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Future Spacelift Requirements Study

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Prepared by

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Engineering and Technology Group

THE AEROSPACE CORPORATION
El Segundo, California

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Future Spacelift Requirements Study

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Foreword

This study addresses future space applications and the derived requirements these potential applications will have on future spacelift systems. This NASA sponsored activity is a comprehensive study of potential missions including those of the military, civil, and commercial users. The study objectively evaluated the key architectural requirements for future launch systems. The results of this study are technical, economic, and policy analyses of future spacelift systems. It is intended to assist NASA and DOD decision-makers in planning technical investments and establishing policy for future U.S. spacelift systems.

The study team was formed from members of The Aerospace Corporation's technical staff who were selected to provide diverse technical expertise and experience. The principal contributors to the study are listed below under the major area they supported:

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Executive Summary

Executive Summary

Background

In 1996, the NASA Advisory Council (NAC) identified a need for a study addressing future launch requirements out through the next twenty or thirty years. In a May 8, 1996 letter from the NAC Chair, Dr. Bradford W. Parkinson, to the NASA Administrator, Mr. Daniel S. Goldin, the Council made the following specific recommendation: "That is, we recommend that NASA develop a family of more probable projected mission models for commercial and Government payloads for the years through 2020 and perform sensitivity analyses of the impact of variations from those models on the design criteria for the Reusable Launch Vehicle (RLV) and the best economic mix of RLV and Expendable Launch Vehicle (ELV) to transport those payloads." As a result of this recommendation, the NASA Deputy Associate Administrator for Space Transportation Technology, Mr. Gary Payton, chartered The Aerospace Corporation to analyze the effect that future mission requirements will have on the Nation's space launch infrastructure. Overall government management of this study was provided by Mr. Dennis Smith of NASA MSFC and Lt. Col. Edward Bolton and Maj. Paul Gydesen of the Air Force Space Command with additional insight provided by Lt. Col. Jess Sponable, AFMC Phillips Laboratory.

The study evaluates the mission needs of the DOD, Civil, and Commercial sectors and addresses all mission requirements without being restricted to those that are most compatible with the planned RLV. The overall scope of the study was also expanded to include assessments of current and needed technology programs and future impacts to government space related policies. This report is the final product of this study which began in September 1996.

Approach

The overall study was divided into two major categories of future space applications and spacelift requirements. The first category addressed conventional or near-term missions and their associated spacelift requirements while the second category focused on the innovative, or more futuristic, applications and their corresponding spacelift requirements. This distinction between conventional and innovative space applications was made because the near-term missions are considerably more predictable and are being enabled by current launch systems. In contrast, the futuristic, innovative space applications are less predictable since many of the missions require spacelift characteristics that are not currently available, and the economic viability of the space application itself has not been conclusively established.

Input data for both categories were gathered from multiple government and industry sources. Some examples of sources for the conventional applications assessment are the National Mission Model, NASA Manifest, commercially available industry projections, individual business plans, and interviews with private companies. Examples of input data for the innovative applications include the Commercial Space Transportation Study, the Air Force's Spacecast 2020 & 2025, various conference papers, and interviews with some of the new innovative spacelift companies.

The conventional applications focused on requirements between the years 2000 and 2010. A complete database was compiled for all predicted missions projected for this time frame. The vast majority of the missions are designed to fly on existing launch vehicles or on launch vehicles with required characteristics that are very similar to today's launch vehicles. Significant assessment outputs include predictions of future launch rates and required spacelift capability and the results of special studies, such as the impact of launching the Teledesic constellation.

Executive Summary

Approach (cont'd)

A complete database was also compiled for potential innovative space applications. Since the timing for the possible implementation of these applications is less specific than the near-term missions, it is assumed that the vast majority of the innovative space applications will be in the 2010 and beyond time frame. The final database consisted of 76 different innovative space application areas. Each one of the applications was assessed for 52 different characteristics. From the full set of characteristics, significant thresholds were identified that provide insight into important future spacelift characteristics. A Space Transportation Economic Index (STEI) was developed as a method of prioritizing the innovative missions to provide some distinction between applications that have launch requirements that are closer to today's capabilities and those missions that require launch capabilities that are considerably more demanding than those that today's launch systems can provide.

Important spacelift system characteristics were established for each class of mission applications. Assessments were made in the areas of technology needs and satisfaction by planned programs, applicability of alternative future spacelift systems, and implications on government policies. Conclusions and recommendations were provided in these general areas.

Conventional Space Applications

The conventional mission assessment developed average flight-rate estimates for civil, military, and commercial missions for the 2000-to-2010 time frame for various launch vehicle categories. All present types of missions including proposed low earth orbit, "Big LEO", communications systems and remote-sensing applications are included. (All other proposed missions such as commercial space manufacturing, and new military missions such as space-based radar, are considered "innovative" applications and are considered in the innovative mission assessment.)

Schedules for military space missions such as SBIRS and GPS are available 15 to 20 years into the future, so establishing average flight-rate estimates for most military missions is straightforward. The bulk of future missions will be commercial, however; and most commercial planning horizons extend only three to five years and are usually based only on satellite purchase orders received. Consequently, there was a need to extrapolate present commercial flight rates and trends into the 2000-to-2010 time frame. Available corporate business plans and published assessments from other sources were used to make projections for planned commercial Big LEO systems.

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Conventional Space Applications (cont'd)

No distinction was made between U.S. and non-U.S. commercial missions because in many cases satellites for non-U.S. owners will fly on domestic launch vehicles such as Atlas, and U.S. commercial missions will fly on foreign launch vehicles such as Ariane. The civil and military missions are U.S. only because these missions always fly on U.S. launches. We did not consider non-U.S. civil or military missions since these missions would not, in general, use U.S. launchers.

The extrapolated flight-rate estimates for conventional missions in the 2000-to-2010 time frame are affected by several trends and uncertainties. One of the most important trends, which is likely to continue into the future, is the steady growth in weight and power of commercial Geostationary Orbit (GEO) communication satellites. In fact, in conversations with industry representatives, the consensus was that the size of future GEO communication satellites is limited only by the availability of large, reasonably priced boosters. (The Titan 4, for example, is too expensive for commercial launches.) When Ariane 5 and Sea Launch become operational, we can expect to see further growth in the sizes of future GEO communication satellites.

Another trend that could have a huge effect on future launch rates is the potential explosive growth of LEO communication satellite systems such as Iridium and Teledesic (as well as Medium-altitude Orbit (MEO) systems such as Odyssey). These are high-risk programs, however, and it is very uncertain at this time how many such systems will actually be deployed. The competition from ground-based fiber as well as growth in digital (Internet-based) services may affect the economic viability of Big LEO systems. On the other hand, some forecasters predict an almost unlimited demand for mobile communications services, especially in emerging markets; and it may turn out that the growth in Big LEO systems will exceed even the present optimistic projections.

In contrast with the projected growth in commercial demand, flight rates for conventional military missions are expected to decrease, primarily because military satellite lifetimes are expected to increase. Military satellites will also be downsized from heavy-lift to medium-lift launchers, with the result that the total pounds-to-orbit per year for military missions may drop as much as 40% during the 2000 to 2010 time frame. Commercial spacelift missions will soon exceed military and civil missions in total weight to orbit.

Executive Summary

Conventional Space Applications Assessment (cont'd)

A range of launch-rate estimates was calculated for each launch vehicle category. A summary of these projections is shown in the table below. The lower or "conservative" flight-rate estimate is based on judgment factors that reflect our estimates of the likelihood that each mission will actually fly. We assumed, for example, that only 50% of the planned Big LEO commercial communication satellites will actually be launched. For more established commercial markets, such as GEO communication satellites, the factors are higher. We also assumed that most planned military and civil missions will actually fly. (The factors used in the study are listed in the detailed database.) The upper or "optimistic" estimate assumes all planned missions in every category will fly. A comparison with 1996 actual launches also highlights the large growth that is expected in the small and medium categories.

LEO Payload	Projected 2000-2010	1996 Actual
Small (< 5000 lbs)	21 to 42 per yr	5 per yr
Medium	30 to 64 per yr	27 per yr
Heavy (expendable) (>40,000 lbs)	6 to 10 per yr	5 per yr
Heavy (STS)	7 to 8 per yr	7 per yr

At the beginning of this study there was considerable discussion whether to include Teledesic with the conventional applications or include it as one of the futuristic innovative applications. We decided to consider launch requirements for Teledesic separately, believing at that time that Teledesic's launch requirements might completely dominate the conventional applications flight-rate estimates. During the course of the study, however, Teledesic revised its constellation design, dramatically reducing the constellation size from 840 satellites to less than 300 satellites.

Executive Summary

<u>Conventional Space Applications (cont'd)</u>

Since Teledesic has not published specific launch plans and manifests, several somewhat arbitrary assumptions were made about what types of launch vehicles would be used and how the Teledesic satellites would be stacked. Though the estimates are highly tentative (Teledesic's plans are in considerable flux at the time of this writing), we assumed that a 288-satellite constellation could probably be deployed over a three-year period by two classes of launch vehicles (Delta III and Atlas IIAR). This hypothetical launch strategy would add a total of 18 flights per year to the medium-lift category, bringing the total flight-rate to between 48 and 82 flights per year during Teledesic's deployment period. These higher flight rates are still well within the world's medium-lift capacity that is predicted to be available in the 2000-to-2010 time frame.

Several focused studies were also completed that addressed specific issues relating to near-term spacelift requirements. Listed below are the bottom-line conclusions for each study. Full details for each study are contained in the main body of the report.

- Space transportation demand vs. supply
  Conclusion: Probable oversupply of medium-to-heavy launchers in the 2000-2010 time frame.

- Market capture analysis for reusable upper stage for RLV
  Conclusion: About 16 missions per year (mostly commercial) might fly on reusable upper stage.

- Big LEO space transportation market and utilization of the RLV
  Conclusion: RLV capacity (40,000 lb) too large for efficient replenishment of LEO constellation. There is a potential big LEO market for a smaller (5,000 lb -10,000 lb) low-cost RLV.

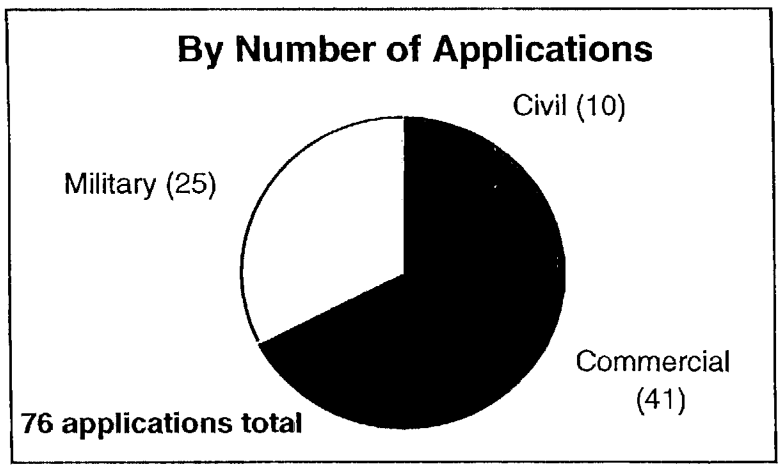
- Impact of commercial demand elasticity on the RLV and limit of private investment
  Conclusion: Private investment levels limited to approximately $1 to $2 billion because high payback burden results in launch costs that are outside of the commercial demand region.

Executive Summary

Innovative Space Applications

Innovative space applications are those missions that generally are not currently enabled by today's launch systems. In this study, a set of 76 potential missions were derived from a wide variety of sources and compiled in a database. The set of missions covers the full range of applications from human planetary exploration and space weapons to commercial applications such as space utilities and tourism. For each application, a technical assessment was made defining the specific spacelift requirements needed for that mission. The technical or economic feasibility of the mission itself was not examined. A standard set of 52 technical assessment questions was developed and used as the basis for the assessment of each application. In addition, several of the applications were divided into separate deployment and servicing missions. Deployment missions are those required to build a system in space, such as a space manufacturing facility. Servicing missions are recurring missions that service the operational facility. It's important to note that this assessment was done without predetermining the configuration of a spacelift system and was based entirely on an objective evaluation of mission requirements.

Figure 1 shows the number of applications divided by sector and the total annual LEO weight to orbit if all applications were enabled. Since the total current launch weight to LEO is under 1million lb per year, enabling all innovative missions would significantly increase the weight to orbit by a factor of 50.



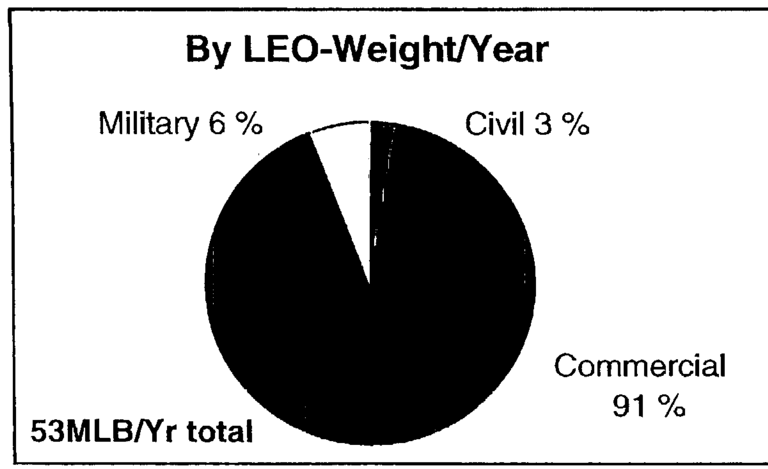


Figure 1

Innovative Space Applications (cont'd)

The majority (~80%) of the innovative applications, based on LEO weight to orbit, require a significant cost reduction in spacelift of 100X below today's cost in order to be enabled. It was quickly recognized that a method of prioritizing the applications was required so an assessment could be made of missions that might be enabled with the next generation launch systems (approx. 3X to 10X cost reduction) as compared to those that will be enabled by more futuristic systems that might provide 100X cost reduction.

The Space Transportation Economic Index (STEI) (Figure 2) was developed as a method of sorting the innovative applications. The STEI provides a comparison of each application's spacelift requirements to current spacelift capabilities and cost. The index considers weight to orbit, flight rate, required cost, and manned vs. unmanned as the primary variables in the evaluation. The index does not consider the economic viability of the specific application, only its spacelift requirements. The chart on the following page shows the results of this assessment. Each dot on the chart is an innovative application, and the arrows point out some of the specific mission areas. Slightly over half (57%) of the applications have STEIs less than 3, and most of these have required cost reduction factors of less than 10X. It is interesting to note that although 57% have STEIs less than 3, this subset only represents 7.4 million lb per year to LEO of the total 53 million lb. The missions with very frequent and heavy lift requirements such as O'Neill space settlements and space utilities clearly have high STEIs.

As a check of the index, we included two present-day applications to see where they would fall on the chart. The current International Space Station (ISS) and the Apollo Program were used as test cases. As expected, the ISS has an index that is very close to 1 which is not surprising because it is enabled at today's launch prices and with current launch systems. The Apollo Program's relatively high index of 4 is also not surprising since the program had launch requirements that are considerably beyond our current capabilities.

As an indication of the variation produced by possible futures, this study provides identification of threshold characteristics for all applications and for applications with STEIs < 3. The STEIs <3 applications represent the set of missions that might possibly be enabled by the RLV, EELV, or some of the new commercial launch systems that are currently in development. The results from the full dataset represent threshold characteristics that will be important for futuristic very low cost spacelift systems.

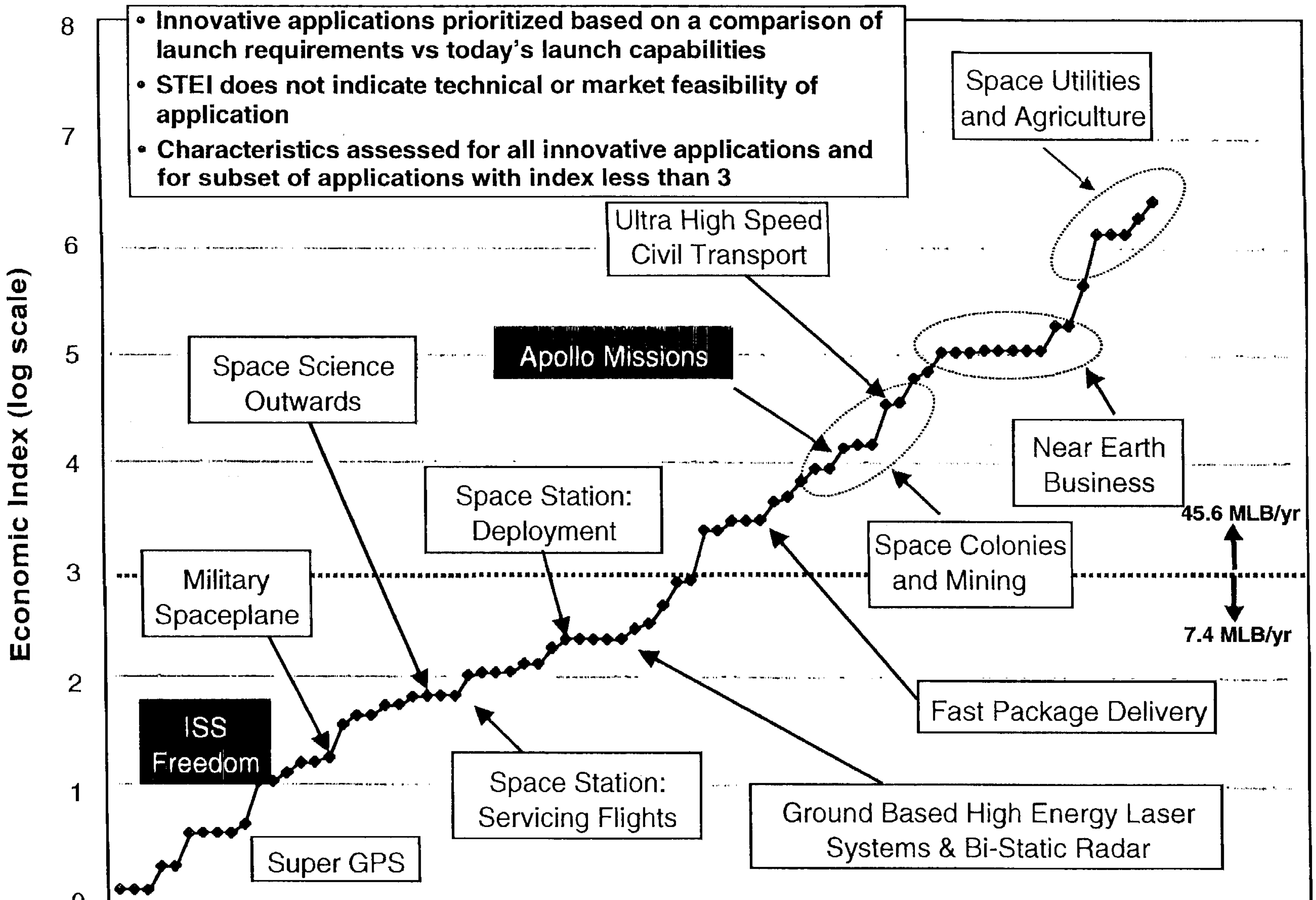


Figure 2. Space Transportation Economic Index (STEI)

Executive Summary

Innovative Space Applications (cont'd)

Each application's individual characteristics were determined based on 52 different criteria. These criteria include performance, reliability and safety, reusability and operability, and economic factors. For most applications, this information was not readily available and major assumptions had to be made regarding the configuration and operation of these innovative systems. Appendix 2 contains detailed data for each application. The full set of individual characteristics was compiled and assessed for threshold characteristics. Figure 3 shows examples of threshold trends for several critical characteristics.

The main body of the report contains several other significant threshold characteristics and Appendix 3 has the remaining set of diagrams for all 52 characteristics that were evaluated for each application.

The price reduction thresholds show the significance of the 100X cost reduction requirement for enabling all applications and that a 3X cost reduction from today's commercial level will enable essentially all of the STEI<3 applications. In this study cost reduction factors are indexed to the lowest launch costs that are currently available ($2500/lb-$4000/lb); therefore, a 3X cost reduction in launch cost is approximately $1000/lb of payload.

The reliability threshold trends indicate that systems with present reliability are sufficient for most of the STEI<3 applications. The 13% of the STEI<3 applications that require a 100X improvement in reliability are Air Force Spaceplane missions which have a stated reliability improvement goal of 100X. The more futuristic missions require reliabilities that are comparable to commercial aircraft because these systems will be transporting people on a near daily basis.

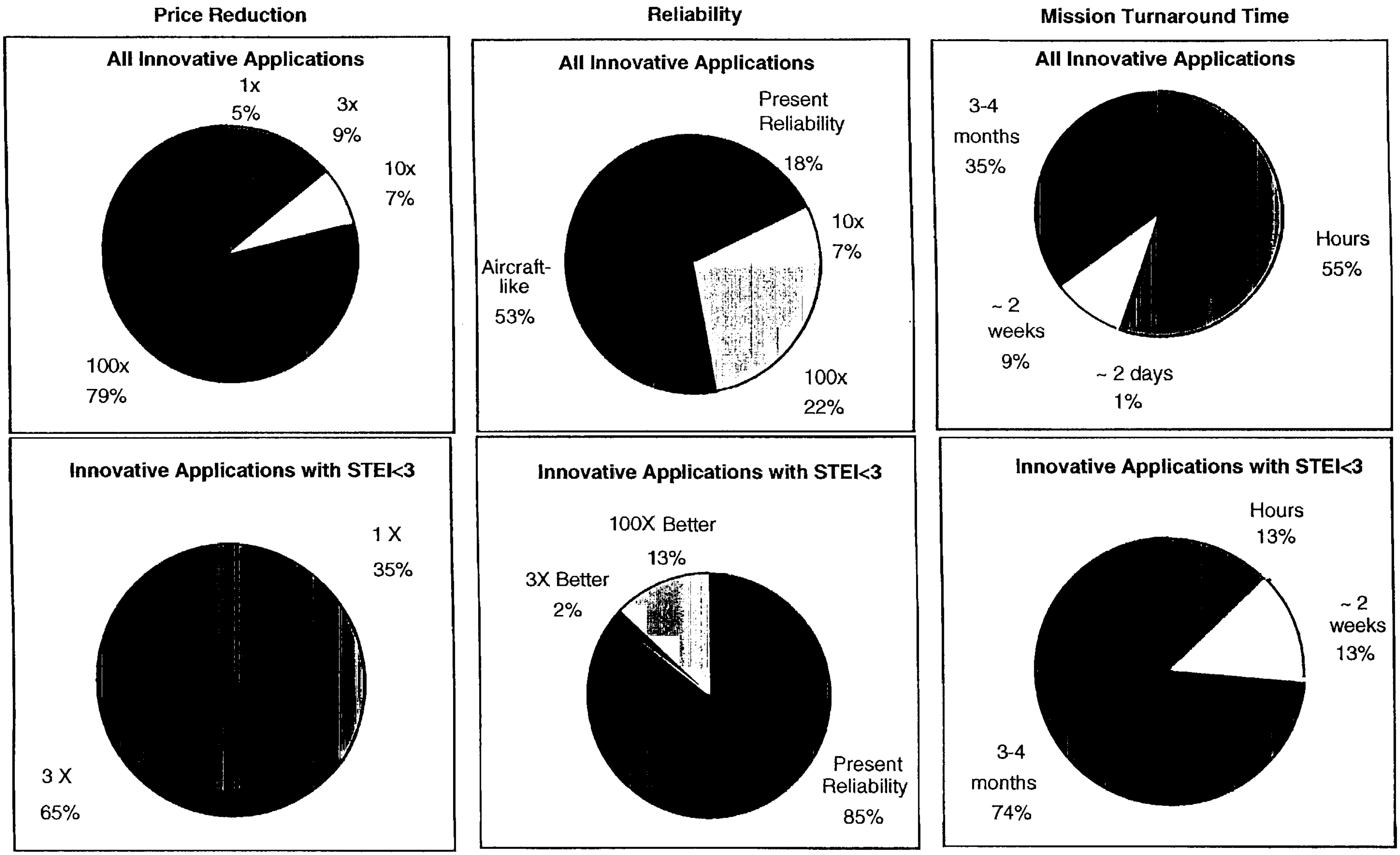


Figure 3. Threshold Characteristics - Examples
(% Breakdown Based on Total Weight To LEO Per Year)

Innovative Space Applications (cont'd)

The mission turnaround time charts show that the majority of the STEI<3 missions do not have rapid turn-around requirements. Several months are acceptable turnaround times for these payloads. The missions in the STEI<3 category that have rapid turnaround requirements are primarily Military Spaceplane missions. The turn-around requirements are considerably different for the full set of innovative missions with a rapid turnaround of just hours being a requirement for missions such as space tourism, rapid package delivery, personnel transports, and servicing of large space habitats.

