (Attached)	7 D	2268(1)	None	None	None	No
	ABCI-2(10)(j)	GEO	10 Y	5000(1)(j); 550(4)	PAM-D(j)	Solid, 2000	Delta	Yes
90 K 89	DOD PAM-22(12)	20000, 63	10 Y	4553(1)	PAM-D	Solid, 2000	Delta	Yes
	ITALSAT-4(10)	GEO	5 Y	690(4)	PAM-D2(j)	Solid, 3250	Delta	Yes
91 K 89	DOD PAM-23(12)	20000, 63	10 Y	4553(1)	PAM-D	Solid, 2000	Delta	Yes
	GRO(5)	Shuttle Orbit (Retrieve)	7 D	3430(1)	TMS	Hydrazine, 2275	None	No
92 K 89	DOD PAM-24(12)	20000, 63	10 Y	4553(1)	PAM-D	Solid, 2000	Delta	Yes
	OCEAN CIRCULATION MISSION(9)	1300, 65	5 Y	1600(1)	Unknown	Unknown	None	No
93 K 89	INTELSAT VI-8(10)	GEO	10 Y	15967(1); 2000(4)	IUS/SRM-1	Solid, 9707	T34D/IUS/SRM-1; Ar-4	Yes
	ARGENTINA(10)	GEO	10 Y	5000(1); 560(4)	PAM-D	Solid, 2000	Delta	Yes
94 K 89	SBTS-A4(10)	GEO	8-10 Y	4627(1); 650(4)	PAM-D(j)	Solid, 2000	Delta	Yes
	HIGH RESO. X- + GAMMA-RAY SPECTR(4)	Shuttle Orbit (Attached)(j)	7 D	1768(1)	None	None	None	No
95 K 89	INSAT 1-I(10)	GEO	8-10 Y	4423(1); 500(4)	PAM-D	Solid, 2000	Delta	Yes
	DBS-B-2(10)	GEO	7-10 Y	1050(4)	PAM-A	Solid, 3450	A/C	Yes

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FLT LS YR(a)	Payload (Code)(b)	Payload Orbit(c) (km/deg)	Service Life(d) (Y or D)	Mass(e) (kg)	Payload Carrier(f)	Payload Carrier Propellant Type, Quantity(g) (kg)	Alternate Launch Vehicle(h)	Terrestrial Equivalent(i) (Yes/No)
96 K 89	EOS-3(9)	Shuttle Orbit (Deploy/Retrieve)	7 D	14515(1)	Free Flyer	None	None	No
97 K	EOS-4(9)	Shuttle Orbit (Deploy/Retrieve)	7 D	14515(1)	Free Flyer	None	None	No
98 K	CAN DBS-1(10) LARGE AREA MOD. ARRAY X-RAY TELESC.(9)	GEO 400, 28.5	7-10 Y 2 Y	2263(3); 1050(4) 9516(1)	PAM-A(j) MMS(j)	Solid, 3450 Hydrazine, 75	A/C None	Yes No
99 K 89	MSL-9(4) DBS-B-3(10) AMS(10) EURECA-2(5)	Shuttle Orbit (Attached) GEO GEO Shuttle Orbit (Retrieve)	7 D 7-10 Y 9-10 Y 10 Y	1893(1) 1050(4) 7000(1); 500(4)(j) 45(1)	MPESS PAM-A PAM-D2 Free Flyer	None Solid, 3450 Solid, 3250 None	None A/C A/C None	No Yes Yes No
100 K 89	CAN DBS-2(10) MSL-10(4) DBS-C-1(10)	GEO Shuttle Orbit (Attached) GEO	7-10 Y 7 D 7-10 Y	2268(3); 1050(4) 1893(1) 1050(4)	PAM-A(j) MPESS PAM-A(j)	Solid, 3450 None Solid, 3450	A/C None A/C	Yes No Yes
101 K 89	DBS-B-4(10) DBS-C-2(10)	GEO GEO	7-10 Y 7-10 Y	1050(4) 1050(4)	PAM-A(j) PAM-A(j)	Solid, 3450 Solid, 3450	A/C A/C	Yes Yes
15 V 89	DOD 89-3(8)							
16 V 89	DOD 89-4(8)							
17 V 89	BRAZIL ERS F/O-1(11) ADV. TIROS-1(11)	Sun Synchronous Sun Synchronous	2 Y 2 Y	1800(4) 1819(1)	MMS(j) MMS(j)	Hydrazine, 75 Hydrazine, 75	Delta Delta	Yes Yes