The full set of launch system characteristics can be naturally grouped into four general mission classes that have unique requirements. These classes were termed Near-term Innovative, Passenger Service, Rapid Access, and Initial Deployment. Figure 4 outlines some of the important attributes of the space transportation systems for each class.

The launch vehicle attributes required for the Near-term Innovative missions are satisfied by a system that has many of the characteristics planned for the first-generation RLV. The Passenger Service and Rapid Access type vehicles have unique requirements that probably will not be available in next generation launch vehicles. The most notable of these requirements are extremely high flight rates of over 300 flights per year, high reliability, a return payload requirement and airport-like ground facilities. The Initial Deployment type vehicle has a heavy lift requirement and flight rates that will require the system to be launched on a weekly basis. Many of the attributes for this system could be met with an expendable or a reusable launch system. However, since most of the missions require an enabling launch price of 10X to 100X less than current prices, the heavy lift vehicle will likely also be a reusable system.

Attribute/Vehicle Class		Near Term Innovative	Passenger Service	Rapid Access	Initial Deployment
Performance	LEO equiv wt (lb)	up to 60 K	40 K	5 K - 20 K	100 K
	Types of Cargo	Satellites	Passenger	Crew/cargo	Cargo/Sats
	Launch Rate	< 50 /yr	> 300 /yr	100 - 500 /yr	< 50 /yr
Reliability	Reliability	1 x - 3 x	> 100 x	> 100 X	> 3 x
Safety	Safe Abort	Optional	Mandatory	Mandatory	Optional
Reusability	Return Payload	No	Yes	Yes	No
	ELV vs. RLV	ELV/RLV	Reusable	Reusable	ELV/RLV
	Manned ?	Optional	Manned	Optional	Unmanned
Operability	Turnaround Time	Monthly	Days	Hours	Monthly
	SC Time on Pad	Days	Hours	Hours	Days
	Facilities	Present	Airport-Like	Airport-Like	Present
Affordability	Insurance/Liability	Same	More	More	Same
	LEO Cost	3 x	10 x - 100 x	3 x - 10 x	10 x - 100 x
Typical Missions		Com Sats	Tourism	MSP	Space Utility
		S S Support	UHSCT	Rapid Package	Human Planetary
		Big LEO	Space Medical	Big LEO Replenishment	Weapons
		Remote Sensing			Business Park

Figure 4. Spacelift Threshold Attributes Summary

Executive Summary

Alternative Launch Futures

The groups of spacelift attributes determined in the innovative space applications assessment can be represented by an evolutionary set of space launch systems. Five different alternative launch futures were considered in this study.

The initial alternative launch group is made up of current systems including initial EELV operations, the Space Shuttle, and current expendable systems. The second is the the Near Term category of next generation launch vehicles such as an RLV that has attributes similar to Lockheed-Martin's Venturestar or U.S. launch startups Kistler, Kelly, Pioneer, etc.), and current launch systems that may still be price competitive such as the Chinese and Russian launch vehicles.

The third spacelift group is a low to medium payload, quick turnaround vehicle with attributes such as those desired for the Air Force Military Spaceplane (MSP). This family would be targeted at very quick turnaround missions that also require high system flight rates and high reliability.

For the fourth and fifth groups, a hypothetical set of vehicles was defined and analyzed separately and as a family. The Super HLV and Super Low Cost MLV are defined to capture the spacelift attributes designated by the heavylift and passenger service categories of applications. These systems are very futuristic, and their development schedules will be determined by market forces.

Payload weight, launch price, reliability, flight rate, and crew rating were the primary factors determining which Innovative Applications were compatible with the defined Alternative Space Launch Futures. Current vehicles' attributes are those exhibited by launch systems today, while the future systems are either based on system requirements or characteristics as they are known today (RLV and MSP) or on Innovative Application requirements (Super HLV and Super Low Cost MLV).

Figure 5 outlines the primary characteristics that were assumed for the five alternative space launch futures. Two very significant characteristics are the high system flight rates for the Super HLV and the Low Cost MLV. These flight rates were the product of an assessment evaluating the inter-relationship between characteristics if these systems were developed as commercial vehicles. If these systems are to provide the required 10X and 100X cost reduction, then extremely high system flight rates will be required to pay for the development cost of the system.

Figure 6 shows the percentage of number of applications captured by each launch future. Additionally, the applications with STEI<3 and the set of all Innovative Applications are analyzed separately to provide an indication of the sensitivity to future mission model assumptions.

The EELV+STS future could capture about 40% of STEI<3 missions while RLV+Commercial would approximately double this number of missions captured to about 80% of the 43 applications. The remaining 20% of the applications are not captured due to incompatible payload weight, flight rate, and/or cost.

Alternative Launch Futures (cont'd)

The Military Spaceplane type systems promise to be a versatile platform capable of launching 60-70% of the STEI<3 innovative applications. Again, the missions it can't capture include higher weight and flight rate applications.

Super Low Cost MLV captures most applications for both STEI<3 and all innovative. The missions that it cannot launch are primarily the heavy application deployment missions which are captured by Super HLV. The few "all innovative" missions that Super HLV and Super Low Cost MLV cannot launch are the extremely high flight rate and payload weight missions with 100x cost reduction requirements. Missions of this type include near daily resupply launches to space settlements.

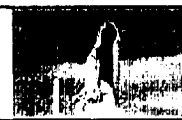
	Current, EELV, STS	RLV + New Commercial	Military Spaceplane	Super Heavy	Super Low Cost Medium
					
Payload Equivalent Weight to LEO	< 60,000 lb	< 60,000 lb	5-20,000 lb	100,000 lb	40,000 lb
Cost Factor	Current Prices	3x Cost Reduction	3x Cost Reduction	10x Cost Reduction	100x Cost Reduction
Reliability Improvement	Current Reliability	3x Better Reliability	100x Better Reliability	10x Better Reliability	100x Better Reliability
System Flight Rate (per year)	50	100	200	240	5000

Figure 5. Alternative Launch Futures Characteristics

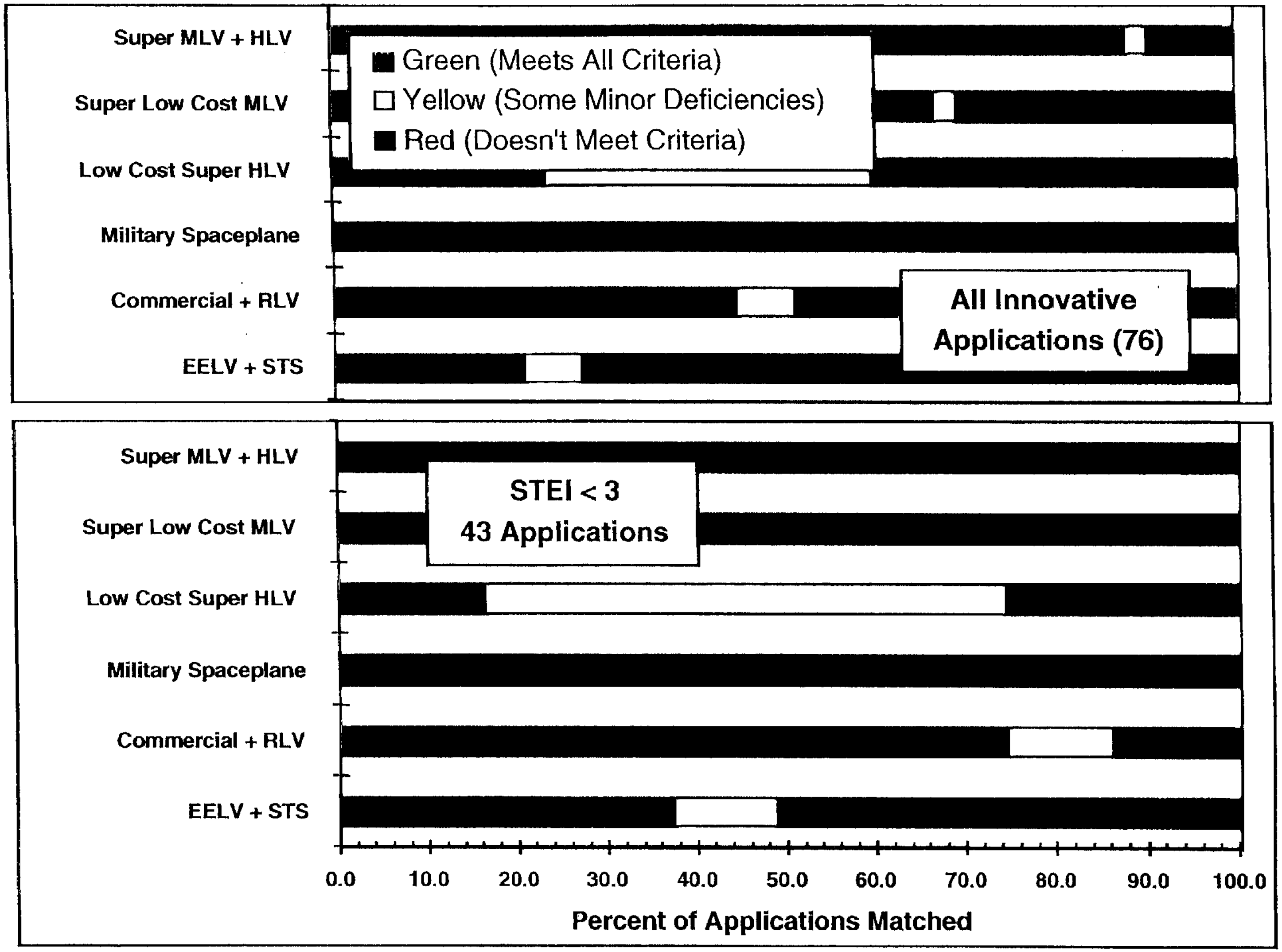


Figure 6. Number of Missions Matching Launch Futures

Executive Summary

Technology Assessment

A technology assessment was conducted and a comparison made between current programs and needed technology to achieve the significant launch vehicle attributes that were identified in the innovative applications assessment. While current technology programs address near term goals and could be considered on track to provide a space transportation cost reduction factor of 3 to 5X, there is little basis for confidence in achieving a 100X cost reduction. The majority of individual technology areas utilize core technologies which may support this far-term goal, but the overall picture is confused by a lack of cohesive effort toward the high flight rates and airport-like operations needed to enable the more innovative spacelift applications identified in this study. A system's engineering methodology is required to derive specific technology goals for each subsystem and major component. Preliminary analysis indicated that, with minor exceptions, core technology programs are sound but must be refocused on the high payoff goals--stressing operability and reliability objectives above performance.

Figure 7 provides a top-level summary of current technologies and how well they are judged to help achieve the 3X, 10X, and 100X cost reductions. As shown on the first line of the figure, to achieve 100X cost reduction a systems engineering approach is called for that defines the necessary system and subsystem technology needs and goals and integrates the components, systems, and operations required to achieve the synergistic advances in reusability, durability, operability and efficiency. The next area that needs greater emphasis is an active Thermal Protection System (TPS) that can handle several hundred cycles without requiring lengthy maintenance. In the area of propulsion performance, increasing Isp or thrust/weight need not be pushed to the limits but rather these advances need to be maintained while integrating the demands of rugged, long-life engines and airframes. Focus on the operations technology goals for 100X or greater levels of cost reduction would bring technology efforts to bear on low-maintenance, long-life, durable components with robust margins; innovative cargo handling and crew/passenger systems; "intelligent" ground support equipment and health monitoring systems; and low-cost propellants.

The overall current situation is that each launch vehicle concept requires unique systems analysis; tools are needed that can span different concepts for comparative in-depth analyses to provide insight as to the levels of operability, reliability, performance, and technology needs for each concept. This approach can also be used to eliminate all critical failure modes and provide safe shutdown before impending failure. Design requirements need to focus on operability, reliability and low cost per flight. High reliability should be sought through selection of design margins, operable subsystems, certification processes, in-flight health management systems, and techniques to eliminate Criticality 1 failures as well as provide safe abort. For rapid turnaround and long life there should be additional considerations for operable fuels and access provisions for maintenance and servicing. Low cost goals should be established through consideration of the complete system -- vehicle and support systems.

Current technology efforts focused primarily on performance improvements with only modest operability improvements will yield only minor cost reductions. Revolutionary approaches are needed to focus on the goals for achieving high flight rates and airport-like operations.

Executive Summary

Technology Assessment (cont'd)

Given that such a leap is needed, it is prudent to select a pathfinder for the 100X cost reduction effort -- NASA's Future X program seems to offer such an opportunity. A focused technology study utilizing a thorough systems analysis approach could support program definition to achieve the needed breakthrough goals. Further, recognizing the benefits of coordination of the efforts of DOD, industry and NASA and of leveraging technology dollars, an IHPRPT-like program could be used to create an integrated National roadmap for spacelift technology and systems development -- logical first targets would be coordination of launch facility and operability enhancements, perhaps emphasizing the goals for Future X.

Cost Reduction		3X					10X					100X				
Technology		Performance	Operability	Reliability	Affordability	Reusability	Performance	Operability	Reliability	Affordability	Reusability	Performance	Operability	Reliability	Affordability	Reusability
SE&I	Systems Analysis						Y	Y	Y	Y	Y					
	Modeling/Tool Development								Y	Y	Y	Y				
Structures	Composite Structures/Tanks						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Composite Tanks (Conformal)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Advanced Metallics						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Thermal	High Temp Alloys						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Protection	Ceramics						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Active TPS															
Propulsion	LOX/LH2 IPD Engine						Y	Y	Y	Y	Y		Y	Y	Y	Y
	LOX/LH2 (Aerospike)						Y	Y	Y	Y	Y		Y	Y	Y	Y
	LOX/RP IPD						Y					Y	Y	Y	Y	Y
	LOX/CH4 IPD						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Combined Cycle Propulsion						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Ultralow Cost Engines								Y							
	HEDM							Y	Y	Y	Y		Y	Y	Y	Y
OTV	Reusable Transfer Stages	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y			Y
	Low Cost Expendable	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y			
Avionics	GN&C/Health Monitoring							Y	Y				Y	Y		
Range	In-flight Refueling	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Containerized Payload System									Y			Y	Y		Y
	Flight Ops Control Center							Y	Y	Y						
	Range Standardization/Turn Time							Y	Y	Y						

	Tech efforts focused on goals or no tech required
Y	Marginal, may achieve goals with shift in emphasis, or underfunded
	Current tech base inadequate or no program

Figure 7 - Current Technology Programs Assessment

Executive Summary

Policy Assessment

Up to the present day, most U.S. launch vehicles have been developed and operated by the U.S. Government, including those now commercially operated like the Delta, Atlas, and Pegasus. Each of these systems was either derived from a military system or developed according to government requirements and specifications. In the future, however, launch systems will increasingly be developed by the commercial industry and operated out of non-federal launch sites for commercial purposes. At the same time, the Government may continue to operate select systems which are different from commercial systems (such as a military spaceplane), but will also likely rely on the commercial industry for the bulk of Government launches into orbit. Adapting to these changes will require a major paradigm shift in the Government's role in space transportation.

As a result, the Government will have to regulate a fundamentally commercial industry, not the government-developed industry it is today. In particular, the Government will no longer play as large a role in oversight of safety at the launch sites themselves. Instead, maintaining safety could increasingly be the responsibility of the vehicle operator, not the government ranges. Today, DOT relies heavily on government personnel and contractors at the ranges to assure safety. The role of the Government then will be to assure safety through regulation and oversight, not on-site involvement in launch preparations. Future space transportation policies and regulations must reflect and support the trend toward substantially higher launch rates; more aircraft-like reliability and operations; reusability; safe abort capability; and the ability to return to the launch site.

As reusable launch vehicles come into operation and launch rates drastically increase, the licensing of launch activity is likely to move toward the current air transportation model. At present, the FAA issues separate licenses for aircraft, airlines, and airports. By contrast, launch licenses are issued to operate a launch system which includes both the vehicle and the operator, which are generally the same for today's launch vehicles. This means that McDonnell Douglas (now part of Boeing) is issued a license to build and commercially operate the Delta II launch vehicle. The license is issued to operate the vehicle for a certain class of payloads and envelope of operations, i.e., a range of launch azimuths, orbital altitudes, and inclinations.

Executive Summary

Policy Assessment (cont'd)

In the future, commercial operators of launch systems that are manufactured by another company -- just as United Airlines operates aircraft built by Boeing -- may need to be issued operator's licenses for vehicles which have flight worthiness certificates. This means that the vehicle itself will need to be qualified separately from its operations.

There are several important aspects of future launch activities that are not covered by current launch policies and regulations. The first of these is the reentry and landing of RLVs or other reentry vehicles. The Commercial Space Transportation Act of 1984 does not authorize the Department of Transportation to regulate reentry of any kind. To remedy this situation, the U.S. House of Representatives recently included language in the Civilian Space Authorization Act, FY 1998 and 1999, H.R. 1275, authorizing DOT to regulate reentry as it does each aspect of launch activity. This Act has passed the House, and is waiting on Senate action before becoming law.

Future policies and regulations will also have to consider the overflight of populated areas. Currently, launches from U.S. ranges occur over unpopulated areas, out over the Atlantic Ocean from Florida and out over the Pacific Ocean from California. By contrast, future operations from currently planned launch sites in Alaska, New Mexico, and Nevada will overfly land and populated areas. Issues that must be examined for overflight of populated areas include vehicle safety and reliability, shock waves, noise pollution, and others. In addition, vehicles routinely reentering from orbit would overfly foreign countries and therefore would need to be covered under international treaties. Whether they are treated as space objects or aircraft in determining overflight rules must be addressed.

While current launch licenses require insurance to cover damage to people and property on the ground, damage to objects already in space caused by launch and satellite debris is not covered. With the proliferation of launch activity and the number of spacecraft in orbit, space debris will be a commercial issue and policies and regulations will need to be developed.

With the routine deployment and retrieval of items from space, the ownership of abandoned or damaged spacecraft will also be an issue. The "salvage rights" of space objects will need to be defined.

Executive Summary

Summary

This study examined the broadest possible range of potential future space applications and identified significant spacelift characteristics and issues relating to future launch vehicles. The study developed databases of future mission requirements and used the data to project launch vehicle requirements and technology needs for both near- and far-term space applications.

The current and in-development family of spacelift systems (Space Shuttle and expendable launch vehicles) can meet the boost needs of planned missions for the 2000-2010 time frame. This includes spacelift for large LEO constellations such as the proposed Teledesic system. The largest space-transportation market in this time frame is projected to be in the commercial medium lift category.

Advanced spacelift system capabilities are required to lower transportation cost and enable a variety of possible future space applications. Threshold characteristics were assessed for the innovative missions, and a comparison was made of the mission requirements to capabilities of existing and planned launch vehicles. Near-term reusable and expendable launch vehicle systems could enable a significant number of the futuristic, innovative missions. For example, the planned expendable commercial vehicles plus the RLV could meet the launch needs of about half of the near-term innovative missions examined in this study. Also, the technology needs of these near-term planned spacelift systems appear to be adequately addressed by the current individual NASA and DOD technology efforts and NASA's X-vehicle programs.

A large cost reduction (100X) spacelift system is needed to enable a much wider array of possible innovative space applications. A super low cost (100X) MLV class vehicle plus a low cost (10X) HLV would enable approximately 90% of the innovative space applications. The only missions not enabled are those requiring a combination of super low cost, heavy lift and rapid turnaround capability.

High system reliability and the ability to achieve a high launch and flight rate per vehicle are key attributes for an economically attractive launch system. For example, to economically justify a commercially developed 100X cost reduction launch vehicle, the total fleet of vehicles must be able to fly several thousand missions per year. In addition, the system must have very high reliability and very low operations and infrastructure costs.

Future technology programs need a long-range focus towards developing the components and subsystems for a 100X cost reduction vehicle. A total systems engineering approach is required that aggressively addresses the attributes necessary to achieve the required airplane-like high flight rates and low-operating costs. It is unlikely that such focused technology programs will be solely pursued by the commercial sector and that heavy Government funding and leadership will be needed for the development of the technologies to achieve these spacelift characteristics.

A major unknown in any future projection is the actual demand-versus-cost relationship of each of the space applications. The elastic demand to these applications is not well defined, and an accurate understanding of the future demand for these space systems is required to provide realistic estimates of future flight rates for commercial business plans. This study did not find a single compelling innovative application that would justify the entirely commercial development of a high -flight-rate launch system.

Executive Summary

Recommendations

Since similar significant spacelift characteristics are needed for the future systems of NASA, commercial users, and the Air Force, a coordinated development effort by NASA and the Air Force should result in the future spacelift systems that will meet the goals of the nation. In order to achieve this coordinated effort, an integrated NASA and Air Force National technology roadmap should be prepared that addresses the development of launch systems from today's vehicles to the MSP and continuing to the future X-vehicles.

NASA should consider integrating the significant spacelift system threshold characteristics identified in this study into their baseline requirements for future X-vehicle programs. In particular, characteristics that affect flight rate, reliability, operability and low maintenance should be included as goals for the next-generation X-vehicles.

NASA and the Air Force should coordinate requirements for the RLV, MSP, and future X-vehicles. The RLV is expected to develop technologies that meet many of the needs of a MSP such as lower operating costs and improved reusability as compared to current launch systems. However, the MSP reliability and operability requirements are more demanding than those of a first-generation RLV, which is designed to the needs of near-term civil and commercial missions. The Air Force development of a system that has the high flight rate and aircraft like operability requirements of the MSP will also provide the technologies required to meet the needs of the more long-range innovative missions that the future X-vehicles should enable. There is a potential for a synergistic flow of technology development from the RLV to the MSP to future X-vehicles.

NASA and the Air Force should investigate future demand-versus-cost elasticity for new, innovative applications of space. A better understanding of market elasticity for launch services will enable a more accurate assessment of the potential future launch rates and can help justify the technology investment required to achieve these lower-cost launch systems.

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Purpose and Study Approach

Purpose

- Provide vital information to support system planners and decision makers at both NASA and Air Force Space Command
- Predict and evaluate potential long-range future DOD, civil, commercial, and international mission requirements for space transportation systems
- Objectively determine the critical launch system and operational characteristics required to meet future mission requirements
  - Evaluate impact of current and planned technology programs on achieving significant characteristics
  - Evaluate alternative spacelift futures and impact on achieving significant characteristics

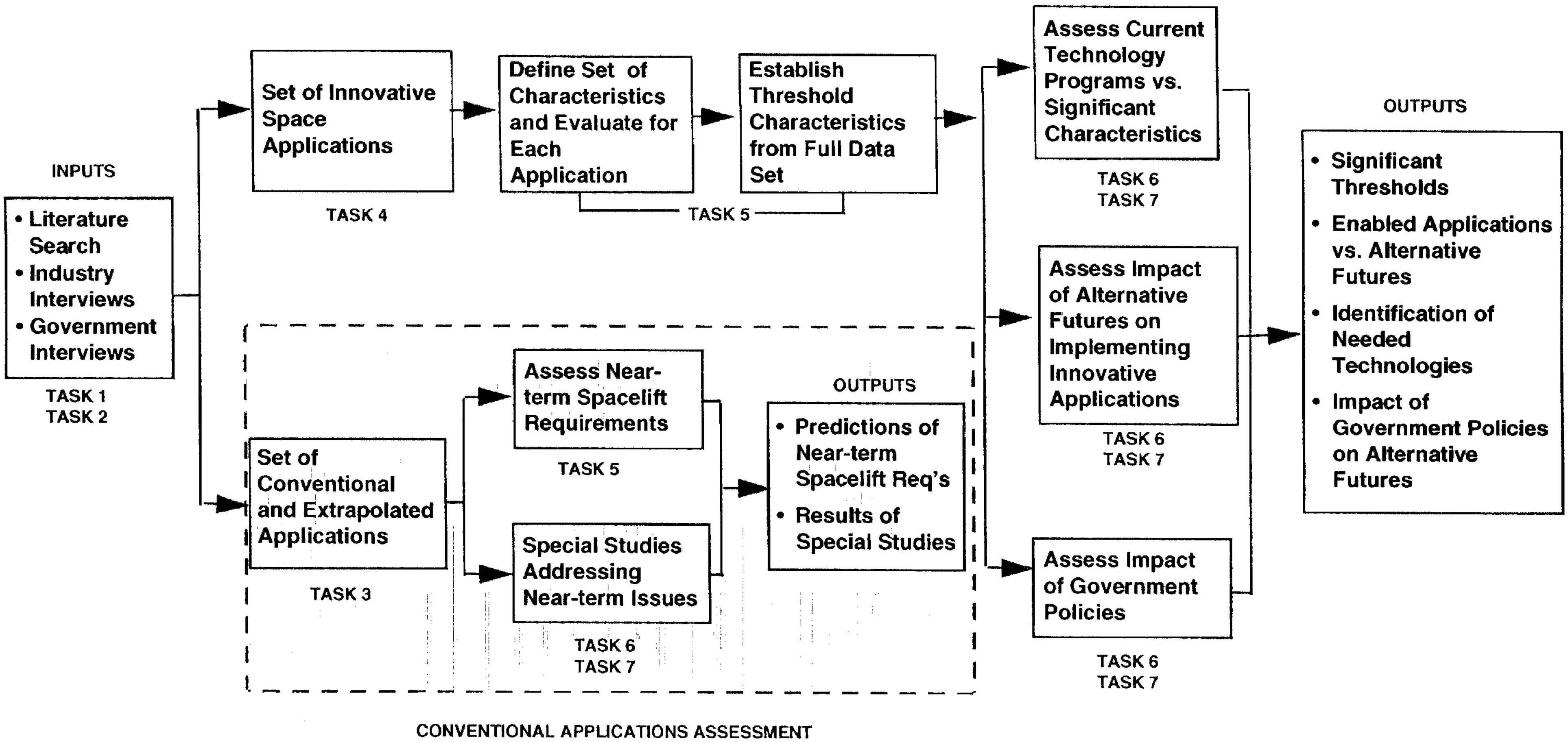
Purpose

Determine critical launch system requirements based on future long-range DOD, civil, commercial, and International mission requirements. The study provides an understanding of future space mission requirements and will be used by NASA and U.S. Air Force Space Command planners in determining the future spacelift characteristics that meet their needs and the needs of the commercial sector.

A unique goal of this study was to objectively focus on mission requirements without advocating specific spacelift systems. Each potential mission was assessed to establish its required launch vehicle characteristics. Then the aggregate of all characteristics was evaluated and compared to the ability of current and planned spacelift systems in meeting these requirements.

The study also provides insight into the impact that current and planned technology programs will have on achieving needed spacelift characteristics. Technology areas that require additional emphasis are also discussed. In addition, the study provides an evaluation of various alternative spacelift futures and their ability to implement the future missions. Also, the future policy issues that result with spacelift systems that require new unique characteristics are discussed.

Future Spacelift Requirements Study Flow



Future Spacelift Requirements Study Flow

The overall study consisted of two major assessments of future space applications and spacelift requirements. The section shown in the dashed line box addresses conventional, or near-term, spacelift requirements and the remaining boxes outline the overall flow for the assessment of innovative, or more futuristic, applications and their corresponding spacelift requirements.

The input data for both assessments consisted of information gathered from multiple government and industry sources. Some examples of sources for the conventional applications assessment are the National Mission Model, NASA Manifest, commercially available industry projections, individual business plans, and interviews with Private companies. Examples of input data for the innovative assessment include the final output of the Commercial Space Transportation Study and the Air Force's Spacecast 2020 & 2025 plus conference papers and interviews with some of the new, innovative spacelift companies.

The conventional applications assessment focused on requirements between the years 2000 and 2010. An extensive database was compiled for all predicted missions that will be launched in this time frame. The vast majority of the missions are designed to fly on existing launch vehicles or on launch vehicles with required characteristics that are very similar to today's launch vehicles. The most significant outputs are predictions of future launch rates and required spacelift capability and the results of special studies, such as the impact of launching the Teledesic constellation.

The innovative assessment also began with the compiling of a complete database of potential innovative space applications. The timing for the possible implementation of these applications is less specific than the conventional applications but is assumed to be in the 2020 and beyond time frame. The final database consisted of 76 different space application areas. Each one of the applications was assessed for 52 different characteristics. From the full set of characteristics, significant thresholds were identified that provide insight into important future spacelift characteristics.

Once the important characteristics were established, then assessments were made in the areas of technology programs, alternative spacelift futures and government policies. The outputs for the innovative assessment consist of conclusions and recommendations in these general areas.

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Data Collection

Data Collection for Conventional and Innovative Applications of Space

- Information gathered from multiple sources
  - The Aerospace Corporation, DOD, industry, and forecast reports
  - Government agencies
    - » NASA
    - » Office of Air & Space Commercialization
    - » Department of Transportation
    - » Office of Aerospace International Trade Administration
    - » Federal Communications Commission
    - » International Telecommunication Union
- Examples of sources utilized
  - AFSPC National Mission Model
  - NASA Manifest
  - COMSTAC Mission Model and LEO Commercial Market Projections
  - Commercial Space Transportation Study (1994)
  - Spacecast 2020 & 2025
  - New World Vistas
  - Satellite Communications Industry Report
  - Trends in Commercial Space
  - International Mission Model
  - Conference papers
  - Interviews with industry

Data Collection for Conventional and Innovative Applications of Space

Information gathered from multiple sources. In addition to sources internal to The Aerospace Corporation, data was obtained from several DOD, civil, and industry sources. Several U.S. Government agencies such as NASA and the Department of Transportation were contacted for input on future mission forecasts. The chart shows several of the Government agencies contacted and the sources utilized.

The National Mission Model provides estimates of DOD and Civil launch requirements out through 2009. The commercial requirements are less well defined and were extrapolated from sources such as the COMSTAC Mission Model, Satellite Communications Industry Reports and various industry business plans.

For information on potential innovative space applications several different sources were utilized. The Commercial Space Transportation Study provided an excellent source of futuristic commercial applications. Sources of military space applications can be found in the New World Vistas and Spacecast 2020 and 2025. In addition, several potential applications were taken from conference papers, current periodicals and from long range planning organizations within The Aerospace Corporation.

For additional input on both the conventional and innovative space applications, representatives from the following corporations were interviewed:

Hughes Space and Communications
Boeing
Lockheed- Martin
Rockwell International
McDonnell-Douglas
Kelly Aerospace
Kistler
Space Access

Data Collection for Conventional and Innovative Applications of Space (Cont'd)

- Space applications divided into two categories
  - Conventional: Extrapolation of today's missions (including Teledesic)
    - » Attributes in assessment: weight, orbit, cost, sector, and application
  - Innovative: Potential future applications that may be enabled if space transportation system has the required characteristics
    - » Aerospace developed and assessed 52 attributes for each innovative application
- Excel databases created for conventional and innovative applications

Data Collection for Conventional and Innovative Applications of Space (Cont'd)

Space applications divided into two categories. Separate Excel databases were developed for the conventional and innovative data. These databases were the primary data source for the study.

The conventional database is an extrapolation of today's missions out to the 2010 time frame. Since these missions have spacelift requirements that are similar to current launch systems, the characteristics in the database are restricted to weight, orbit , cost, sector and application. The complete database is contained in Appendix 1.

The Innovative database consists of the 76 different application areas and the 52 characteristics that were assessed for each application. The development of this database involved far more than just a data-gathering exercise in that the characteristics for each application had to be determined from the brief descriptions that were available. The assessment of each application required several major assumptions and these are also included in the database. The complete database is contained Appendix 2.

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Conventional Applications

Near-Term Requirements

- Forecasts of space-transportation requirements for conventional space missions
- Comprehensive database compiled for military, civil, and commercial sectors
  - Commercial includes both U.S. and non-U.S.
  - Military and civil are U.S. only
- Extrapolated flight rates for 2000 - 2010 based on:
  - Present flight rates
  - Trends in satellite lifetimes, sizes, etc.
  - Future flight schedules (when available)
  - Published business plans (e.g., Teledesic)

Near-Term Requirements

The conventional mission assessment developed average flight-rate estimates for civil, military, and commercial missions for the 2000-to-2010 time frame for various launch vehicle categories. Conventional missions include all present types of missions including proposed "Big LEO" communications systems and remote-sensing applications. (All other proposed missions such as commercial space manufacturing, and new military missions such as space-based radar, are considered "innovative" applications and are considered in the innovative mission assessment in the next section.)

Schedules for military space missions such as SBIRS and GPS are available 15 to 20 years into the future, so establishing average flight-rate estimates for most military missions is straightforward. The bulk of future missions will be commercial, however; and most commercial planning horizons extend only three to five years and are usually based only on satellite purchase orders received. Consequently, we had to develop procedures and criteria in order to extrapolate present commercial flight rates and trends into the 2000-to-2010 time frame. For planned commercial Big LEO systems, for example, we looked at corporate business plans for these ventures, when these were available, as well as published assessments from other sources.

We made no distinction between U.S. and non-U.S. commercial missions because in many cases non-U.S. missions will fly on domestic launch vehicles such as Atlas, and U.S. commercial missions will fly on foreign launch vehicles such as Ariane. The civil and military missions are U.S. only because these missions always fly on U.S. launches. We did not consider non-U.S. civil or military missions since these missions would not, in general, use U.S. launchers.

Trends Affecting Extrapolated Requirements

- Weight growth of commercial GEO communications satellites
- Potential new applications
  - Teledesic and other "Big LEO" applications
- Increasing satellite lifetimes

Program	Current	Future
SBIRS	5.6 yrs (DSP)	10 - 12 yrs
GPS	6.5 yrs (IIR)	12.7 yrs (IIF)
Com. sat.	7 - 10 yrs	12 - 15 yrs

- Uncertainty: National interest in space exploration and man-in-space missions
- Uncertainty: New threats, technologies and future military roles in space

Trends Affecting Extrapolated Requirements

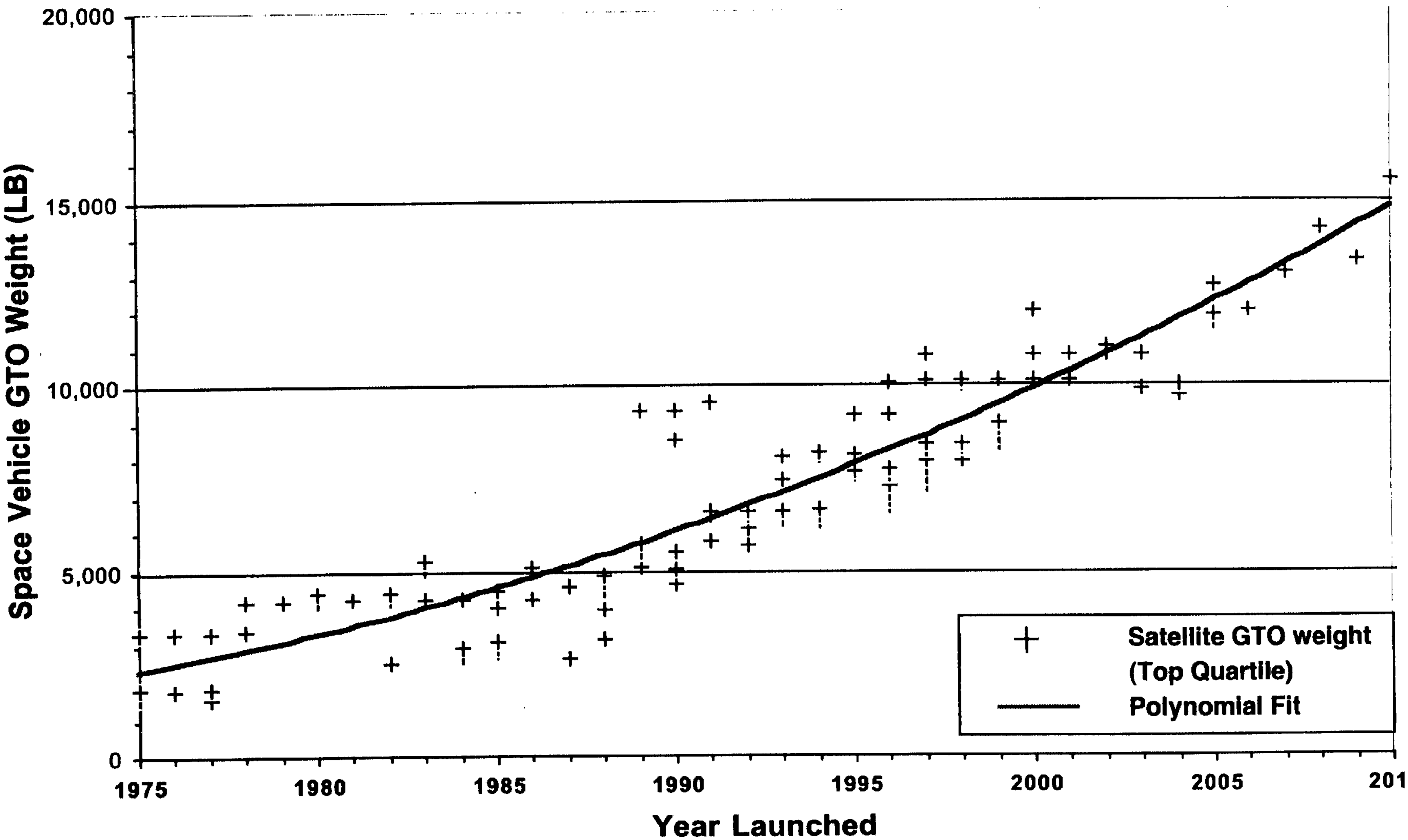
The extrapolated flight-rate estimates for conventional missions in the 2000-to-2010 time frame are affected by several trends and uncertainties. One of the most important trends, which is likely to continue into the future, is the steady growth in weight and power of commercial GEO communication satellites. In fact, in conversations with industry representatives, the consensus was that the size of future GEO communication satellites is limited only by the availability of large, reasonably priced boosters. (The Titan 4, for example, is too expensive for commercial launches.) When Ariane 5 and Sea Launch Zenit become operational, we can expect to see further growth in the sizes of future GEO communication satellites.

Another trend that could have a huge effect on future launch rates is the potential explosive growth of LEO communication satellite systems such as Iridium and Teledesic (as well as MEO systems such as Odyssey). These are high-risk programs, however, and it is uncertain at this time how many such systems will actually be deployed. The competition from ground-based fiber as well as growth in digital (Internet-based) services may affect the economic viability of Big LEO systems. On the other hand, some forecasters predict an almost unlimited demand for mobile communications services, especially in emerging markets; and it may turn out that the growth in Big LEO systems will exceed even the present optimistic projections.

In contrast with the projected growth in commercial demand, flight rates for conventional civil and military missions are expected to decrease, primarily because of budget constraints and the fact that military satellite lifetimes are expected to increase. Military satellites will also be downsized from heavy-lift to medium-lift launchers and civil satellites from medium to small launchers. The net result is that the total pounds-to-orbit per year for government missions may drop as much as 40% during the 2005-to-2010 time frame. Commercial spacelift missions will soon exceed government missions in total weight to orbit.

Both the military and civil extrapolated flight-rate estimates are subject to uncertainties which limit the accuracy of any forecast. The discovery of life on Mars, the emergence of new space-based military threats, or a change in domestic priorities or goals could dramatically affect civil or military flight rates in just a few years.

GTO Com. Sat. Weight Growth Trend



GTO Commercial Satellite Weight Growth Trend

Commercial GEO communications satellite weights are increasing. Many in the industry feel that the future growth in the size of communications satellites is limited only by the availability and affordability of larger launch vehicles. Designers are driven to larger satellites to maximize the number of leasable transponders that can be placed in an orbital slot, which have become increasingly expensive to acquire. Heavier satellites also tend to have larger payload mass fractions and more redundancy and therefore longer lifetimes (up to 15 or more years for the latest generation). When Ariane 5 and Sea Launch become operational, we expect manufacturers will respond by building larger satellites to take advantage of the increased launch capability.

It is interesting to note that the increasing weight-growth trend for commercial communication satellites is counter to the weight-reduction trends evident for civil and military payloads. All these weight-growth trends are driven largely by the availability and affordability of space launch.

Near-Term Spacelift Requirements

LEO Payload	Military	Civil	Commercial	Total
Small (< 5000 lb)	1 to 2	4 to 8 per yr (Experiments, weather)	16 to 32 per yr (LEO com. sats. primarily)	21 to 42 per yr
Medium	7 to 11 per yr	1 to 4 per yr	22 to 49 per yr (LEO, GEO com. sats.)	30 to 64 per yr
Heavy (expendable) (> 40,000 lb)	2 to 3 per yr	1 every 4 or 5 yrs (Cassini type)	4 to 6 per yr (GEO com. sats.)	6 to 10 per yr
Heavy (STS)	---	7 to 8 per yr (Space Station)	---	7 to 8 per yr
References	National Mission Model	NASA ELV and Upper Stages Program Planning; NASA ELV Long Range Planning	DOT LEO Commercial Market Projections; COMSTAC Mission Model	

Near-Term Spacelift Requirements

Summary of the projected launch rates for all sectors in the 2000-to-2010 time frame. The detailed database on which this summary chart is based is documented in Appendix 1. A range of launch-rate estimates is given for each payload weight category. The lower or "conservative" flight-rate estimate is based on judgment factors that reflect our estimates of the likelihood that each mission will actually fly. It was assumed, for example, that only 50% of the planned Big LEO commercial communication satellites will actually be launched. For more established commercial markets, such as GEO communication satellites, the factors are higher. It was also assumed that most planned military and civil missions will actually fly. (The factors used in the study are listed in the detailed database.) The upper or "optimistic" estimate assumes all planned missions in every category will fly.

The overall assessment of demand shows the number of launches by weight to orbit class broken down into Small (less than 5000 lb to LEO), Medium and Heavy (40,000 lb or more) lift categories for the three business sectors. In the detailed database, the Medium category is further broken down into Small - Medium, Medium and Medium - Heavy. Ambiguity arises from the fact that Big LEO satellites can be stacked in multiples. Reasonable estimates were made of the number of Big LEO satellites that might be stacked, but the reader should keep in mind that there is a good deal of uncertainty in the relative flight rates among the median categories. (The specific assumptions on multiple payload stacking are documented in the detailed database.) The uncertainty due to the variety of stacking options is another reason why there is a large range of flight-rate estimates for the medium-lift category (30 to 64 flights per year).

One final note: The RLV was not considered in developing the flight-rate estimates for conventional missions. For servicing flights to the space station, for example, the RLV is expected to replace STS flights on an approximately two-for-one basis, which would increase the flight-rate estimates presented here.

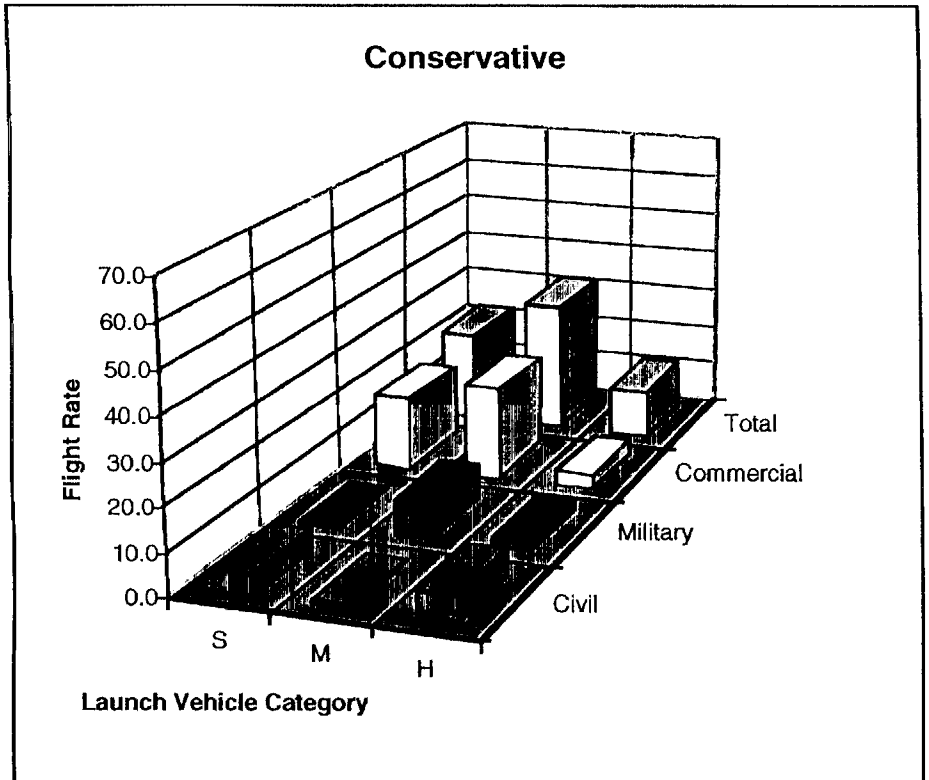
Projected vs. Present Actual Launch Rates

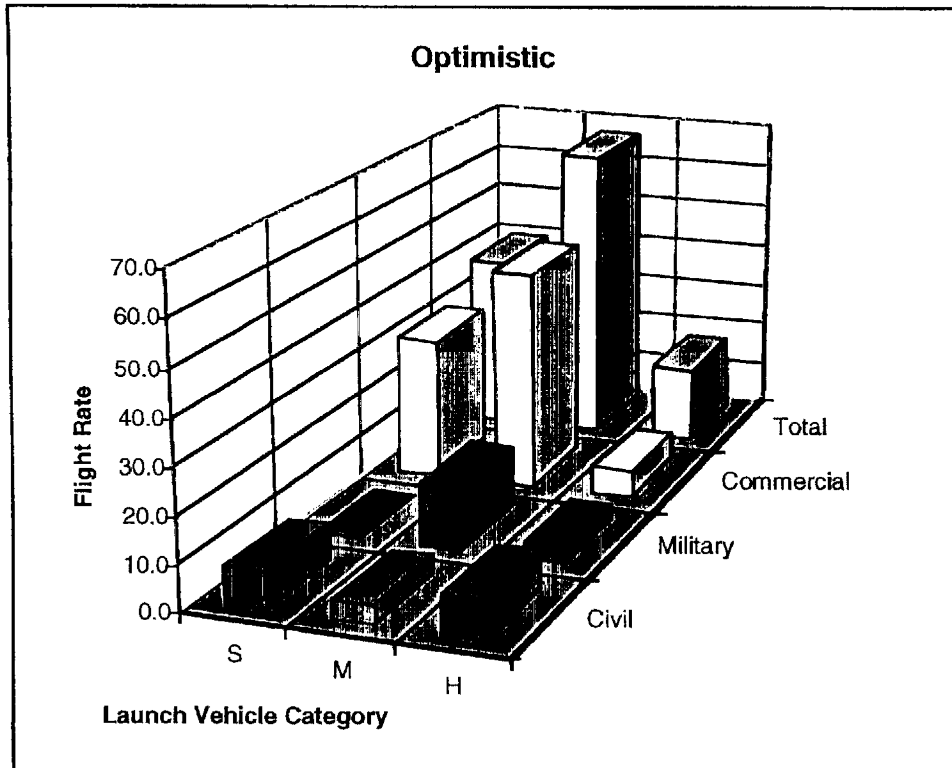
LEO Payload	Projected 2000-2010	1996 Actual
Small (< 5000 lb)	21 to 42 per yr	5 per yr
Medium	30 to 64 per yr	27 per yr
Heavy (expendable) (>40,000 lb)	6 to 10 per yr	5 per yr
Heavy (STS)	7 to 8 per yr	7 per yr

Projected Vs. Present Actual Launch Rates

Substantial growth in flight rates are expected in the small- and medium-lift categories. Flight rates in the small-lift category (< 5000 lb) may increase from four to eight times over present flight rates to replace individual satellites in constellations. Flight rates in the medium-lift category could double. Flight rates in the heavy-lift category (> 40,000 lb) may also increase somewhat, depending on the demand for launching heavy military satellites and possibly new markets for heavy (10,000 lb or larger) GEO communications satellites.