18 V 89	MAG. FIELD SURVEY B(11) COBE(9)	300, 97 (Deploy) 900, Polar Orbit (Deploy)	5 Y 1 Y	5000(4) 2948(1); 1200(4)	Free Flyer MMS(j)	None Hydrazine, 75	None None	No No

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FLT LS YR[a]	Payload (Code)[b]	Payload Orbit[c] (km/deg)	Service Life[d] (Y or D)	Mass[e] (kg)	Payload Carrier[f]	Payload Carrier Propellant Type, Quantity[g] (kg)	Alternate Launch Vehicle[h]	Terrestrial Equivalent[i] (Yes/No)
19 V 89	LIDAR MONIT. OF AIR QUALITY(4)	Shuttle Orbit (Attached)	7-10 D	1360(1)	None	None	None	No
	OER-1(11)	Various	3 Y	7258(1); 1700(4)[j]	MMS[j]	Hydrazine, 900-9700	Delta	No
	NOSS-1(Equiv)(5)	Shuttle Orbit (Retrieve)	7 D	3430(1)	TMS	Hydrazine, 2275	None	No
20 V 89	ADV. OP. MET. SYS.(11)	833, 99	2 Y	1100(1)	Unknown	Unknown	Delta	Yes
	NOSS-2(Equiv)(5)	Shuttle Orbit (Retrieve)	7 D	3430(1)	TMS	Hydrazine, 2275	None	No
102 K 90	TELESAT M(10)	GEO		6237(1); 800(4)	PAM-D2	Solid, 3250	A/C	Yes
	MSL-11(4)	Shuttle (Attached)	7 D	1893(1)	MPESS	None	None	No
	VERY LONG BASELINE RADIO INTER.(9)	400-5000, 45 (Deploy)	2 Y	16000(1)[j]	MMS[j]	Hydrazine, 75	None	No
103 K 90	REFLIGHT OPPORTUNITY							
104 K 90	DOD 90-1(8)							
105 K 90	DOD 90-2(8)							
106 K 90	SIRTF-1(4)	Shuttle Orbit (Attached)	10 D	6800(1)	IG + 2P	None	None	No
	SPAS-04(9)	Shuttle Orbit (Deploy/Retrieve)	7 D	1088(1)	Free Flyer	Nitrogen, 60[j]	None	No
107 K 90	OPMET-1(11)	GEO	4 Y	698(3); 351(4)	PAM-D (Offloaded)	Solid, 1400	Delta	Yes
	INSAT F/O(10)	GEO	8 Y	4500(1); 550(4)[j]	PAM-D	Solid, 2000	Delta	Yes
	MSL-12(4)	Shuttle Orbit (Attached)	7 D	1893(1)	MPESS	None	None	No
108 K 90	EOS-5(9)	Shuttle Orbit (Deploy/Retrieve)	7 D	14515(1)	Free Flyer	None	None	No

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FLT LS YR[a]	Payload (Code)[b]	Payload Orbit[c] (km/deg)	Service Life[d] (Y or D)	Mass[e] (kg)	Payload Carrier[f]	Payload Carrier Propellant Type, Quantity[g] (kg)	Alternate Launch Vehicle[h]	Terrestrial Equivalent[i] (Yes/No)
109	INTELSAT VI-9(10)	GEO	10 Y	15967(1); 2000(4)	IUS/SRM-1	Solid, 9707	T34D/IUS/SRM-1; Ar-4	Yes
K	SABS(10)	GEO	10 Y	1050(4)	PAM-A[j]	Solid, 3450	A/C	Yes
90								
110	INTELSAT VI-10(10)	GEO	10 Y	15967(1); 2000(4)	IUS/SRM-1	Solid, 9707	T34D/IUS/SRM-1; Ar-4	Yes
K	MOBILSAT-1(10)	GEO	10 Y	4600(1)[j]; 550(4)	PAM-D	Solid, 2000	Delta	Yes
90								
111	EURECA-3(9)	Shuttle Orbit (Deploy)	1 Y	3500(1)	Free Flyer	None	None	No