Flight Rates by Sector (Excludes Teledesic)

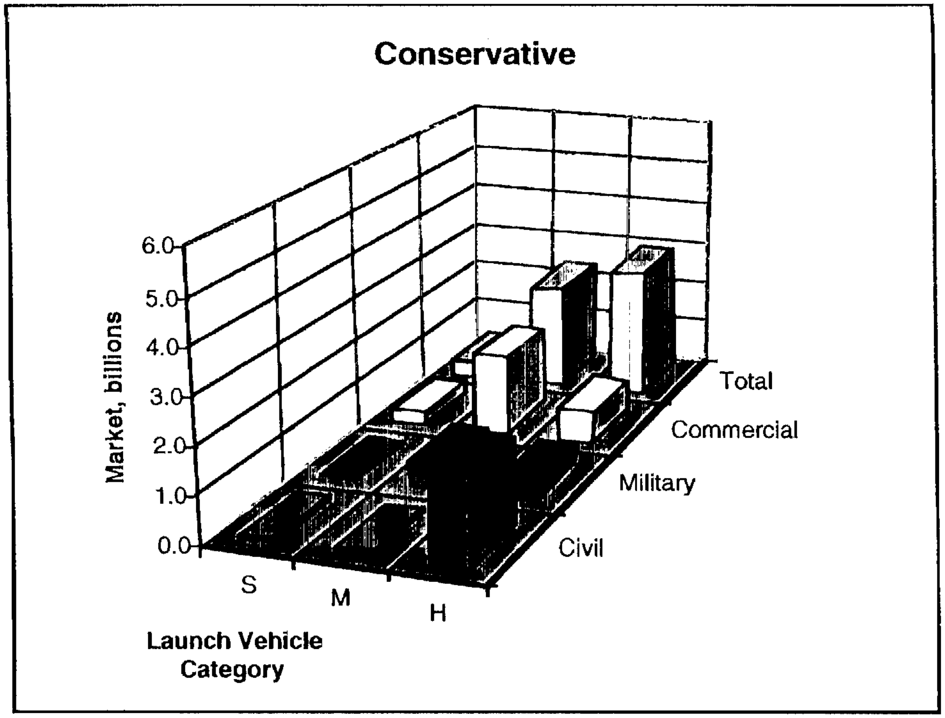


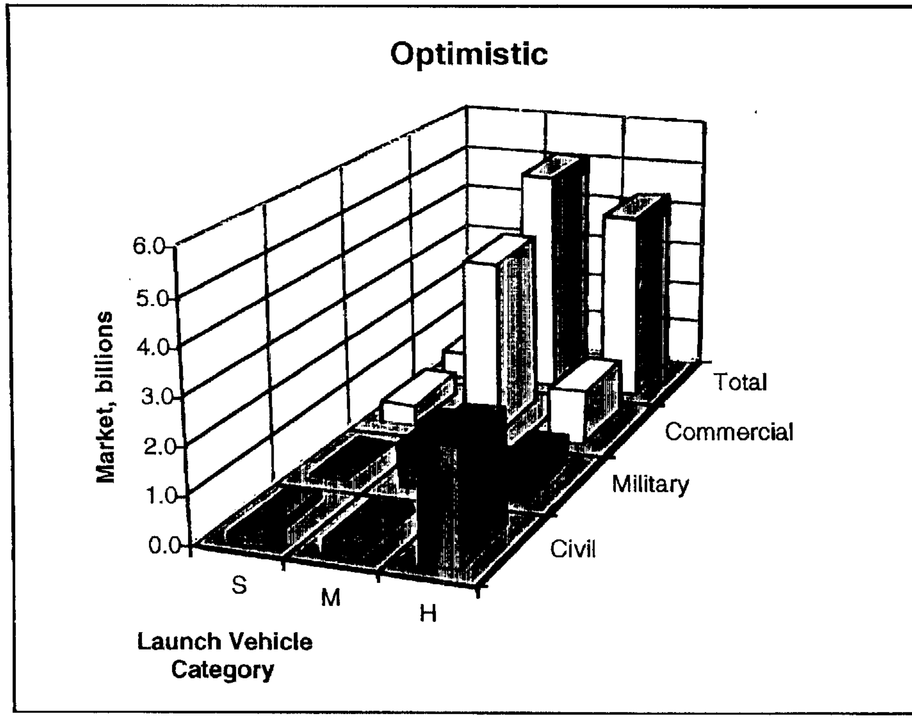


Flight Rates by Sector

The two categories with the largest projected flight rates are commercial small- and medium-class payloads. The plots in this chart are the summary conservative and optimistic flight-rate estimates listed in the previous charts. The military and civil flight rates are projected to be substantially lower than commercial flight rates in the 2000-to-2010 time frame. (Again note, however, that the commercial category contains both U.S. and non-U.S. commercial launches.) Most heavy-lift flights (Titan 4 or EELV and STS) will be civil and military, though the weight-growth trend in GEO commercial communication satellites (discussed in a later chart) may increase heavy-lift commercial flights in the future.

Markets by Sector (Excludes Teledesic)





Markets by Sector

The largest space-transportation market in the 2000-to-2010 time frame is expected to be the commercial medium-lift category. In order to provide an estimate of the relative sizes of the space-transportation markets, we multiplied the flight rates in each category by the following typical launch prices:

Small:	$ 15 million	(Pegasus)
S - M:	$ 25 million	(Taurus)
Medium:	$ 60 million	(Delta)
M - H:	$100 million	(Atlas IIAS)
Heavy:	$200 million	(Ariane 5)
STS:	$300 million	

The Small category market is relatively small, despite projected flight rates that range from 20 to 40 flights per year. (Most commercial launch developers, such as Space Access, will compete in the Small launch category.) The heavy-lift civil market looks large because of the present high cost of the Titan 4 and STS, but in a true sense does not represent a commercial space-transportation market opportunity.

Teledesic Impact On Launch Rates

LV Class	Stacked SVs	Assumed Allocation	Build-Up Launch Rate 1 Yr	2 Yrs	3 Yrs
Delta III	5/LV	150 (51%)	30 per yr	15 per yr	10 per yr
Atlas IIAR	6/LV	144 (49%)	24	12	8

- Maximum build up (288-sat constellation, 1-yr build-up) requires about 54 launches in Atlas IIAR/Delta III class
- Probable build-up, 3-year build-up) requires about 8-10 launches per year in each of the 2 LV categories considered
- Conclusion: Probable Teledesic build-up launch rates within world-wide launch capacity

Teledesic Impact On Launch Rates

Teledesic launch requirements are within the world's projected launch capacity. At the beginning of this study we were uncertain whether to include Teledesic with the conventional applications or include it as one of the futuristic innovative applications. It was decided to consider launch requirements for Teledesic separately, believing at that time that Teledesic's launch requirements might completely dominate the conventional applications flight-rate estimates. During the course of the study, however, Teledesic revised its constellation design, dramatically reducing the constellation size from 840 satellites to 288 satellites.

Since Teledesic has not published specific launch plans and manifests, it was necessary to make rough assumptions about what types of launch vehicles would be used and how the Teledesic satellites would be stacked. Though our estimates are highly tentative (Teledesic's plans are in considerable flux at the time of this writing), it is estimated that a 288-satellite constellation could probably be deployed over a three-year period by Delta III and Atlas IIAR, each flying about 8 to 10 flights per year. This hypothetical launch strategy would add a total of 18 flights per year to the medium-lift category, bringing the total flight-rate to between 48 and 82 flights per year during the three-year deployment period. This marginal increase in flight rates is still well within the world's medium-lift capacity predicted to be available in the 2000-to-2010 time frame. (A later chart addresses launch capacity.)

Teledesic (and similar recently announced systems such as Motorola's Celestri concept) will want to deploy much faster than the three-year deployment period assumed in our analysis. The financial costs on the invested capital at the time of the first launch will probably be on the order of $1 billion per year (on a total investment of between $8-$12 billion dollars). Thus, launching the entire constellation in two years, instead of three, would provide much needed revenue (estimated to be several million dollars per year) one year earlier. (Service cannot start until nearly all of the satellites have been deployed and crosslink connectivity established.) The deployment rate is limited primarily by launch-pad and launch-crew availability. Teledesic would probably choose additional types of launchers beyond the two U.S. launches we assumed in this analysis. A very likely scenario, in our opinion, is that Teledesic will redesign the constellation, reducing the number of satellites from 288 to less than 100 and possibly reducing the orbital inclination as well, in order to be able to launch the entire constellation in a shorter period of time and be able to generate revenue sooner.

Launch Rates and Market Estimates

Sector	Description	Orbit	Launch Vehicle Category	Conservative Flight Rate	Optimistic Flight Rate	Conservative Market (millions)	Optimistic Market (millions)
Commercial	Remote Sensing	LEO-P	S	2.0	4.0	30	60
Commercial	Remote Sensing	LEO-P	M	1.0	3.0	25	75
Commercial	Little LEO Deployment	LEO	S	4.6	9.2	69	138
Commercial	Little LEO Deployment	LEO	M	0.4	0.8	10	20
Commercial	Little LEO Replenishment	LEO	S	4.9	9.8	74	147
Commercial	Big LEO - Deployment	LEO	M	5.5	10.9	300	599
Commercial	Big LEO - Replenishment	LEO	S	4.3	8.6	65	129
Commercial	MEO Comsats - Deployment	MEO	M	0.9	1.7	94	187
Commercial	MEO Comsats - Replenishment	MEO	M	0.4	0.7	21	42
Commercial	Mega LEO - Deployment	LEO	M	0.0	21.0	0	2310
Commercial	Mega LEO - Replenishment	LEO	S	0.0	8.4	0	126
Commercial	GEO Comsats (small)	GEO	M	5.3	9.4	318	564
Commercial	GEO Comsats (medium)	GEO	M	8.1	22.4	891	2462
Commercial	GEO Comsats (heavy)	GEO	H	3.6	6.0	720	1195
Military	LEO-Polar platforms	LEO-P	S	1.1	2.0	16	30
Military	LEO-Polar platforms	LEO-P	M	1.2	2.5	70	150
Military	MEO platforms	MEO	M	2.8	3.3	168	198
Military	GEO platforms	GEO	M	1.8	3.3	106	198
Military	GEO platforms	GEO	H	0.8	0.8	154	165
Military	Classified Missions		M	1.2	1.4	74	85
Military	Classified Missions		H	1.4	1.5	289	308
Civil	LEO Applications	LEO	S	0.6	0.9	9	13
Civil	Remote Sensing	LEO-P	S	3.4	3.9	51	59
Civil	Remote Sensing	LEO-P	M	0.5	1.5	30	86
Civil	Science Applications	HEO	M	0.0	0.3	0	11
Civil	Science Applications	HEO	H	0.0	0.1	0	25
Civil	Science Applications	GEO	M	0.0	0.8	0	45
Civil	Interplanetary Missions	PL	S	0.5	1.1	8	16
Civil	Interplanetary Missions	PL	M	0.0	1.5	0	70
Civil	Interplanetary Missions	PL	H	0.0	0.1	0	25
Civil	Unspecified Orbit		S	0.0	2.1	0	33
Civil	Space Station (using STS)	LEO	H	6.0	8.0	1800	2400

Launch Rates and Market Estimates

GEO com. sats. In the medium and heavy launch vehicle classes make up the vast majority of the future commercial spacelift market. This chart provides more detail behind the summary results presented in the previous charts. Each line in the table is actually a roll up of a detailed spreadsheet database developed for each individual mission. (Appendix 1 contains the detailed data.) The "Mega LEO" entry refers to Teledesic, and in this particular example reflects an optimistic estimate of 21 flights per year of a medium-class launch vehicle. The summary results presented in previous charts do not include Teledesic, however.

Special Studies Using Conventional Data

- Space transportation demand vs. supply
  - Conclusion: Probable oversupply of medium-to-heavy launchers in 2000 - 2010 time frame
- Market capture analysis for reusable upper stage for RLV
  - Conclusion: About 16 missions per year (mostly commercial) might fly on reusable upper stage
- Big LEO space-transportation market and the RLV
  - Conclusion: RLV capacity (40,000 lb) too large for efficient replenishment of LEO constellation
  - Conclusion: Potential Big LEO market for smaller (5000 lb - 10,000 lb class) low-cost RLV

Special Studies Using Conventional Data

Special, focused studies. This chart presents the bottom-line conclusions of a number of special studies, requested by NASA and others, which are representative of the types of questions that can be answered using the conventional spacelift database. Each of these three studies is discussed in more detail in the following charts.

Near-Term Medium-Lift Capacity

Vehicle	Flight Rate (per yr) Typical	Max
Delta II/III*	10	17
Atlas II Class*	12	12
Ariane V**	14	20
Long March 2E***	3	5
Proton***	8	18
H2	2	4
Sea Launch	6	9
Total	55	85

*One of these classes may be replaced by EELV with 10 to 15 flights per year, including heavy-lift variant.

**Twice actual launch rate -- assumes two satellites per launch.

***Commercial launches. U.S. export restrictions end in year 2000.

Near-Term Medium-Lift Capacity

Estimate of the world's medium-lift launch capacity in the 2000-to-2010 time frame. These estimates do not include EELV which may eventually replace military Delta and Atlas flights and perhaps add an additional capacity of up to 20 commercial flights per year. Nor do these estimates include the proposed RLV, which would add an additional capacity of up to 42 flights per year (about 16 of which would be space station servicing missions, which would replace about 7 or 8 STS flights per year).

The maximum flight rates are limited primarily by launch pad and crew cycle times. Production of the flight hardware can probably be increased well beyond the maximum flight rates assumed in the chart. During the 1960's, for example, production of the Atlas ICBMs reached a level of 30 per month.

Medium-Lift Demand Vs. Capacity

- Flight-rate estimate for 2000 - 2010 time frame includes commercial, U.S. civil, and U.S. military but excludes Teledesic

Projected Demand		World-Wide Capacity	
Conservative	Optimistic	Typical	Max
30 flts/yr	64 flts/yr	55 flts/yr	85 flts/yr

- Conclusions:
  - Potential over capacity in medium-lift category
  - Reliability, infrastructure investment and other factors may limit actual supply
  - RLV will add capacity of about 42 flights per year

Medium-Lift Demand Vs. Capacity

Oversupply of medium-lift capacity projected. This chart compares the projected satellite demand for medium-lift launches to the launch-capacity estimates presented in the previous chart. These data suggest, based on average flight rates, that there may be as much as a 50% oversupply of medium-lift launchers in the 2000-to-2010 time-frame, a finding consistent with conclusions of other recent studies. These estimates assume that all these launch systems remain operating in this time frame.

Earlier charts explained that deployment of Teledesic might add approximately 18 medium-lift flights per year over a three-year period, a significant increase in demand, but still not large enough to cause a shortage of launch capacity.

The significance of these excess-capacity projections should not be overlooked. The present (temporary) shortage of launch vehicles is due to the spike in demand caused by the deployment of new generations of GEO communications satellites, the present export restrictions on Russian and Chinese launchers, and start-up problems with the H2 and Ariane 5 launchers--conditions which are expected to be largely mitigated after about 2002. A new medium-lift launcher trying to enter this market, such as the proposed commercial RLV, will face considerable price competition in government subsidized markets. Future launch prices, which present supply and demand factors have driven up, may begin to fall as export controls end and new launchers come on line.

FSRS Vs. NASA RLV Baseline

	NASA*	FSRS
Civil	16 flts/yr	21 flts/yr
Military	14	5
Commercial	12	14
	42	40

- Differences in military flight-rate estimates due to polar-orbit constraints and decreasing military launch rates.
- Estimated commercial flight rate is highly uncertain and depends on upper-stage options available with RLV.

*Shaw, E. J., "Reusable Launch Vehicle Economics: The RLV Case Study Model," NASA Briefing, 1996.

FSRS vs. NASA RLV Baseline

This chart compares the near-term RLV mission capture model used in this study to the RLV mission model assumed in a NASA study. The FSRS model assumes that the RLV will capture more civil flights (21 vs. 16) and slightly more commercial flights (14 vs. 12) than the NASA model. The NASA model assumes the RLV will capture 14 military flights per year, whereas this study projects that the number of potential military missions captured is likely to be much lower, perhaps only five per year. The large difference in military flights arises in part because many military missions are launched into polar orbits (there are presently no plans for the RLV to launch into polar orbits) but mostly because the overall military launch rate is projected to decrease in the future due largely to the fact that lifetimes of future military satellites are expected to increase by 40 to 50% over present satellite lifetimes.

RLV/Reusable Upper Stage Market Capture

- Identify civil, military and commercial missions that could be launched by RLV and reusable upper stage
- Probability factors applied to optimistic flight-rate estimates:
  1. Probability planned missions will actually fly
  2. Probability RLV will capture missions that fly
  3. Probability reusable upper stage will capture MEO/GEO missions that fly on RLV

- Study requested by Steve Creech (NASA, X-37 Program)

RLV/Reusable Upper Stage Market Capture

An estimate was made for the number of flights captured by a reusable upper stage that takes payloads from LEO to MEO or GEO (e.g., a reusable space tug that flies out of the RLV) using the database of projected military and civilian flight rates in the 2000-to-2010 time frame. The total number of LEO missions "captured" by a proposed new launch system is calculated based on the projected flight rate for each mission, the estimated probability that each mission will actually fly and the probability that the mission will be captured by the new launch vehicle.

Potential Market Capture

	RLV	Reusable Upper Stage
Civil	21 flts/yr	1 flt/yr
Military	5	4
Commercial	14	11
	40	16

- Most upper-stage missions are commercial
- Commercial estimate highly dependent on uncertain market-capture assumptions
- RLV flight-rate estimates based on FSRS data and differ from NASA's RLV baseline mission model

Potential Space Tug Market Capture

An economical reusable RLV space "tug" could capture about 16 missions per year, mostly commercial GEO com. sats. This chart shows market capture estimates computed for the RLV and a hypothetical reusable upper stage or space tug. The assumptions for this example are fairly conservative:

1. DBS (military Direct Broadcast Service) and Teledesic are assigned a zero probability of flying. SMTS (Brilliant Eyes) is given a 25% chance. And 33% of the proposed Big LEO systems are assumed to fly.
2. The RLV captures all non-polar military and civil missions in its weight class. STS missions to the space station are replaced on a two-for-one basis.
3. The RLV captures 50% of the smaller GEO com. sats. and 100% of the Big LEO systems. The RLV does not capture large commercial GEO com. sats. (too heavy).
4. The reusable upper stage captures all of the MEO/GEO missions that fly on the RLV.

Obviously changing any of these assumptions will produce different market-capture estimates.

Projected Big LEO Flight Rates

- Flight-rate estimates assume:
  - Big LEO satellites launched 5 - 6 at a time on medium-lift LVs
  - Replenishment sats are launched 1 at a time on small LVs

Small LVs		Medium LVs	
Conservative	Optimistic	Conservative	Optimistic
14 flts/yr	28 flts/yr	7 flts/yr	14 flts/yr

Projected Big LEO Flight Rates

Deployment and sustainment of Big LEO constellations will require many medium and small launcher flights, but the actual flight rates are highly uncertain at this time. A special separate study was performed using the conventional mission database to determine how well the proposed RLV's requirements match Big LEO replenishment requirements. As a first step a range of estimates for Big LEO launch rates for different classes of launch vehicles was compiled. It was assumed that about 75% of Big LEO satellites would be launched in stacks of five or six on medium-lift launch vehicles. (Iridium, for example, deploys five satellites at a time on a Delta II launcher.) The remaining 25% of Big LEO satellites are assumed to be deployed one at a time by small (<5000 lb LEO capacity) launchers to replenish individual outages in the constellation.

Depending on the orbit inclination and launch price, the RLV might be able to capture a significant fraction of the deployment market, launching 6 to 12 satellites at a time. The following chart addresses the RLV's ability to capture the Big LEO replenishment market.

Big LEO Replenishment Efficiency

Parameter	GPS	Iridium	Teledesic (840 sats)
Sat/orbit plane	4 sats	11	44
No. of planes	6 planes	6	21
Sats/LV	1 sat	2	3
Sats/LV	2 sats	4	6
Sats/LV	8 sats	16	24
Excess*	0%	4	2
Excess	12%	14	6
Excess	88%	68	26

*Percentage of replenishment sat lifetime spent as "excess" spare. Calculated from

$$\text{LOSS} = \frac{1}{N}\left[\frac{M+1}{2} - 1\right]$$

where N is number of sats per orbit plane and M is number of sats per LV.

Big LEO Replenishment Efficiency

The RLV's 30,000- to 40,000-pound lift capacity to LEO is not well suited to the mission of replenishing Big LEO constellations. If more than one satellite is launched to replenish a single failed satellite, then the additional satellites beyond the one needed to replenish the failed satellite must "wait" to go into service until other satellites in the orbital ring fail. The replenishment efficiency loss factors calculated in this chart are the approximate percentages of satellite lifetime "lost" as an "excess" spare. If failed satellites are replenished one at a time the loss factor is zero. (The loss formula assumes satellites do not change orbital planes.)

For two stacked satellites per launch, the replenishment efficiency loss is probably negligible (2% to 9%), but with eight satellites per launch (typical of RLV replenishment launches for Big LEO constellations) the replenishment efficiency loss can be quite large (26% to 88%), depending on the number of satellites per orbital ring.

The loss factors for Teledesic (the third column) are based on the original 840-satellite constellation. For a 288-satellite Teledesic constellation, the replenishment efficiency loss will be higher, again depending on the final number of satellites per orbital ring.

These replenishment efficiency calculations suggest that, unless the RLV is significantly more economical than smaller launchers, or additional satellite fuel is allocated for orbital plane changes, the RLV's large capacity is not well suited for Big LEO replenishment launches. Delta II-class launchers (or even smaller) that carry two or three Big LEO replenishment satellites would be more efficient in terms of constellation maintenance. In fact, several small commercial reusable launcher concepts such as the Kelly Space Plane are targeting the Big LEO replenishment market.

Commercial Demand Elasticity and the RLV

- **Question addressed:** Is there sufficient commercial demand elasticity to allow the RLV to be developed entirely as a commercial venture?

- **Conclusions:**
  - Private capital for LV development limited to about $1 billion due to payback requirements
  - Government "anchor tenant" flights will not push demand and prices into elastic region
  - RLV must be priced "at the market" to recover costs-- demand will not "take off"
  - Conclusions agree with other studies

Commercial Demand Elasticity and the RLV

Private development of RLV is considered. Economic relationships among launch price, annual flight rate, government and private development cost shares, and flight operations costs were explored in a simple finance model. A key aspect of the calculations is a parametric elastic-demand relationship between the commercial flight rate and launch price. The usual approach in launch-vehicle finance analysis is to assume a fixed "mission model" or constant flight rate and a "target" launch price and then calculate the resulting rate of return on the development investment. This model assumes a 25% ROI and by iterating parametric models for demand and operations costs, finds the required "market equilibrium" launch rate and price. The model results (discussed in the following charts) suggest that the payback period for government-funded development is minimized when there is some level of cost sharing with private industry.

Commercial Space Transportation Study

- "Alliance" of aerospace companies* performed market study from June 1993 to April 1994 under contract from NASA Langley
- Focus on potential applications and markets rather than system solutions
- Developed commercial demand "elasticity" data based on extensive market analysis

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*Boeing, General Dynamics, Lockheed, Martin Marietta, McDonnell Douglas and Rockwell (now just two companies!)

Commercial Space Transportation Study

Demand elasticity data from the Commercial Space Transportation Study (CSTS) provides a basis for evaluating the economics of a privately financed RLV. This study only considered "enabling" launch prices for innovative applications--the highest price at which significant space-transportation demand for an innovative application would occur. Lowering the launch price below the enabling price will, in most cases, increase the demand for a specific application beyond the demand at the enabling price. The slope of the demand vs. price curve (in log-log coordinates) is defined as the demand elasticity.