K	INTELSAT VI-A-1(10)	GEO	10 Y	15967(1); 2000(4)	IUS/SRM-1	Solid, 9707	T34D/IUS/SRM-1; Ar-4	Yes
90	MOBILSAT-2(10)	GEO		4600(1)[j]; 550(4)	PAM-D	Solid, 2000	Delta	Yes
112	INTELSAT VI-A-2(10)	GEO	10 Y	15967(1); 2000(4)	IUS/SRM-1	Solid, 9707	T34D/IUS/SRM-1; Ar-4	Yes
K	RAINBOW-2(10)	GEO	10 Y	5000(1)[j]; 650(4)	PAM-D	Solid, 2000	Delta	Yes
90								
113	SATCOM F/O-1(10)	GEO	10 Y	7000(1); 800(4)[j]	PAM-D[j]	Solid, 2800	A/C	Yes
K	HITCHHIKER-2(4)	Shuttle Orbit (Attached)	7 D	2268(1)	None	None	None	No
90	NATIONAL EXCH.(10)	GEO	10 Y	5000(1); 550(4)[j]	PAM-D[j]	Solid, 2000	Delta	Yes
114	EOS-6	Shuttle Orbit (Deploy/Retrieve)	7 D	19051(1)	Free Flyer	None	None	No
K	CAN DBS-3(10)	GEO	7-10 Y	2268(3); 1050(4)	PAM-A[j]	Solid, 3450	A/C	Yes
90	X-RAY OBS(9)	400, 28.5	2 Y	300-3500(4)	MMS	Hydrazine, 2400	None	No
115	DBS-B-5(10)	GEO	7-10 Y	1050(4)[j]	PAM-A	Solid, 3450	A/C	Yes
K	OPEN-I EML(9)	Eccentric Equa., Apogee, 12 Re	4 Y	1000(1)	PAM-A	Solid, 3450; Hydrazine, 500	A/C	No
90	DOD PAM-25(12)	20000, 63	10 Y	4553(1)	PAM-D2	Solid, 3250	Delta	Yes
116	DBS-B-6(10)	GEO	7-10 Y	1050(4)[j]	PAM-A	Solid, 3450	A/C	Yes
K	LDEF-3(6)	Shuttle Orbit (Deploy)	1 Y	9979(1)	Free Flyer	None	None	No
90								
117	DBS-C-3(10)	GEO	7-10 Y	1050(4)[j]	PAM-A	Solid, 3450	A/C	Yes
K	MSL-13(4)	Shuttle	7 D	1893(1)	MPESS	None	None	No
90	DOD PAM-26(12)	20000, 63	10 Y	4553(1)	PAM-D2	Solid, 3250	Delta	Yes

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(Continued)

FLT LS YR(a)	Payload (Code)(b)	Payload Orbit(c) (km/deg)	Service Life(d) (Y or D)	Mass(e) (kg)	Payload Carrier(f)	Payload Carrier Propellant Type, Quantity(g) (kg)	Alternate Launch Vehicle(h)	Terrestrial Equivalent(i) (Yes/No)
118 K 90	DBS-C-4(10) MSL-14(4)	GEO Shuttle Orbit (Attached)	7-10 Y 7 D	1050(4)(j) 1893(1)	PAM-A MPESS	Solid, 3450 None	A/C None	Yes No
119 K 90	DBS-C-5(10) SIRTF-2(4) SOT-2(4)	GEO 400, 45 (Attached) Shuttle Orbit (Attached)	7-10 Y 8-10 D 7-10 D	1050(4)(j) 6800(1) 3100(4)	PAM-A IG + 2P IPS	Solid, 3450 None None	A/C None None	Yes No No
21 V 90	DOD 90-3(8)							
22 V 90	DOD 90-4(8)							
23 V 90	NOSS-3(Equiv)(11) COBE(5)	700,87 (Deploy) Shuttle Orbit (Retrieve)	7 D 7 D	3816(4) 2948(1)	TMS MMS	Hydrazine, 2275 Hydrazine, 75	Delta None	No No
24 V 90	ADV TIROS-2(11) RADARSAT(11)	Sun Synchronous Sun Synchronous	2 5 Y	2300(1) 2400(4)	MMS(j) MMS(j)	Hydrazine, 75 Hydrazine, 75	None Ar-4	Yes No
25 V 90	SOLAR TERR. LAB(9)	Polar	5 Y	14700(1)	MMS	Hydrazine, 75	None	No
26 V 90	GP-B(9) OER-2(11) MAG. FIELD SURV. (5)	500, 90 Various 300, 97 (Resupply)	1 Y 3 Y 7 D	1270(4) 7258(1); 1700(4)(j) 5000(1)	MMS PAM-A MPESS	Hydrazine, 75 Solid, 3450 Hydrazine, 4000	Delta Delta None	No Yes No
120 K 91	REFLIGHT OPPORTUNITY							

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FLT LS YR(a)	Payload (Code)(b)	Payload Orbit(c) (km/deg)	Service Life(d) (Y or D)	Mass(e) (kg)	Payload Carrier(f)	Payload Carrier Propellant Type, Quantity(g) (kg)	Alternate Launch Vehicle(h)	Terrestrial Equivalent(i) (Yes/No)
121 K 91	TELESAT N(10)	GEO	10 Y	6158(1); 800(4)	PAM-D2(j)	Solid, 3250	A/C	Yes
	INTELSAT VI-A-3(10)	GEO	10 Y	15967(1); 2000(4)	IUS/SRM-1	Solid, 9707	T34D/IUS/SRM-1; Ar-4	Yes
	STARLAB(4)	Shuttle Orbit (Attached)	10-15 D	6800(1)	None	None	None	No
122 K 91	DOD 91-1(8)							
123 K 91	DOD 91-2(8)							
124 K 91	EOS-7(9)	Shuttle Orbit (Deploy/Retrieve)	7 D	22850(1)	Free Flyer	None	None	No
	OPMET-2(11)	GEO	4 Y	698(1); 340(4)	PAM-D(j) (off-loaded)	Solid, 1400	Delta	Yes
	SBS F/O(10)	GEO	7 Y	7200(1); 850(4)(j)	PAM-D2	Solid, 3250	A/C	Yes
125 K 91	SIRTF-3(4)	Shuttle Orbit (Attached)	10 D	6800(1)	IG + 2P	None	None	No
	SATCOM F/O-2(10)	GEO	8-10 Y	7000(1); 800(4)(j)	PAM-D2	Solid, 3250	A/C	Yes
126 K 91	SPAS 05(9)	Shuttle Orbit (Deploy/Retrieve)	7 D	1088(1)	Free Flyer	Nitrogen, 60(j)	None	No
	DOD PAM-27(12)	20000, 63	10 Y	4553(1)	PAM-D2	Solid, 3250	Delta	Yes
	ADV. THERMAL MAP. APP.(11)	400, 57	1 Y	1200(4)	TMS	Hydrazine, 2275	Delta	No
127 K 91	SIRTF-4(4)	Shuttle Orbit (Attached)	10 D	6800(1)	IG + 2P	None	None	No
	EURECA-3(5)	Shuttle Orbit (Retrieve)	7 D	45(4)	Free Flyer	None	None	No
	SATCOM F/O-3(10)	GEO	8-10 Y	7000(1), 800(4)(j)	PAM-D2	Solid, 3250	A/C	Yes
128 K 91	INTELSAT VI-A-4(10)	GEO	10 Y	15967(1); 2000(4)	IUS/SRM-1	Solid, 9707	T34D/IUS/SRM-1; Ar-4	Yes
129 K 91	VOIR(7)	Venus Orbit	1 Y	2415(3)	PAM-D2	Solid, 3250	A/C	No
	DBS-C-6(10)	GEO	7-10 Y	1050(4)	PAM-A	Solid, 3450	A/C	Yes

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FLT LS YR[a]	Payload (Code)[b]	Payload Orbit[c] (km/deg)	Service Life[d] (Y or D)	Mass[e] (kg)	Payload Carrier[f]	Payload Carrier Propellant Type, Quantity[g] (kg)	Alternate Launch Vehicle[h]	Terrestrial Equivalent[i] (Yes/No)
130	CAN DBS-4(10)	GEO	7 Y	2268(3); 1050(4)	PAM-A	Solid, 3450	A/C	Yes
K	GOES(11)	GEO	7 Y	840(4)	PAM-D2	Solid, 3250	A/C	Yes
91	DOD PAM-28(12)	20000, 63	10 Y	4553(1)	PAM-D2	Solid, 3250	Delta	Yes