CSTS performed limited market analyses to estimate the demand elasticities for potential new commercial applications. The RLV elastic demand analysis described in the following charts is based on the commercial demand elasticity data for the 30,000-lb-to-LEO market provided in the CSTS report. In our estimate, the commercial demand data was augmented with a fixed number of government "anchor tenant" flights, which we assumed are not affected by the launch price.

The CSTS report considered potential new markets for space transportation that might open up if launch prices were reduced. The CSTS report did not address space transportation requirements beyond total LEO payload weight and launch price. We made the assumption that all 30,000-lb LEO payloads included in the CSTS data would fly on one class of RLV. This assumption biases the results in an optimistic manner, because if space transportation markets do expand at lower launch prices, then a variety of launch vehicles (probably subsidized by different governments, as today) would compete for a share of the market. No one launch vehicle would capture the entire market, as we have assumed here.

The CSTS report authors assigned confidence factors to each potential demand scenario ranging from "High Probability" (high confidence that demand will occur) to "Low Probability" (very speculative). The economic analysis results presented in the next charts are based on the "High Probability" data. Runs with the "Medium Probability" elasticity data showed the same basic trends.

RLV Cost Estimates

	NASA Baseline	Aerospace[1]	Koelle[2]
Development	$ 8.5 billion	$ 6.0 billion	$ 16.0 billion
Operations	300 million/yr 5 million/flt	320 million/yr 8 million/flt	400 million/yr 3 million/flt

Notes:

1. Cost estimates provided by Jay Penn (17 October 1996). Similar to Rockwell proposed design.
2. Cost estimates from paper by H. H. Koelle and D. E. Koelle, 47th International Astronautical Congress, 7 - 11 October 1996.

RLV Cost Estimates

Estimates of the cost to develop an RLV vary considerably. This chart shows the range of typical cost estimates for a 40,000-lb class single-stage-to-orbit reusable launch system using different cost models. The Aerospace estimate was used in the finance model results discussed in the next chart.

Elasticity Model

$$N_C = N_0 \left(\frac{P_0}{P} \right)^{\gamma}$$

N_C = flight rate at lower price P

N_0 = flight rate at present price P_0

CSTS Data	N_0	γ	P_0
Conservative	4 flts/yr	1.2	\$200 million
Optimistic	5	1.3	\$200 million

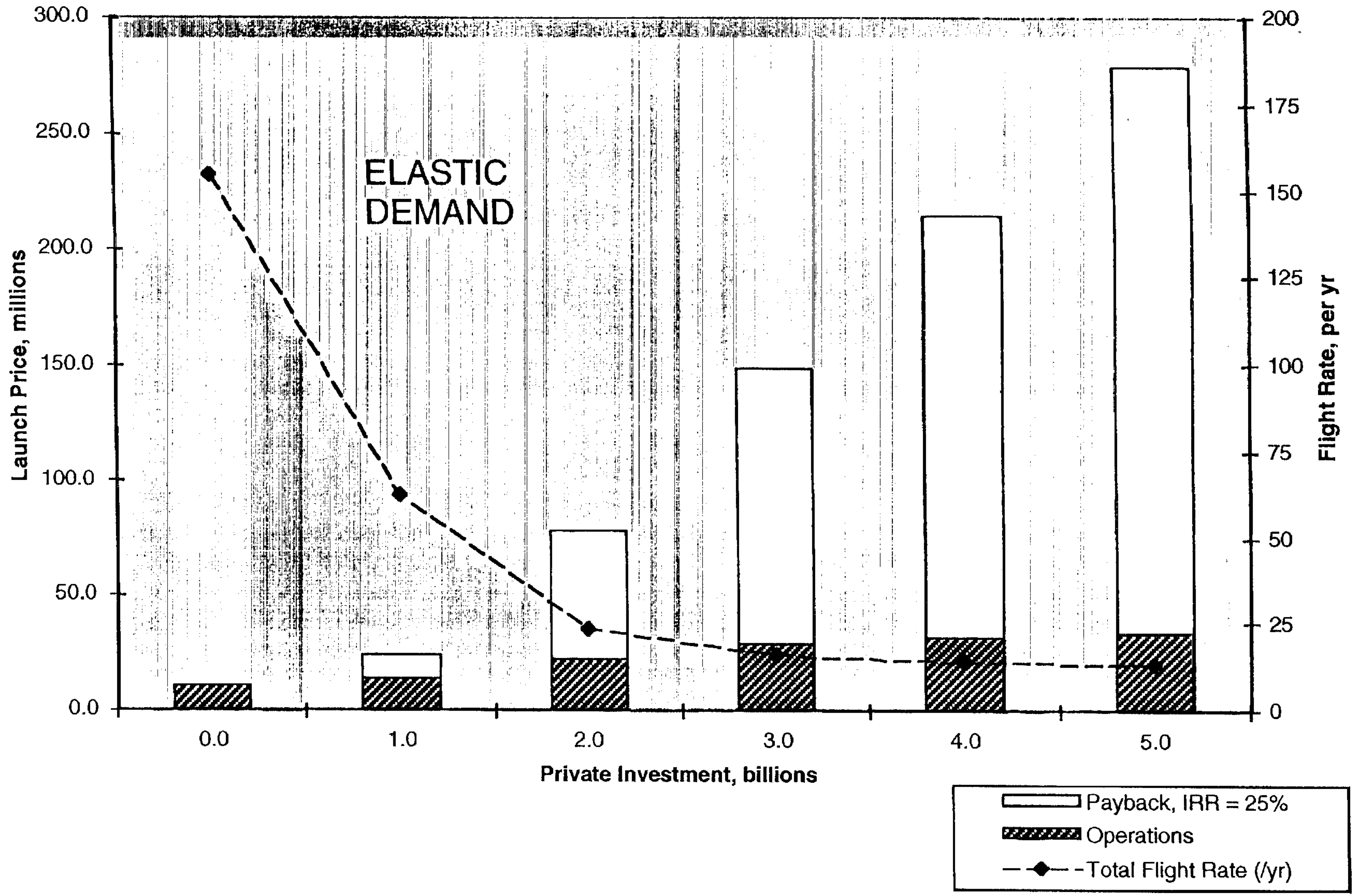
Elasticity Model

The commercial flight rate demand is assumed to be a function of launch price. The specific parametric form of the demand elasticity relationship is shown in the chart. The parameters of the elasticity model were fitted to the demand data given in the CSTS final report corresponding to a 30,000-lb LEO-equivalent launch vehicle. The CSTS data includes estimates of both commercial market capture and the enablement of new space applications. Of course, any such model is highly uncertain and even the CSTS "High Probability" elasticity scenario (the most conservative) must be considered largely guesswork. The total flight rate is the sum of the commercial and government flight rates.

The economic analysis assumes that the government flight rate is constant regardless of launch price. It is further assumed that some portion of the development of a new launch system is funded through private investment and that the launch price, at least during the first ten years of flight operations, reflects private-investment payback and ROI requirements.

A key aspect of the model is the assumption that there is an elastic demand relationship between the launch price and flight rate (for commercial payloads). Since the launch price in turn depends on the flight rate, the model must be solved in an iterative fashion to determine the market equilibrium price/flight-rate solution for each set of investment assumptions.

Launch Price, Demand, and Investment Payback



Launch Price, Demand and Investment Payback

Private investment in RLV development is likely to be severely limited unless the government provides loan guarantees or other subsidies to reduce the up-front costs and financial risks. This figure shows the launch-price/flight-rate market equilibria for levels of private investments ranging from $0 to $5 billion. (The total development cost is assumed to be $6 billion.) The inputs for the commercial flight rate are iterated manually in a spreadsheet until they match the High Probability elastic demand given in the CSTS report.

It is obvious from the plot that private investment levels beyond $1 or $2 billion cause a dramatic reduction in the flight rate because the increased payback burden kills commercial demand. This result is consistent with other launch-system concept studies, including a NASA study, which concluded that private investment in launch vehicle development will be limited to at most a few billion dollars unless government loan guarantees or other subsidies are available to investors.

On the other hand, the model suggests that there is a three- to four-year "payback" for the government investment, which appears quite favorable. In this particular example, the government payback period is minimized when private investment is $1 billion. A higher level of private investment increases the price and reduces the commercial flight rate so the government ends up paying substantially more per flight. With zero private investment the price is marginally lowered but not enough to offset the additional $1 billion government development cost.

The fact that government payback is optimized with <u>some</u> level of private investment is the most significant insight provided by an elastic demand/flight-rate model.

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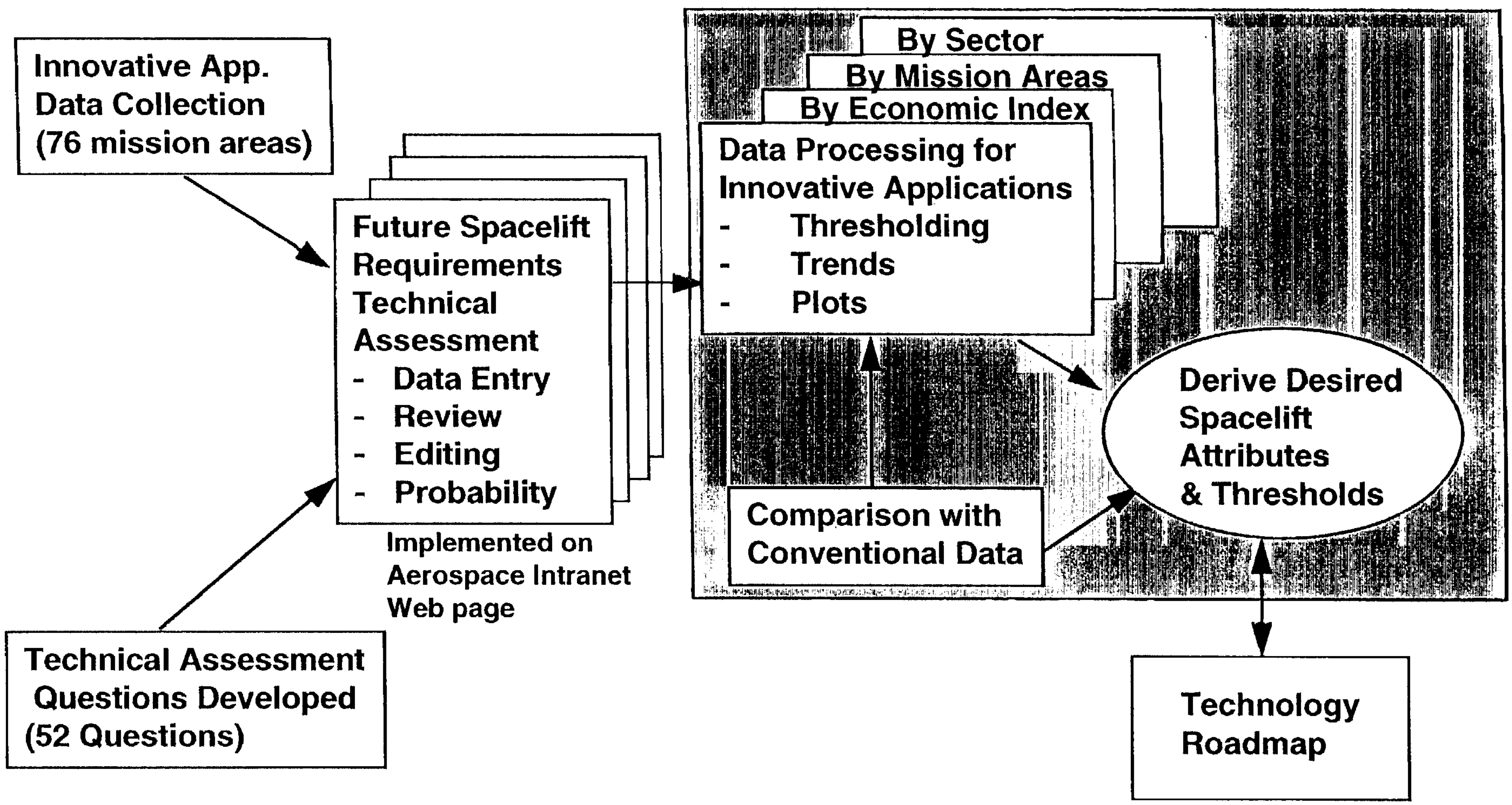
Innovative Applications

Innovative Applications Process Flow



Innovative Applications Assessment Process Flow

The Innovative Applications identification and assessment consisted of four parts: data collection, questionnaire development, technical assessment, and data processing and analysis. The data collection was from multiple sources, including the in-house resources of The Aerospace Corporation, industry, NASA, DOD and other government agencies. The data collection resulted in a total of 76 innovative applications grouped into 3 different mission areas: Civil (10), Commercial (41) and Military (25). Military applications included various categories such as Military Space Plane, Space Surveillance, Advanced Communications, Navigation and Weapons. Typical commercial missions include Space Business Park, Space Tourism, Rapid Package Delivery, Space Mining and Space Utilities, etc. Civil missions include Planetary Defense, Human Planetary Explorations, and Space Habitat.

Innovative Applications Process

- Examined potential future (2020 and beyond) applications that are currently not enabled
- Space transportation aspect only, and not economic or technical viability of application
- Innovative applications data collected in 76 mission areas
  - Defined initial deployment and servicing missions
- 52 technical assessment questions developed and then assessed for each application
- Aerospace web site developed for data collection and evaluation
- Space Transportation Economic Index (STEI) developed to filter data
- Determined application threshold characteristics
- Derived spacelift attributes from threshold characteristics

Innovative Applications Process

In order to characterize and define each of these concepts, a list of 52 questions was developed by an Aerospace team. The questions were grouped into 6 major space launch attribute areas (Affordability, Operability, Reliability/Safety, Reusability, Environmental and Performance).

In many cases, the available information for these innovative applications consisted of only a short notional description of the concept. In order to quantify space launch requirements for such sketchy ideas, a team of Aerospace experts further developed each innovative application to a workable solution, and estimated what spacelift characteristics would be needed to make the idea feasible. The process of technical assessment involved review of existing data as well as careful extrapolation of sketchy ideas to quantitative data.

All of the innovative applications were collected on an in-house developed Web site. The data collected were linked to an Excel spreadsheet. Key characteristics were charted and compared in each different sector, and can be grouped or charted in several different ways. This is a powerful capability that can accommodate any new data or input and organize the data to see what is the impact on space launch requirements. The data processing and analysis involved sorting, filtering, and plotting the data in various ways to view and understand the trends in the database. The spacelift attributes associated with the innovative applications database were then used in the technology assessment and the alternative futures assessment.

Innovative Applications for Military Sector

Seq. No.	Index No.	Application Type
1	(1)	Global Surv, Recon, and Targeting System - deployment
2	(1.1)	Global Surv, Recon, and Targeting System - servicing flight
3	(2)	Hyperspectral
4	(3)	Light, Affordable, On-demand Surveillance Sats
5	(4)	Military Spaceplane
6	(5)	Space Control
7	(6)	Space Mine
8	(7)	Space Surveillance
9	(8)	Space Traffic Control
10	(9)	Missile Warning
11	(10)	Bi-Static Radar
12	(11)	Orbit Debris Removal
13	(13)	Global Area Strike System (GASS)
14	(14)	Force (PGM) Delivery from Space
15	(15)	Interceptors
16	(16)	Delivery of Electromagnetic Radiation from Space - deployment mission
17	(16.1)	Delivery of Electromagnetic Radiation from Space - servicing flight
18	(18)	Solar-Powered High Energy Laser System. - deployment mission
19	(18.1)	Solar-Powered High Energy Laser System. - servicing flight
20	(19)	Space-Based High Energy Laser System - deployment mission
21	(19.1)	Space-Based High Energy Laser System - servicing flight
22	(20)	Ground-Based High Energy Laser System - deployment mission
23	(20.1)	Ground-Based High Energy Laser System - servicing flight
24	(21)	KEW Kinetic Energy Weapons
25	(23)	Communications

Innovative Applications Military Sector

The 25 types of military applications derived in this study are listed on this chart. The second column of the listing is the index number used in the database. Note that there are separate entries for the deployment and servicing missions.

Significant missions include communications, space control, surveillance, and military spaceplane. Note that what is implied by military spaceplane is not the transport itself, but the missions that would be filled or accomplished by it.

Particular attention was paid in the database development process to ensure that there is no double counting of missions in different guises.

Innovative Applications for Commercial Sector

Seq. No.	Index No.	Application Type
1	(28)	Communications - Positioning Satellite Services
2	(30)	Remote Sensing
3	(25)	Communications - Fixed Satellite Services
4	(26)	Communications - Broadcast Satellite Services
5	(27)	Communications - Mobile Satellite Service - deployment mission
6	(27.1)	Communications - Mobile Satellite Service - servicing flight
7	(29)	Space Manufacturing - deployment mission
8	(29.1)	Space Manufacturing - servicing flight
9	(34)	Transportation - Fast Package Delivery
10	(36)	Transportation - Space Tourism
11	(37)	Transportation - UHigh Speed Civil Transport
12	(39)	Transportation - Space Servicing and Transfer
13	(40)	Entertainment - Digital Movie Satellite
14	(44)	Space Utilities - Molniya - deployment mission
15	(44.1)	Space Utilities - Molniya - servicing flight
16	(45)	Space Utility - GEO - deployment mission
17	(45.1)	Space Utility - GEO - servicing flight
18	(46)	Space Utility - SunSync - deployment mission
19	(46.1)	Space Utility - SunSync - servicing flight
20	(47)	Space Utility - Lunar - deployment mission

Innovative Applications for Commercial Sector

There were 41 innovative mission types defined for the commercial sector. These fall into various mission categories such as new missions (settlements, medical, research facilities), communications, entertainment, transportation (tourism, delivery), utility and mining (energy and natural resources). Clearly, many of these applications are interrelated, so that enabling one application is likely to spawn others, and vice versa. For example, a space settlement will provide additional destination for tourism, while proven transport capabilities will further enhance the likelihood that people will want to settle in space or the moon. These higher order effects are not taken into account in this study. The database consists of rough first-order estimates for the quantities.

Innovative Applications for Commercial Sector

Seq. No.	Index No.	Application Type
21	(47.1)	Space Utility - Lunar - servicing flight
22	(48)	Space Utility - Space-to-Space Power Beaming
23	(49)	Space Advertising
24	(50)	Space Burial
25	(51)	Novelties
26	(52)	Space Product Demonstration
27	(53)	New Missions - Space Business Park - deployment mission
28	(53.1)	New Missions - Space Business Park - servicing flight
29	(53.2)	New Missions - Space Medical
30	(53.3)	New Missions - Space Settlements (O'Neill Habitats)
31	(53.4)	New Missions - Space Settlements (Lunar Outpost)
32	(53.5)	New Missions - Space Agriculture
33	(53.6)	Entertainment - Orbiting Movie Studio
34	(53.7)	Entertainment - Space Athletic Events
35	(53.8)	Entertainment - Space Theme Park
36	(56)	New Missions - Debris Removal
37	(58)	Space Mining - LOX - deployment mission
38	(58.1)	Space Mining - LOX - servicing flight
39	(59)	Space Mining - Helium-3 (He3) - deployment mission
40	(59.1)	Space Mining - Helium-3 (He3) - servicing flight
41	(60)	Nanosat Applications

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Innovative Applications Areas (Civil)

Seq. No.	Index No.	Application Type
1	(31)	Government Missions - Space Station Missions - deployment mission
2	(31.1)	Government Missions - Space Station Missions - servicing flight
3	(32)	Government Missions - Human Planetary Exploration
4	(33)	Government - Space Science Outwards
5	(22)	Super GPS
6	(35)	Transportation - Hazardous Waste Disposal
7	(12.1)	Planetary Defense -- Sky Survey
8	(12.2)	Planetary Defense -- Sky Guard
9	(12.3)	Planetary Defense -- System Development
10	(38)	Transportation - Space Rescue

Innovative Applications Areas (Civil)

Ten mission types were defined for the innovative civil applications. Prime examples include advanced space station, space and planetary exploration and science applications, space rescue, hazardous waste disposal, and planetary defense.

Technical Assessment Questionnaire

- Basic Information
  - Sector
  - Likely deployment period
  - Primary payload/cargo
- Reliability/Safety
  - Launch reliability required
  - Launch insurance considerations
  - Government indemnification requirements for launch services
  - Nuclear materials on board
  - Overflight over populated areas an issue
  - Safe abort requirement
  - Return-to-launch-site capability after abort
  - Crew/passenger ejection during ascent/descent

Technical Assessment Questionnaire

Listing of the technical assessment questions. The set of 52 questions developed to characterize the transportation needs of the applications cover the following categories of basic information: affordability, environmental compatibility, reliability/safety, reusability and performance. An Aerospace team developed answers to these 52 questions to provide information about the launch characteristics and any special needs of the applications in a standardized format. This process required developing insights into all aspects of the launch vehicle planning and operations process in order to determine which attributes of the applications would be relevant to determining the spacelift requirements.

An important question not addressed is the likelihood of occurrence of the missions. Clearly, some applications are more likely than others to occur, while others may never be implemented, even if the enabling launch transport considerations were satisfied. There is no direct measure of this factor in the database because it was deemed that since most of these innovative applications are somewhat far into the future, there are too many unknown factors that could influence their implementation. A methodology, termed Space Transportation Economic Index (STEI), was derived to provide one objective means to sort and prioritize the potential missions. This methodology is described and discussed in subsequent charts.

Technical Assessment Questionnaire (Cont'd)

- Performance
  - Payload to LEO
  - Orbit
  - Inclination
  - Estimated average flight rate
  - Est. flights for one-time surge
  - Confidence in flight rates
  - Multi-azimuth launch
  - Final-orbit injection required
  - Acceptable transition time to final orbit
  - Injection accuracy requirement (basic launch system)
  - Rendezvous requirement
  - Payload fairing/bay-size requirements
  - Max g-load and vibration requirement
  - Surge requirements (for individual launch vehicle)

Technical Assessment Questionnaire (Cont'd)

- Reusability
  - Crew Requirement
  - Return payload mass
  - Return-to-launch site requirements
  - Return cross-range requirement
  - On-orbit mission duration (for launch vehicle)
  - Affordability
  - Enabling launch price
  - Launch price elasticity
- On-orbit Operations
  - On-orbit refueling required
  - On-orbit payload change out required
  - On-orbit cargo transfer required
  - On-orbit crew transfer required (space suits)
  - On-orbit crew transfer required (shirt sleeves)

Technical Assessment Questionnaire (Cont'd)

- Launch Operations
  - Turn time (for launcher)
  - Schedule importance
  - Launch facilities range requirements
  - Time required to swap reintegrate substitute payload
  - Call-up time for space-transportation service
  - Rapid cool-down requirements for return payload
  - Launch range operations for application
  - Alternate landing site(s) required
  - Standing-alert capability
  - Payload fuel handling prior to launch
  - Payload fuel handling inflight/abort
  - Payload fuel handling and safing after landing
  - Launch during conflict conditions
- Environmental Compatibility
  - Environmental standards for applications

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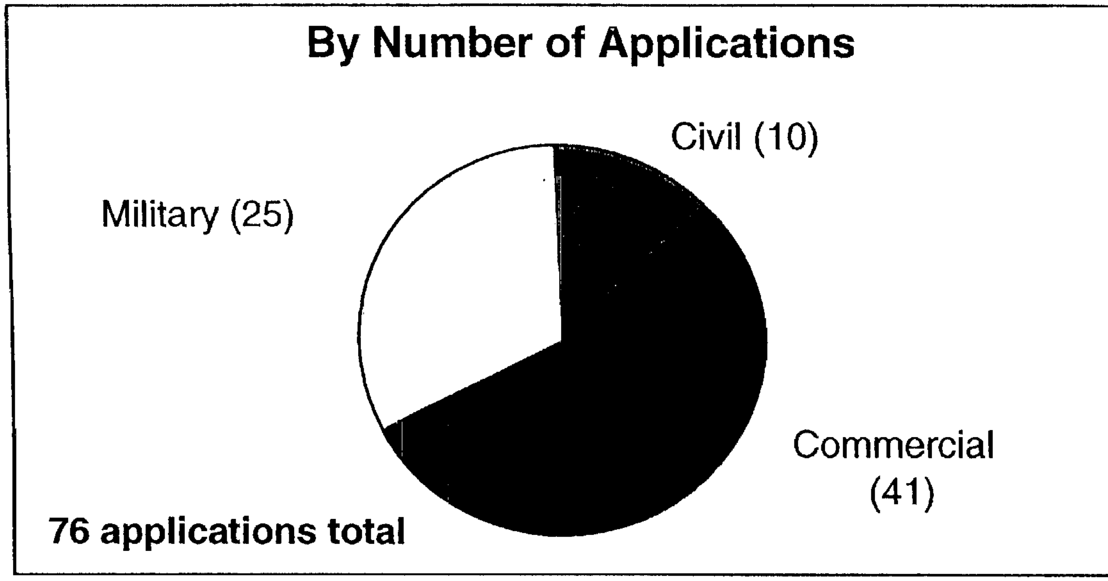
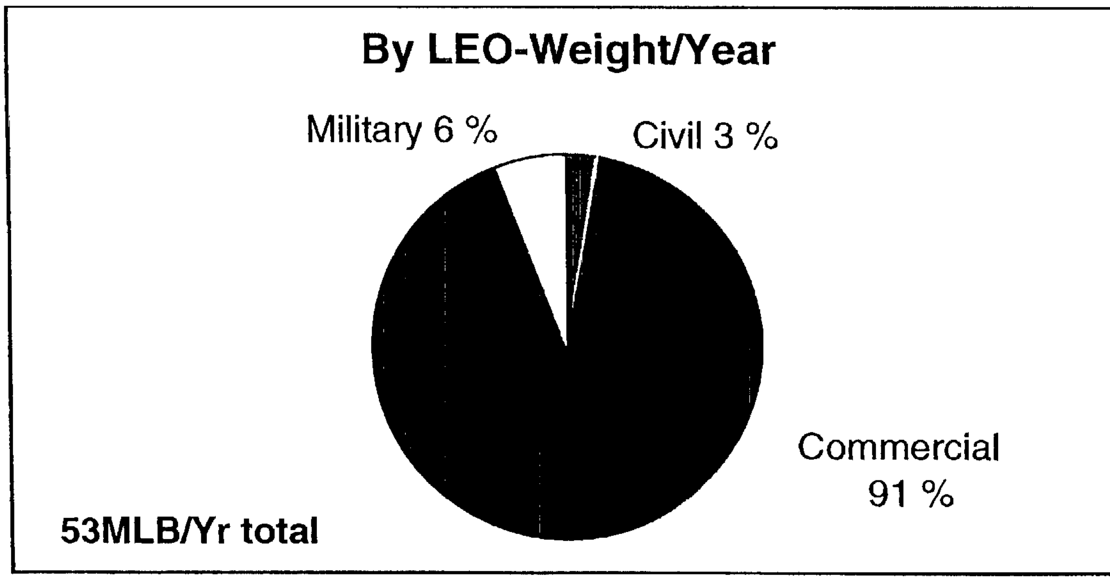
Innovative Applications Database: By Sectors

- **Civil**
  - Human Planetary Exploration
  - Space Station
  - Hazardous Waste
  - Planetary Defense
- **Military**
  - Military Spaceplane
  - Weapons
  - Space Control
  - Global Surv & Reconnaissance
- **Commercial**
  - Space Settlements
  - Rapid Package
  - Space Utilities
  - Space Tourism
  - Lunar Mining

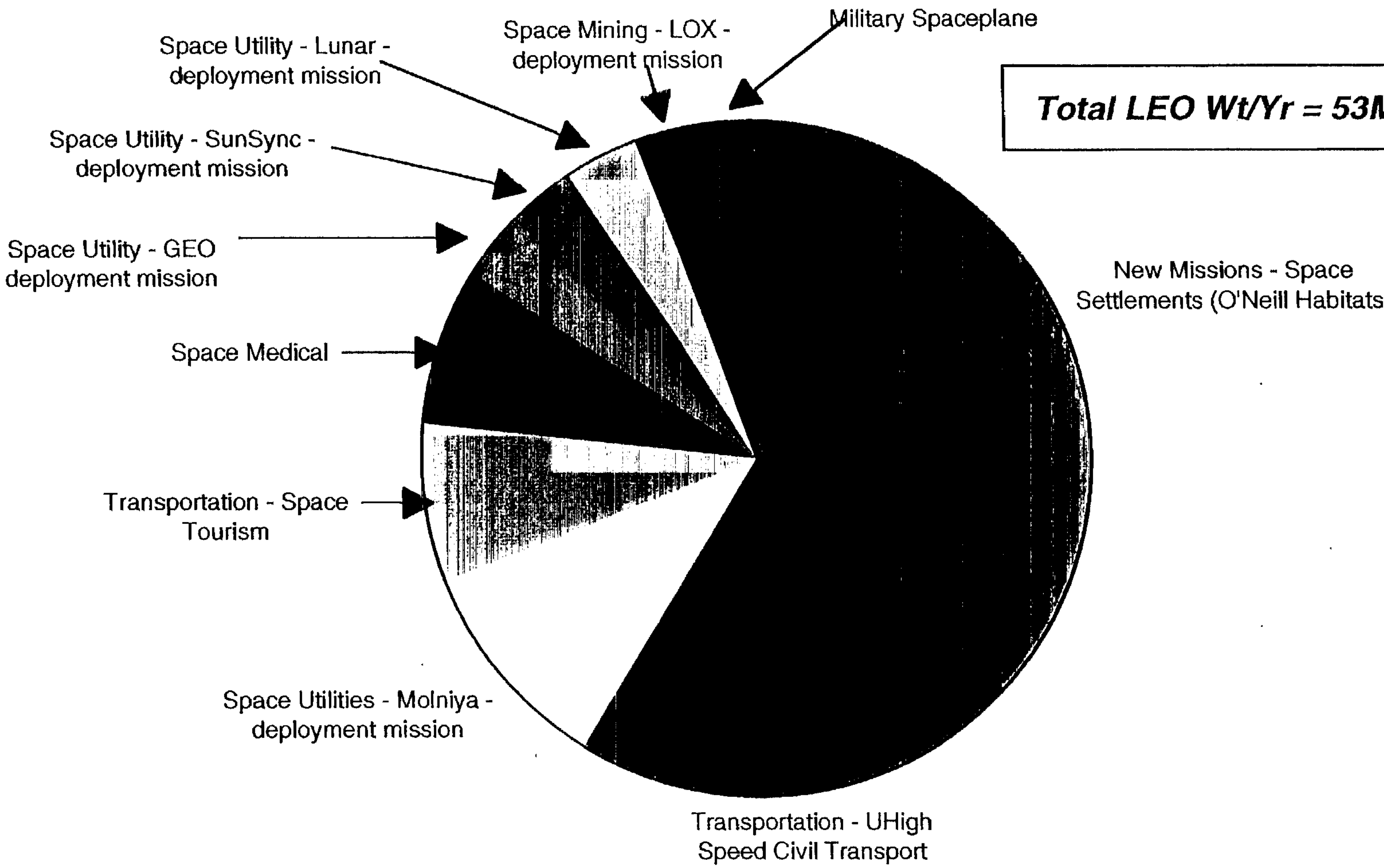




Innovative Applications Database: By Sectors

A broad breakdown of the entire database by sectors and representative missions is depicted here. The relative fractions of total missions in each sector (civil, military, and commercial) is shown by the number of applications and also by LEO weight per year. The commercial sector constituted the largest number of applications, and also dominated the database in terms of payload weight per year to LEO. Also listed are some typical representative missions for each of the sectors.

Largest 10 Applications by Weight/Year



Total LEO Wt/Yr = 53MLb/Yr

- 10 Applications account for 77% of total LEO Wt/Yr
- Initial deployment flights are spread over 5 years

Largest 10 Applications by Weight/Year

Largest 10 applications are shown for the entire innovative mission database. Several correlations were made to determine which types of applications and characteristics are prominent in the database (and therefore drive the spacelift requirements). The 10 largest applications by LEO weight per year are shown in a pie chart.

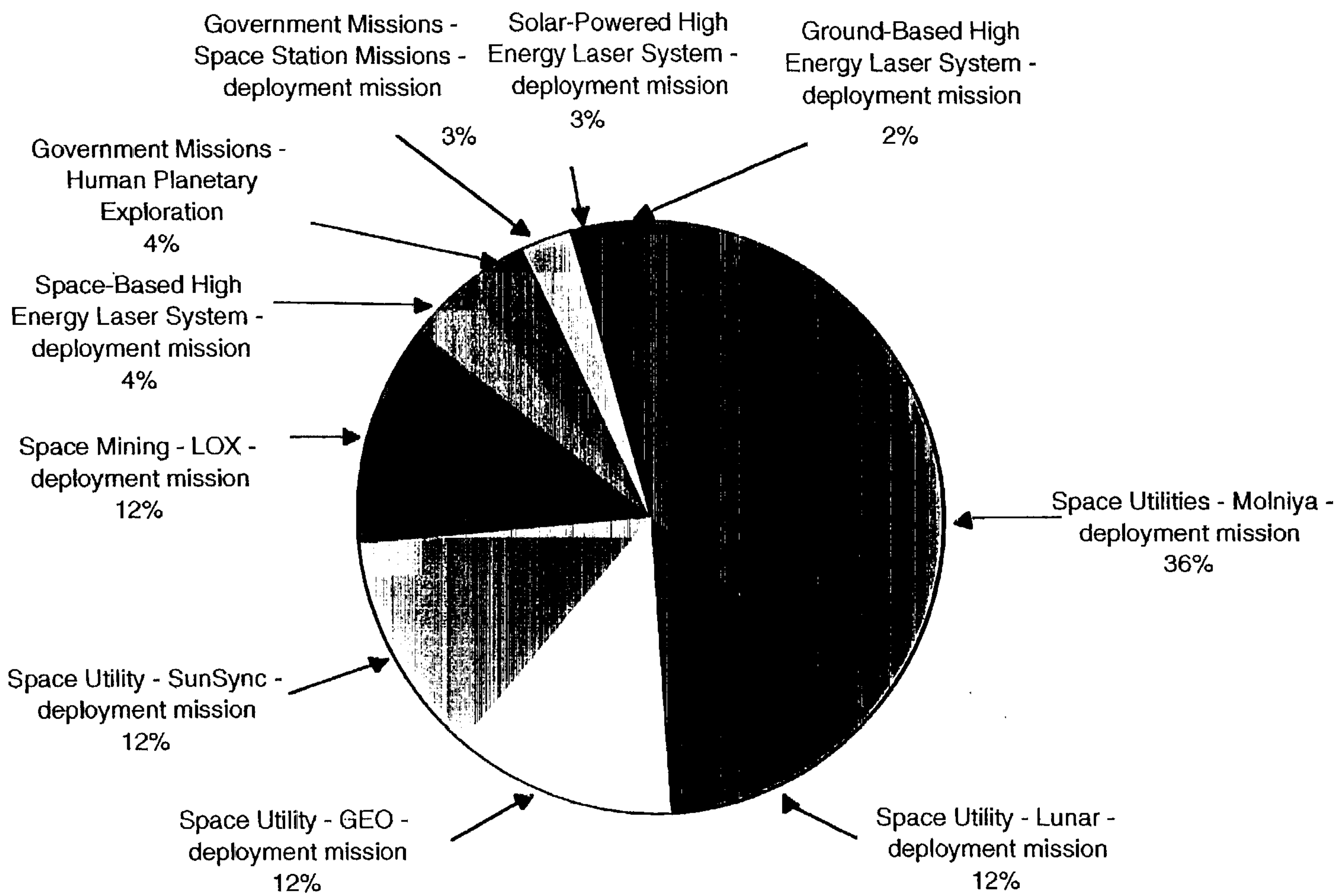
"LEO weight per year" will be used in subsequent charts, and is defined as follows:

LEO weight per year = LEO payload per flight * (# of recurring flights per year + # of initial deployment flights/5)

The database is populated by missions that are recurring (number of flights per year), one-time deployment (number of flights), or both. In order to normalize the data for comparison, the one time deployment missions are assumed to be spread over 5 years.

This assessment shows that 10 missions make up about 77% of the total annual weight to orbit. In fact, 3 missions make up about half the database by LEO weight per year.

Largest 10 Initial Deployment Missions



- 10 Applications account for 90% of entire initial deployment weight
- Total weight to LEO = 64 MLB

Largest 10 Initial Deployment Missions

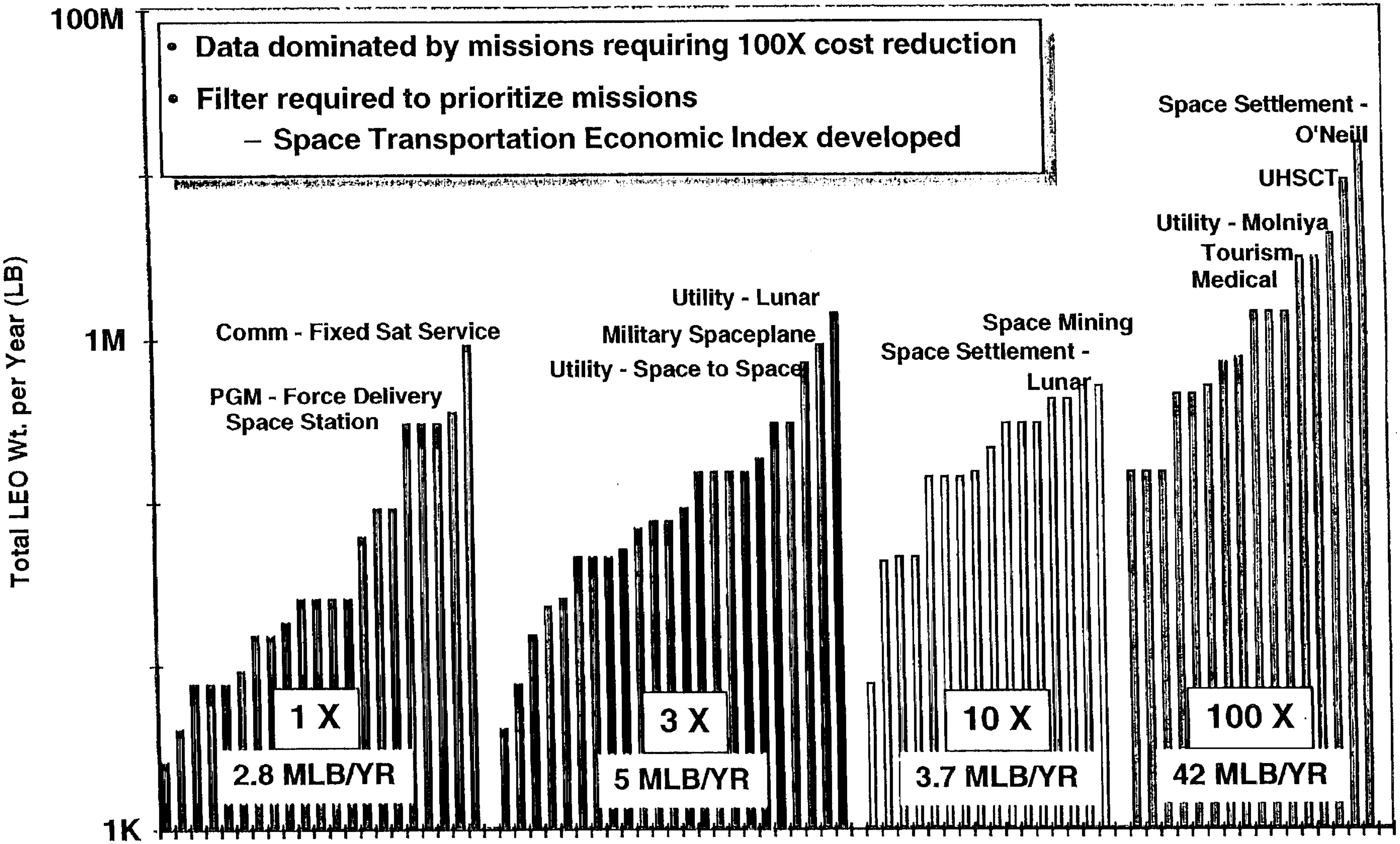
The 10 initial deployment missions having the greatest mass-to-orbit requirement were identified. The initial deployment mass used in this chart is the product of the LEO equivalent weight of each launch and the number of expected launches for initial deployment. The 10 largest initial deployment missions account for 90% of the total deployment weight of 64 Mlb for all missions. This number should be compared to today's launch rate of about one Mlb per year. Missions that require large scale initial deployment include establishment of various space utility (solar power) systems and various space exploration endeavors.

It should be noted that assumptions were made as to the launch rate associated with the initial deployment and the actual manifesting of these payloads could be done in different ways. In most cases, it should not matter whether the initial deployment is performed with a large launcher and fewer flights, or with a smaller launcher and a greater number of flights.

As a point of interest, the O'Neill Habitat Mission does not show up as one of the large initial deployment missions because it was assumed that this application would have a daily heavy-lift requirement for both initial construction and day-to-day operations.

Enabling Price Reduction Factors

All Innovative Applications



PGM: Precision Guided Munitions
UHSCT: Ultra High Speed Civil Transport

Enabling Price Reduction Factors

An estimate was made of the price reduction believed necessary to enable each of the innovative applications. Each application in the database is shown grouped into the estimated price reduction factor area. The price reduction factor is the amount by which the cost of launch must be reduced from today's commercial rates of $4000-$5000/lb before the application is expected to become enabled. It is important to emphasize that the price reduction factors are those deemed necessary to enable the application, but do not necessarily represent a profitable operating launch price level. The demand elasticity for each particular application was not modeled. The total LEO weight per year for each application is plotted as a representation of the 'market size' of the mission.

The total LEO weight per year for all the applications in the database is 53.5 Mlb/yr, compared to approximately 1 Mlb./yr launched currently. Note that the vertical axis is in logarithmic scale, so that the few largest applications, such as space settlements, ultra high speed civil transport, and space tourism dominate the database.

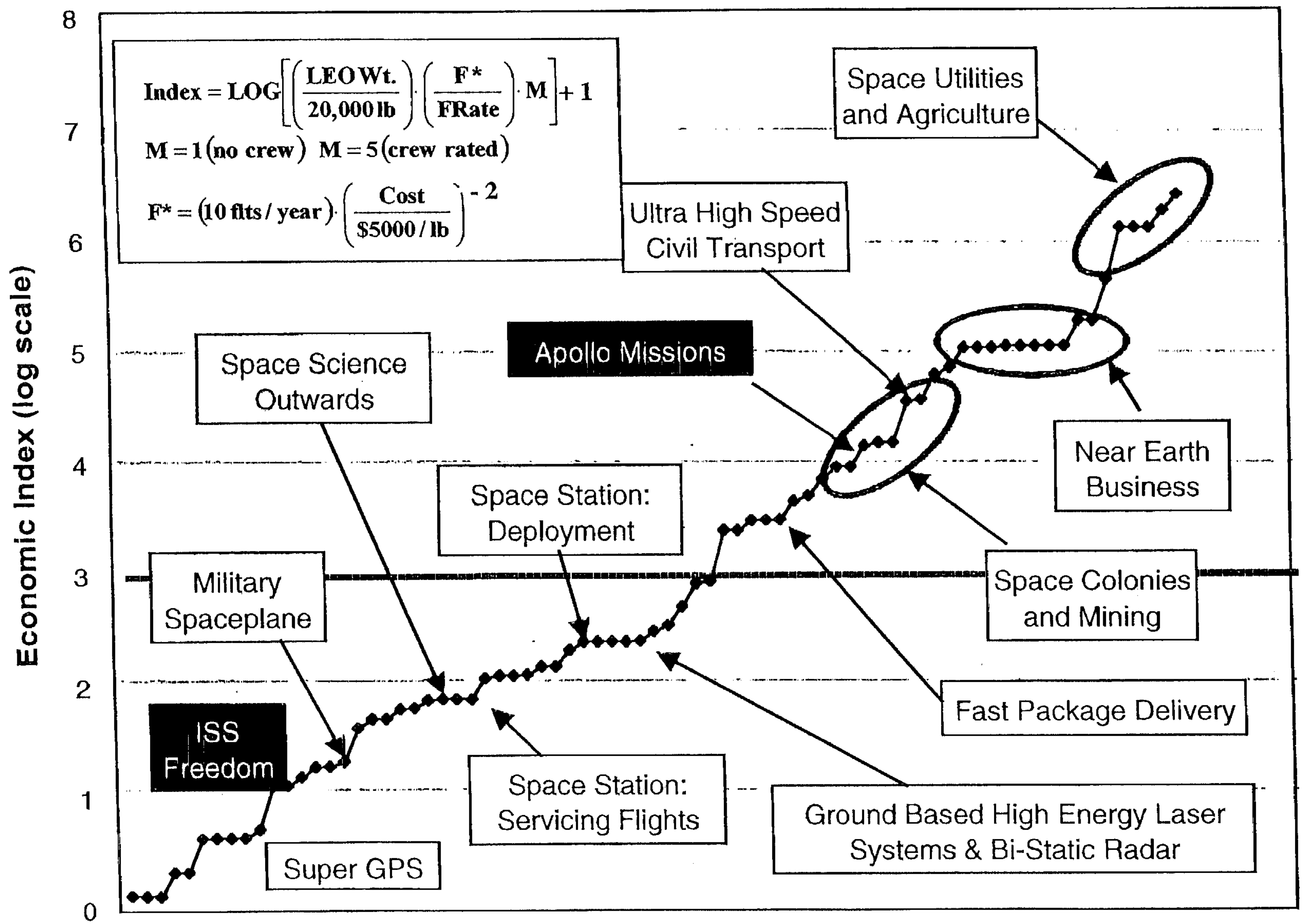
It is important to note that market elasticity, which is a measure of how the market expands as a function of price reduction, is not included in the database.

Space Transportation Economic Index

$$\text{Index} = \text{LOG}\left[\left(\frac{\text{LEO Wt.}}{20{,}000\,\text{lb}}\right)\cdot\left(\frac{F^*}{\text{FRate}}\right)\cdot M\right] + 1$$

$$M = 1(\text{no crew}) \quad M = 5(\text{crew rated})$$

$$F^* = (10\ \text{flts/year})\cdot\left(\frac{\text{Cost}}{\$5000/\text{lb}}\right)^{-2}$$



Space Transportation Economic Index

The Space Transportation Economic Index (STEI) was derived to provide a quantitative method to sort and prioritize the innovative missions. The database is populated with applications of varying levels of definition and feasibility. Some applications are more likely to become operational than others, while others are quite futuristic, and may have difficulty becoming enabled for reasons other than the launch market, such as technical difficulty or the economic feasibility of the application itself. In an attempt to properly weigh information about the less futuristic missions, a Space Transportation Economic Index (STEI) was developed to rank the applications. Four properties of the applications are used in the formulation of the index: flight rate, cost, weight, and manned requirement.

$$\text{Index} = \text{Log}[\,(\text{LEO Wt}/20{,}000) * (F^*/\text{Flt Rate}) * M] + 1$$

$$M = 1 \text{ (no crew)} \; ; \; M = 5 \text{ (crew rated)}$$

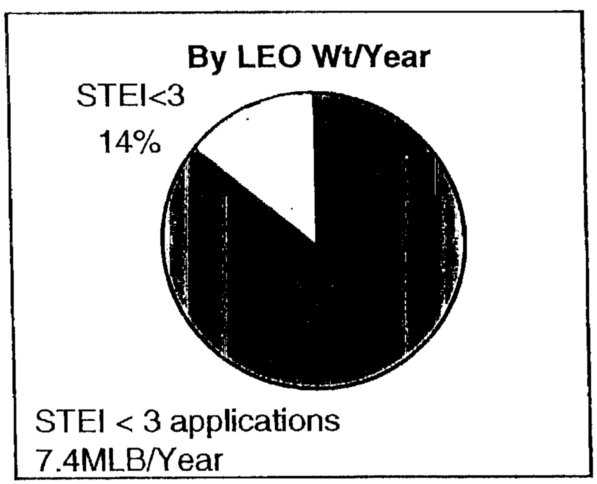
$$F^* = (10 \text{ Flts/yr}) * (\text{Cost}/\$5000/\text{lb})^{-2}$$

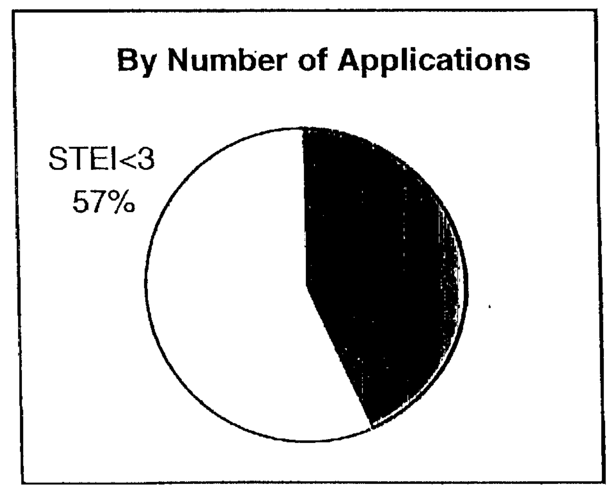
The STEI assumes that launch vehicle economics can be modeled by a supply and demand curve defined by the cost of launch and the flight rate. Roughly speaking, the economic flight rate F* basically defines the shape of the supply curve, and the flight rate F (the demand) is compared against it. A major assumption is that each application is considered by itself, without regard for the fact that a launch system will have multiple missions to support its flight rate. A STEI value of 1 corresponds to today's launch economics and capabilities relative to the medium lift class, while values of STEI larger than 1 indicate missions that are more challenging from a launch economics and lift capacity perspective. However, the STEI should not be viewed as an indicator of strictly present versus future launchability, since any application with a sufficiently high flight rate will have a low STEI.