131	SATCOL F/O-1(10)	GEO	7-10 Y	1050(4)[j]	PAM-A[j]	Solid, 3450	A/C	Yes
K	SBTS F/O-1(10)	GEO	7-10 Y	1050(4)[j]	PAM-A[j]	Solid, 3450	A/C	Yes
91	LDEF-3(5)	Shuttle Orbit (Retrieve)	1 D	0(1)	FSS	None	None	No
132	MEXSAT F/O-1(10)	GEO	7-10 Y	4600(1)[j]; 650(4)	PAM-D	Solid, 2000	Delta	Yes
K	SOT-3(4)	Shuttle Orbit (Attached)	10 D	3100(4)	IPS	None	None	No
91	MSL-15(4)	Shuttle (Attached)	7 D	1893(1)	MPESS	None	None	No
133	SATCOL F/O-2(10)	GEO	7-10 Y	1050(4)[j]	PAM-A[j]	Solid, 3450	A/C	Yes
K	SBTS F/O-2(10)	GEO	7-10 Y	1050(4)[j]	PAM-A	Solid, 3450	A/C	Yes
91	SOIL MOISTURE RES.(9)	465, 60	2-3 Y	550(1)	MMS	Hydrazine, 75	None	No
134	EOS-8(9)	Shuttle Orbit (Deploy/Retrieve)	7 D	14515(1)	Free Flyer	None	None	No
K 91	SPC F/O-1(10)	GEO	7 Y	1050(4)[j]	PAM-A	Solid, 3450	A/C	Yes
135 K	ORB. IR SUBMIL. TELESC.(9)	1000, Earth Orbit	10 Y	1000(4)	MMS	Hydrazine, 75	None	No
91	OPEN-2(IPL)(9)	Helio. Orbit, Sunward Lib. Pt.	4 Y	1000(1)	PAM-A	Solid, 3450; Hydrazine 500	None	No
	HITCHHIKER-3(4)	Shuttle Orbit (Attached)	7 D	2268(1)	None	None	None	No
136	OPEN-3(GTL)(9)	Mult. Lunar Swing by, 5-15 Lunar R	4 Y	1000(1)	PAM-A	Solid, 3450	None	No
K 91	UPPER ATM-RES SAT.(9)	500, 70	1.5 Y	4000(1)	TMS	Hydrazine, 2275	Delta	No
137 K	ADV. X-RAY ASTROPHY. FAC.(9)	500, 28.5	10-15 Y	10000(4)	MMS	Hydrazine, 75	None	No
91	SPC F/O-2(10)	GEO	7-10 Y	1050(4)[j]	PAM-A	Solid, 3450	A/C	Yes
	X-RAY TIMING EXP.(9)	400, 28.5	2 Y	1000(1)	Unknown	Unknown	Scout	No
27 V 91	DOD 91-3(8)							

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FLT LS YR[a]	Payload (Code)[b]	Payload Orbit[c] (km/deg)	Service Life[d] (Y or D)	Mass[e] (kg)	Payload Carrier[f]	Payload Carrier Propellant Type, Quantity[g] (kg)	Alternate Launch Vehicle[h]	Terrestrial Equivalent[i] (Yes/No)
28 V 91	DOD 91-4(8)							
29 V	MAG. FIELD SUR.(5)	300, 97 (Resupply)	7 D	5000(1)	MPESS	Hydrazine, 4000	None	No
91	BRAZIL ERS F/O-2(11)	Sun Synchronous	2 Y	1800(4)[j]	MMS	Hydrazine, 75	Delta	No
	ADV TIROS-3(11)	Sun Synchronous	2 Y	1819(1)	MMS	Hydrazine, 75	Delta	No
	TERS(11)	Sun Synchronous	4 Y	1800(4)	MMS	Hydrazine, 75	Delta	No
30 V	OER-3(11)	Various	3 Y	7258(1); 1700(4)	PAM-A	Solid, 3450	Delta	Yes
91	ADV. LAND OBS. SYS.(11)	705, 90	5 Y	1600(1)	MMS	Hydrazine, 75	None	No
31 91	DOD 91-5(8)V							
32 V	OPEN-4 (PPL)(9)	Eccentric polar orbit, apogee 15 Re	4 Y	1000(1)	PAM-A	Solid, 3450; Hydrazine, 500	None	No
91	NOSS-(Equiv)3(5)	Shuttle Orbit (Retrieve)	7 D	3430(1)	TMS	Hydrazine, 2275	None	No