All the applications in the innovative database are plotted as points in this chart. In addition, two data points (Apollo missions and International Space Station Freedom) external to the present study are plotted for comparison. An important aspect of STEI is demonstrated by the Apollo data point (STEI=4), which is that a large value of STEI does not mean that the mission will not happen. Apollo was a mission that was driven by national will, not by economic viability. From a space transportation perspective, the ISS is more economically feasible and confirmed by a STEI value of 1.

Space Transportation Economic Index Application

- STEI indicates the economic viability of launching each application
  - STEI does not indicate technical or market feasibility of the application
  - STEI was used to sort and divide the applications
  - Applications with STEI less than 3 have key launch requirements that are closer to today's launch capabilities
- Key threshold characteristics are presented for all applications and those applications with STE-Index less than 3
  - Price reduction, reliability, number of flights per year, weight to LEO, launch facilities, turnaround time, and upper stage needs



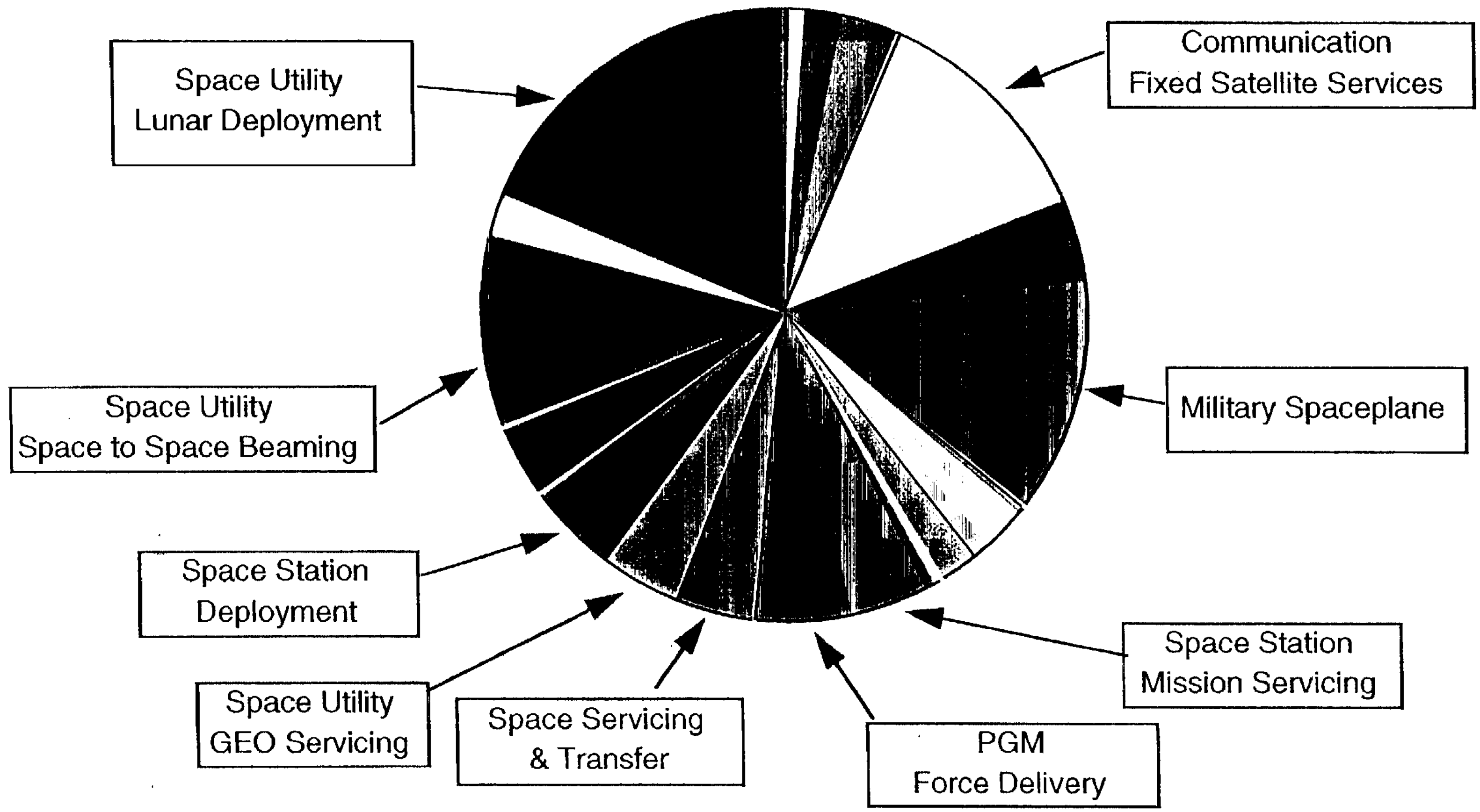


Space Transportation Economic Index Application

Space Transportation Economic Index applied to innovative database. The STEI as defined in the previous chart was applied to the entire innovative database to sort it into two parts. An STEI value of 3 was used to divide the database into near-term, less performance and economically challenging missions and more futuristic applications. Key characteristics are presented for both the entire database and also for applications with STEI$<$3. The remaining set of characteristics are presented in Appendix 3.

Applications with STEI$<$3 comprise about half the entire database by number, but only 14% by payload weight per year to LEO. The total LEO weight of the STEI$<$3 missions is about 7.4 million LB per year, which is almost an order of magnitude larger than today's launch capability of about a million LB per year.

STEI<3 Applications by LEO Weight/Year

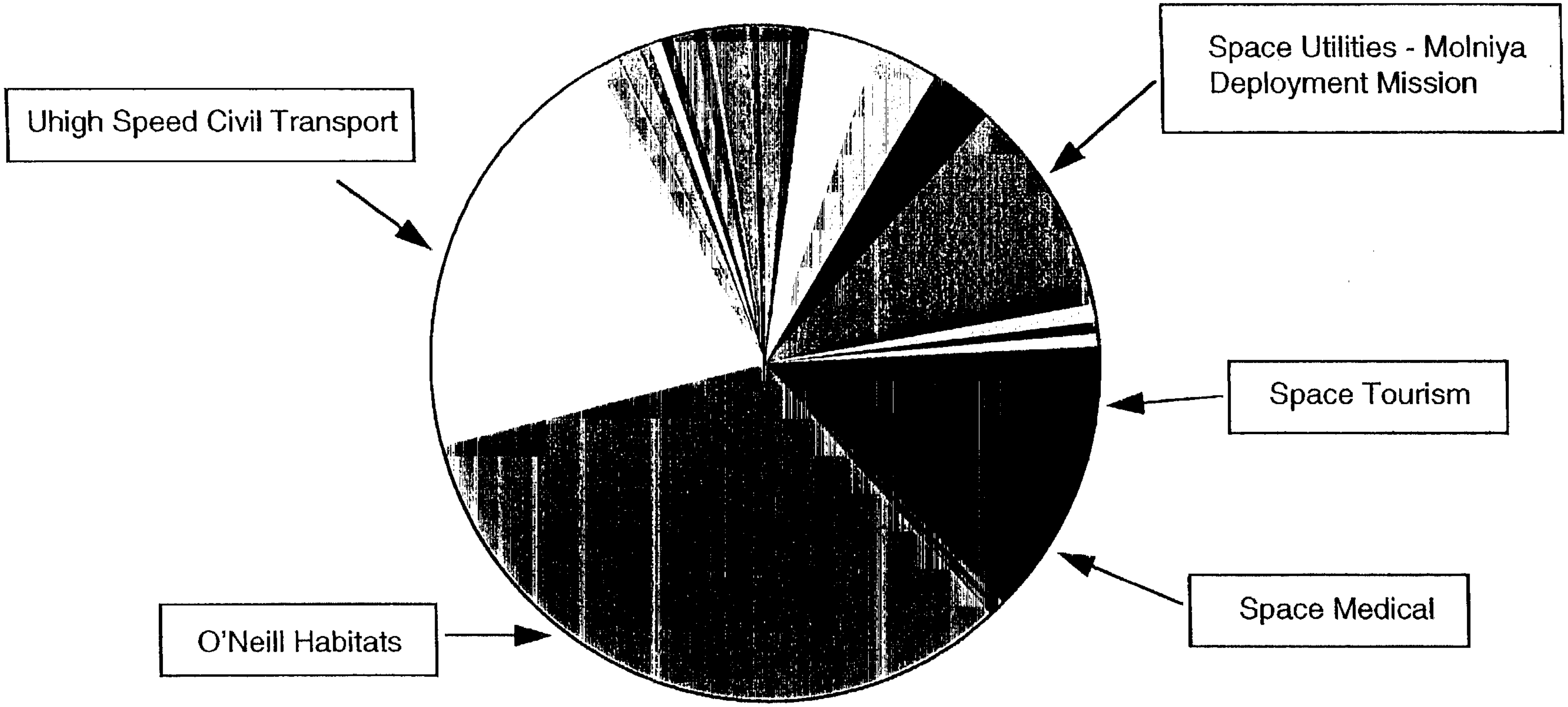


- % based on total LEO weight per year
- These represent the near-term missions
- There is an even distribution over several types of missions
- Total weight to LEO per year = 7.4 MLB/Yr

STEI < 3 Applications by LEO Weight/Year

The STEI<3 applications with greatest annual total weight are shown. This chart shows the types of missions that populate the STEI<3 part of the database and their relative demands. There is no single dominant application, although space utilities in various forms comprise a significant portion of the database. It may appear somewhat inappropriate to have space utilities in the STEI<3 category, which has been described as being 'near-term'; but it is consistent with the definition of the STEI in that any application that can support a sufficiently high flight rate will get a lower STEI value.

STEI >3 Applications by LEO Weight/Year



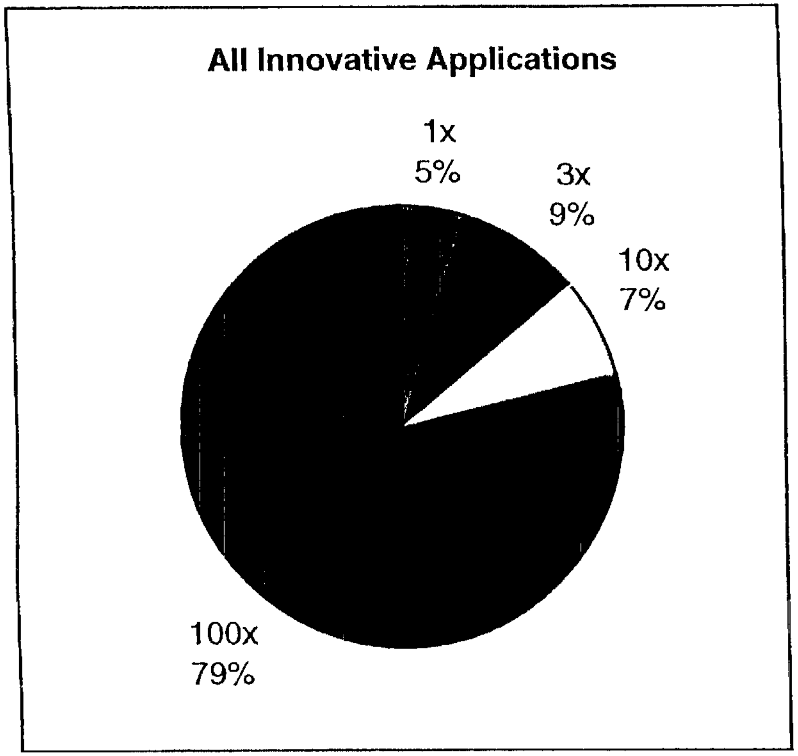
- % based on total LEO weight per year
- These represent the far-term missions
- Few missions make up a large part of the total weight to orbit
- Total weight to LEO per year = 45.5 MLB/Yr

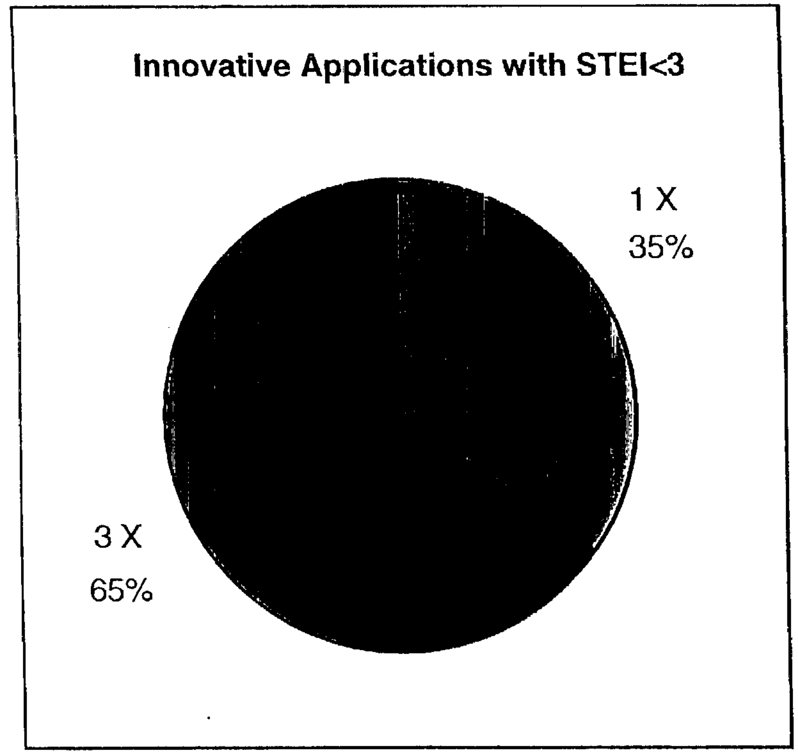
STEI > 3 Applications by LEO Weight/Year

The largest STEI>3 applications are shown. The largest total weight STEI>3 spacelift applications are more or less the same as those of the entire database and are dominated by challenging applications such as the O'Neill space habitats, ultra high speed civil transports, and space tourism, all of which require the transport of large numbers of people.

Threshold Characteristics: Price Reduction

(% breakdown based on total weight to LEO per year)



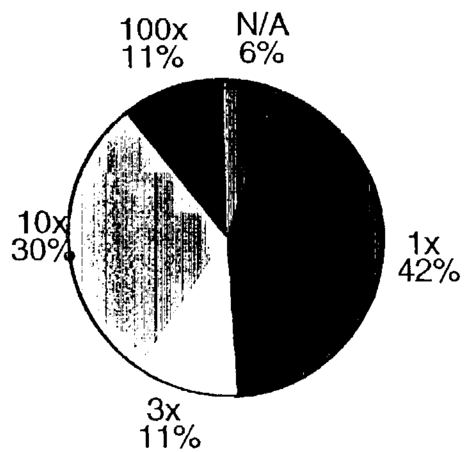


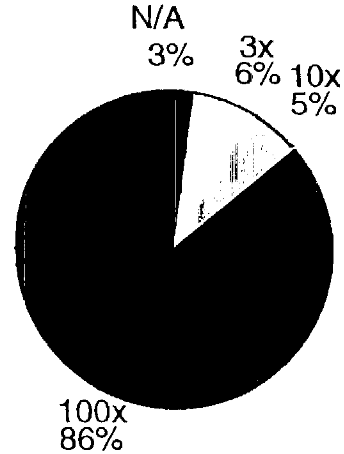
- Majority of missions enabled at 100X price reduction
- Majority of missions enabled at 3X price reduction

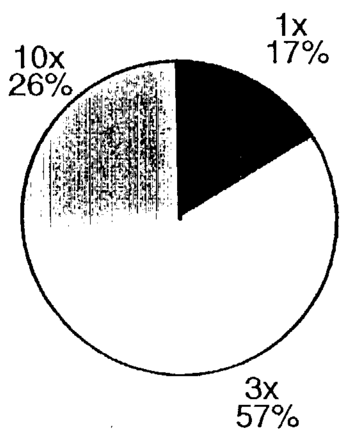
Threshold Characteristics: Price Reduction

Enabling price reduction thresholds are illustrated in the figure. A 3X price reduction will enable all missions with STEI < 3. The 1X price reduction (present prices) category is comprised of applications such as communications, military force delivery, and space station missions. A majority of applications for the entire database requires on the order of 100 X price reduction from today's commercial ELV levels to be enabled. These include applications such as space settlement, tourism, and utilities. As previously mentioned, the data in this chart does not imply that it will be economically or technically feasible to launch the mission just because the enabling launch price reduction requirement is achieved.

Innovative Applications by Sectors: Enabling Price Thresholds







- Majority of civil sector requires <10X reduction
- Majority of commercial sector requires 100X reduction
- Military sector requires 3-10X reduction

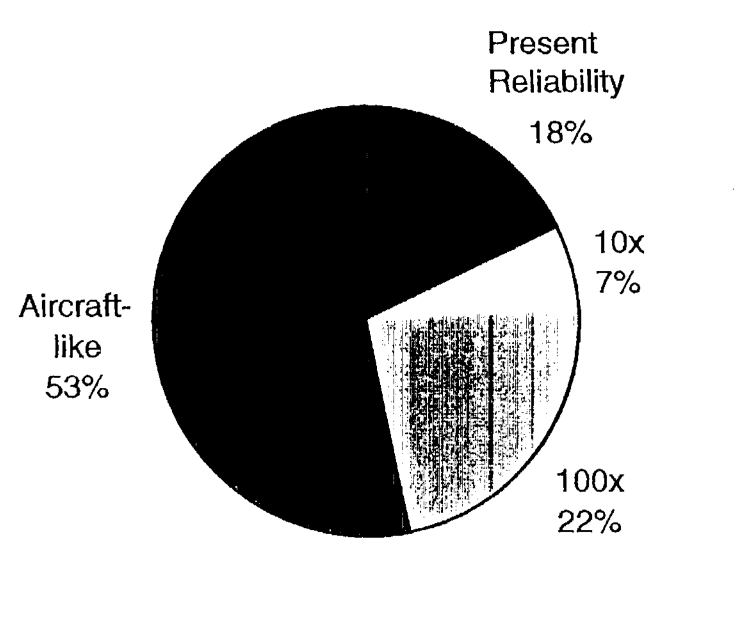
Innovative Applications by Sectors: Enabling Price Thresholds

Enabling price thresholds are predicted for each sector in this chart. Interesting observations about the differences in the requirements for the civil, commercial and military sectors can be made. In the case of enabling price thresholds, a majority of commercial applications require 100X price reduction, while a 10X price reduction should be adequate for most civil and military applications.

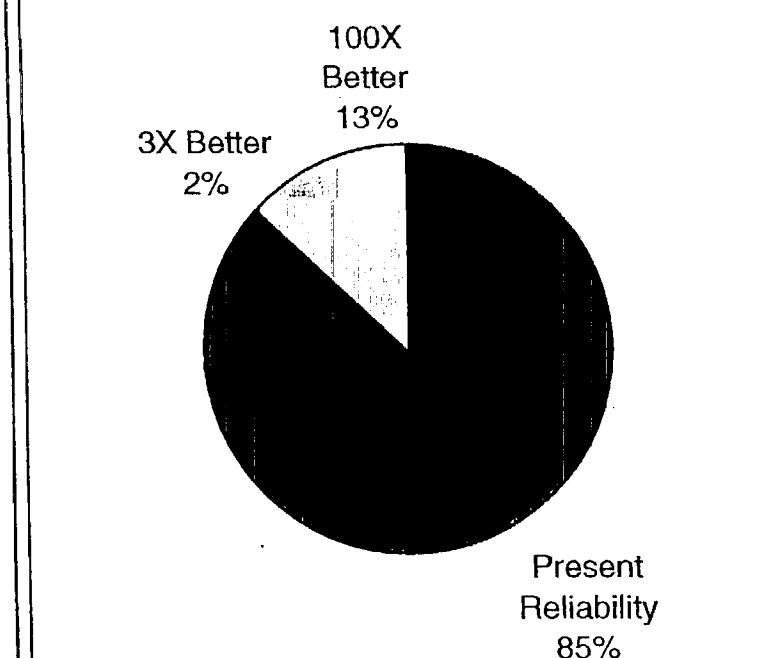
Threshold Characteristics: Reliability

(% breakdown based on total weight to LEO per year)

All Innovative Applications



Innovative Applications with STEI<3



- Majority of applications require 100X or better reliability improvement

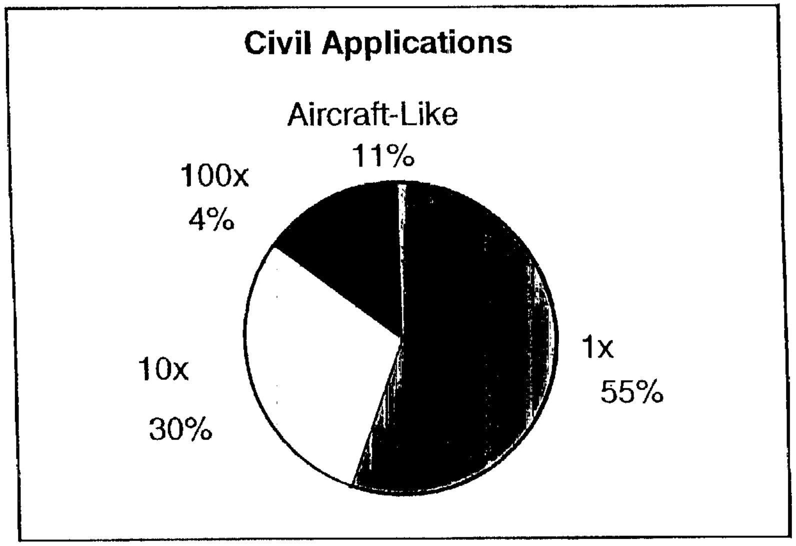
- Present reliability is acceptable to majority of applications
- Military Spaceplane requirement is 100X reliability improvement

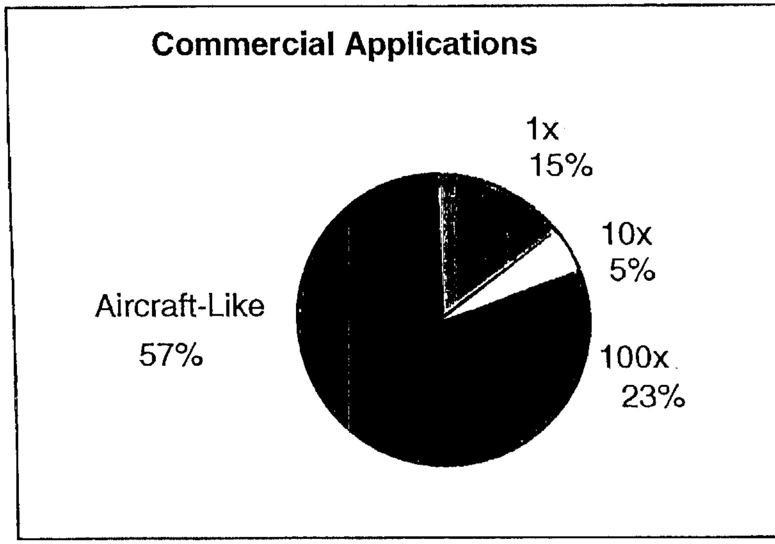
Threshold Characteristics: Reliability

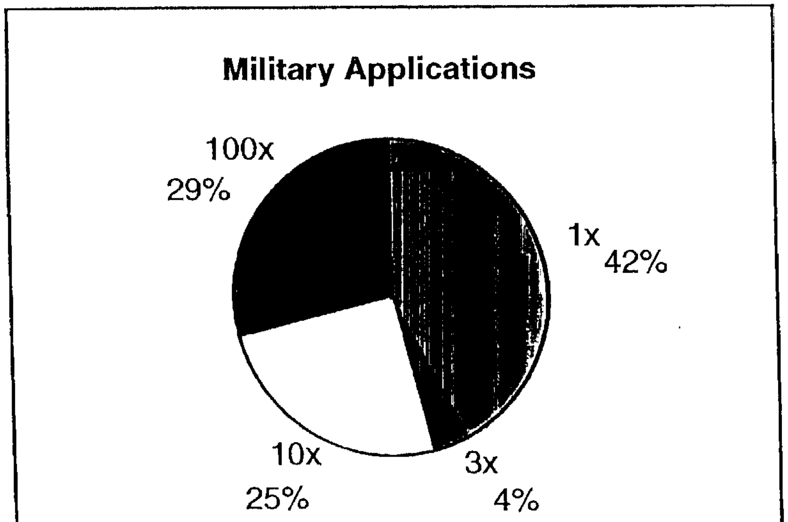
Reliability threshold requirements are illustrated here for the two future applications groupings. The reliability levels of current launch vehicles are acceptable to a majority of the missions with STEI<3. The military spaceplane, which falls in the STEI<3 category, has a stated requirement for a significantly better reliability than that of current launch vehicles.

For the entire database, a majority of missions require reliability improvement of 100X or more to a level of that associated with experimental aircraft.

Innovative Applications by Sectors: Reliability Thresholds







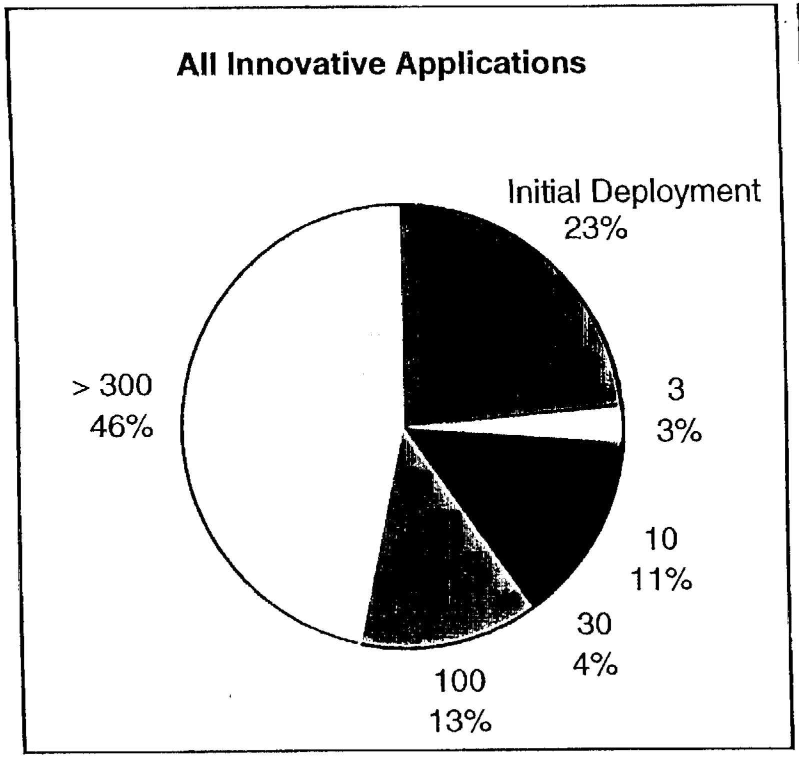
- Majority of civil sector requires <10X improvement
- Majority of commercial sector requires >100X improvement
- Military sector requires both present and 100X improvement

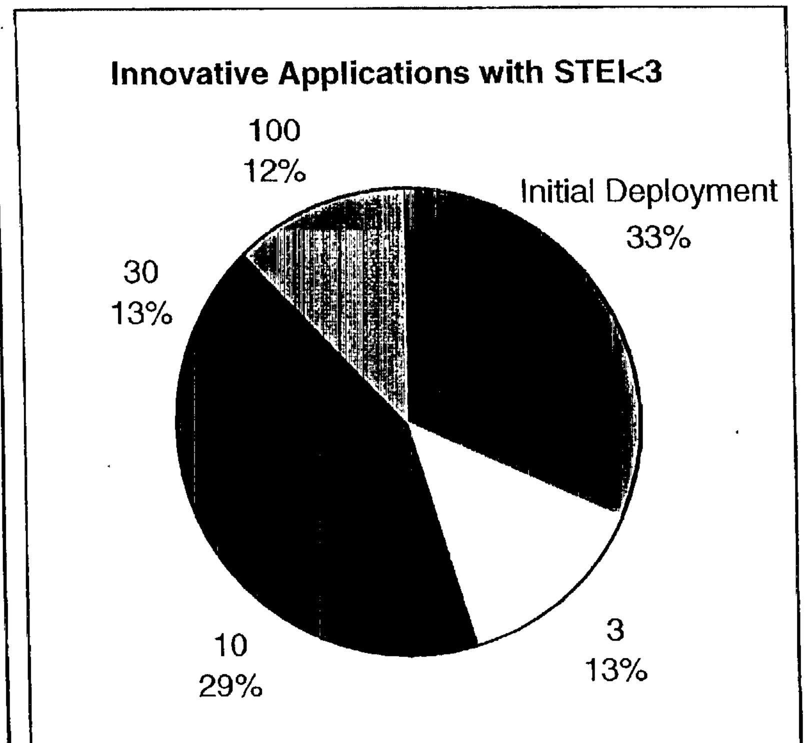
Innovative Applications by Sectors: Reliability Thresholds

Reliability requirement thresholds are depicted here for each sector. The vast majority of all innovative applications in the commercial sector require more than 100X reliability improvement from today's levels. Aircraft-like reliability levels are required for several applications that carry passengers. The majority of civil sector missions require 10X reliability improvement or less from current space shuttle and ELV levels. The military sector has a large number of missions that are projected to be enabled with current ELV reliability levels and a significant number of future missions that require 100X and 10X reliability improvements.

Threshold Characteristics: Number of Flights/Yr

(% breakdown based on total weight to LEO per year)





- High flight rate and initial deployment missions make up majority

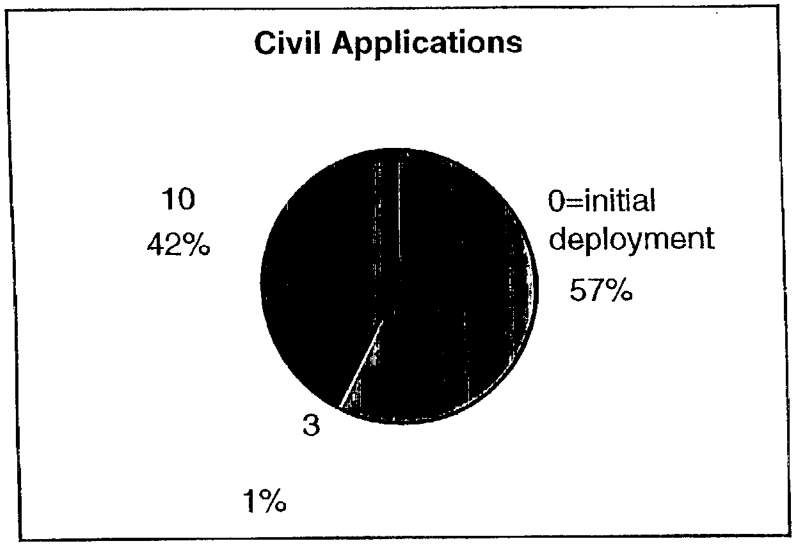
- Even distribution of flight rates

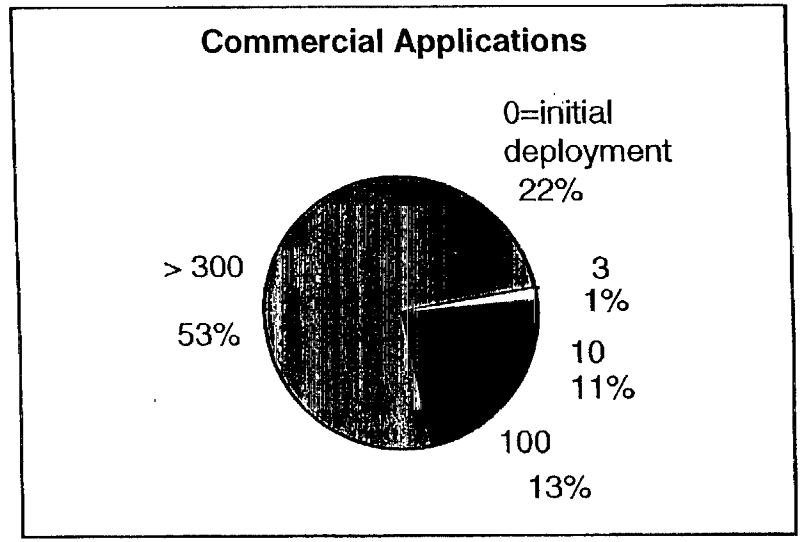
Threshold Characteristics: Number of Flights/Yr.

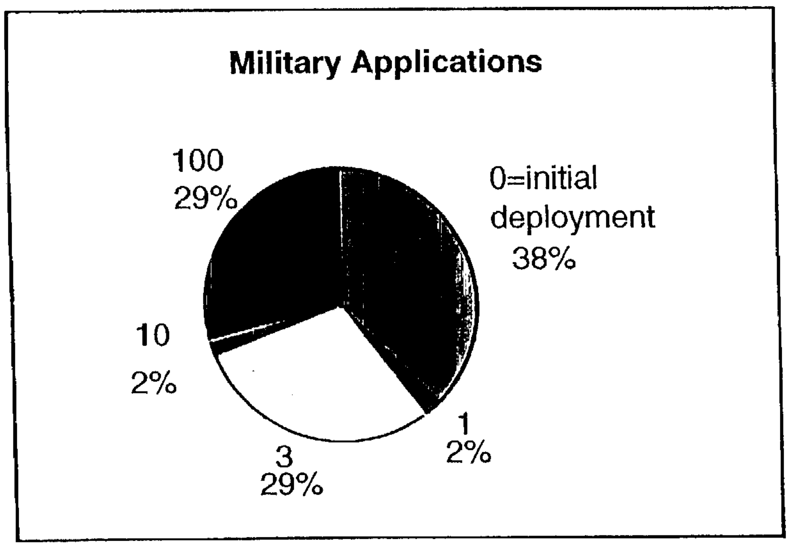
Our estimate of the future trends and range in number of flights per year is illustrated. The annual number of flights depicted here is that level expected for the mission at the enabling price. This is distinguished from price elasticity information in which the number of flights can be expected (in most cases) to increase with the decrease in price of the launch.

Since the database is populated by missions that are recurring (number of flights per year), one-time deployment (number of flights), or both, it is necessary to include the initial deployment missions in the flight rate breakdown (normalized by spreading over 5 years). For STEI< 3 missions, there is an even spread of flight rate requirements, while the entire database shows a large sector that requires daily flights (>300 per year). For both the STEI<3 and the entire database, the initial deployment flight rate requirements are significant.

Innovative Applications by Sectors: Flight Rate Thresholds







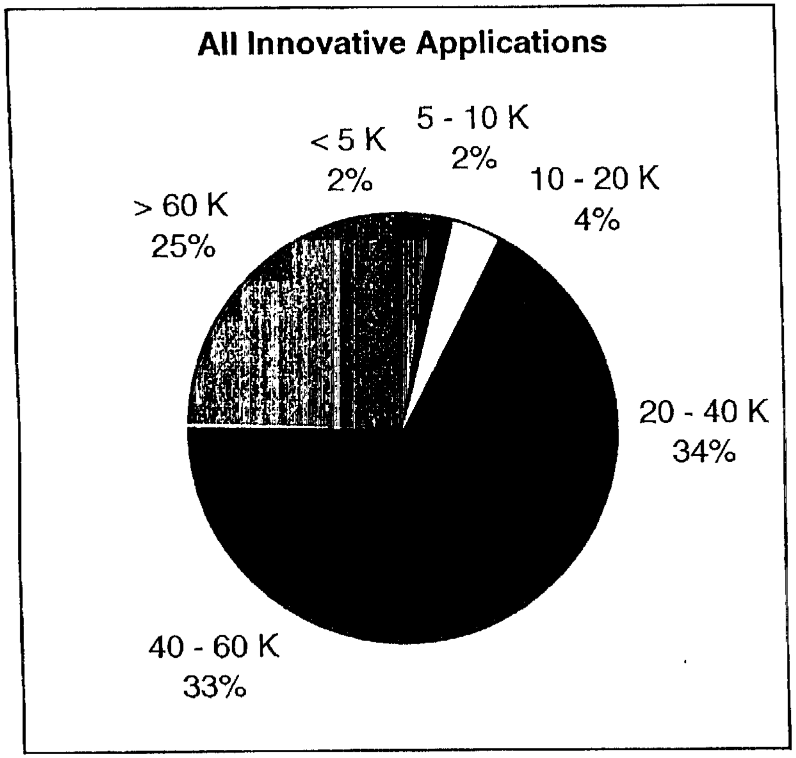
- Majority of civil sector requires initial deployment and <10 flts/yr
- Majority of commercial sector requires >100 flts/yr
- Military sector requires both initial deployment, present rates and >100 flts/yr

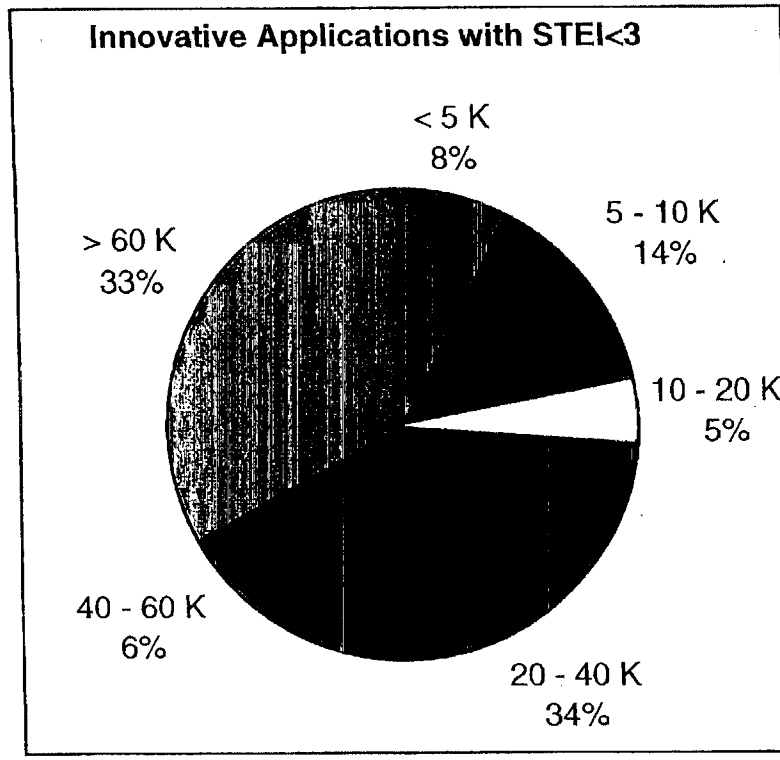
Innovative Applications by Sectors: Flight Rate Thresholds

Flight rate thresholds are shown to vary considerably for each sector. Innovative missions in the civil sector have low (<10 per year) flight rate requirements, while the commercial sector has high (>300 per year) flight rate requirements. The military has a mix of both high and low flight rate missions. Innovative mission sectors have significant initial deployment requirements. About 57% of the civil mission flights are projected to be devoted to initial deployments or one-time applications.

Threshold Characteristics: Equiv. Wt to LEO (lb)

(% breakdown based on total weight to LEO per year)





– **Medium, heavy and ultra heavy payloads**

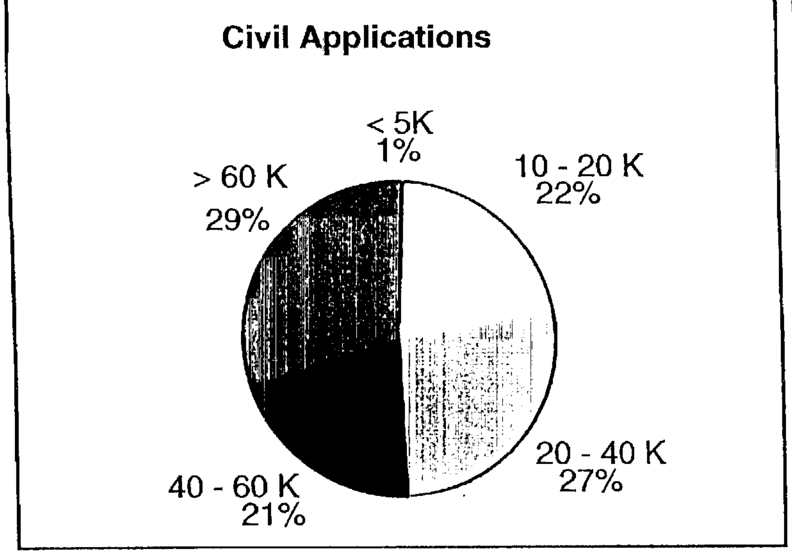
– **Medium, heavy, and ultra heavy payloads, but also significant amount of small payloads**

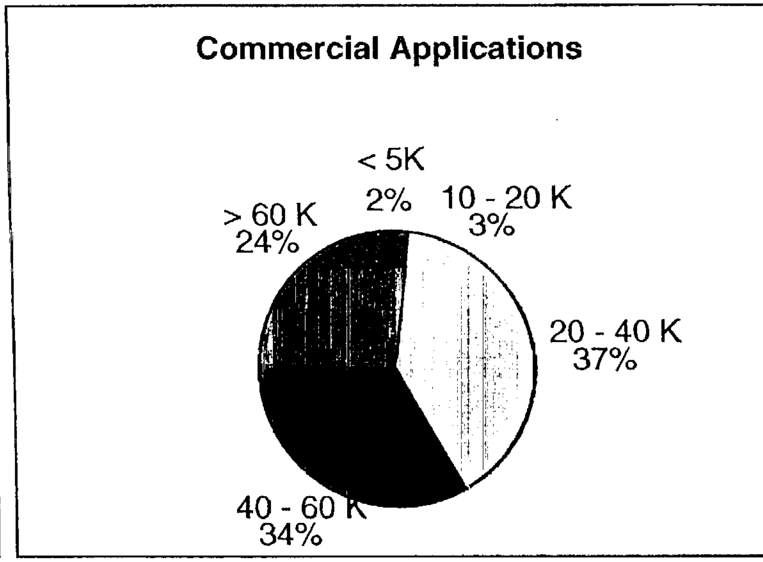
Threshold Characteristics: Equivalent Weight to LEO

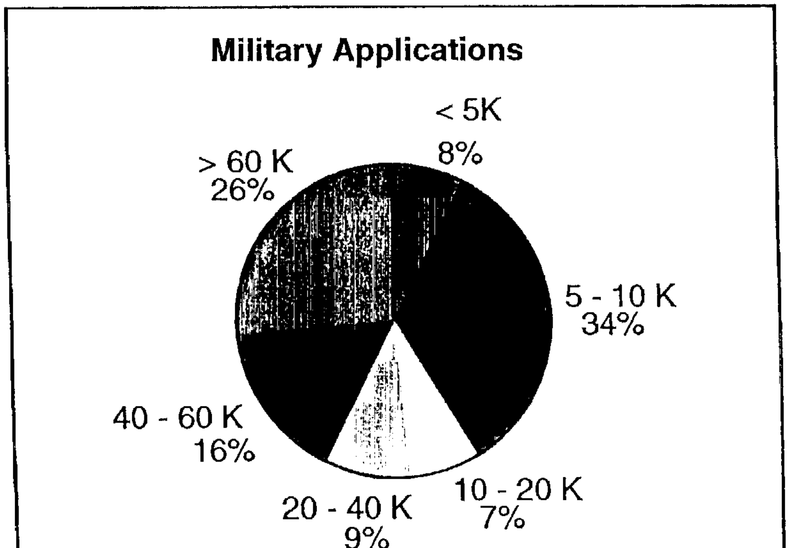
Equivalent weight to LEO requirements are characterized in this chart. The performance requirement to the specific mission orbit for each application is normalized to an equivalent LEO value. For both STEI<3 and the entire database, there is an even spread of the payload weight requirement, from small to very heavy. Note that the projected requirement for heavy lift (greater than 40 K lb to LEO) is significant (comprising 39% and 58% of the lift requirement for the near-term and full set of innovative applications, respectively).

Many of the innovative future missions are poorly defined at this time. This projection of weight to LEO represents our best judgment of the requirement for reasonable mission accomplishment. It is recognized that several of the heavy lift applications would have significantly lower requirements due to technology advances, or be accomplished by using a greater number of smaller, lighter elements and assembly on-orbit. This latter approach is likely to increase mission complexity and cost and affect the overall economic viability of the application.

Innovative Applications by Sectors: LEO Weight Thresholds







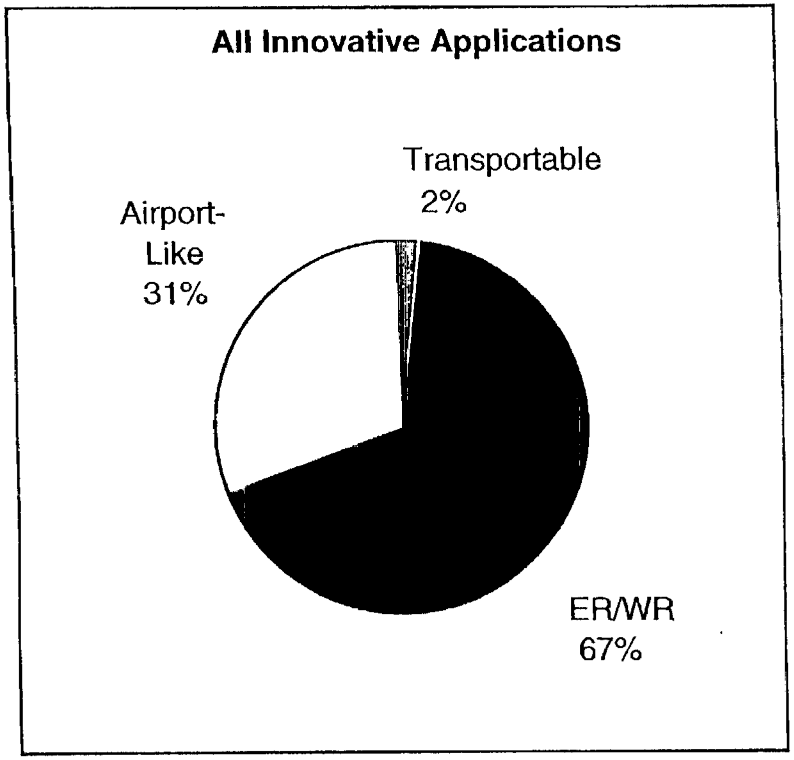
- All sectors have significant amount of missions in small, medium and large weight classes

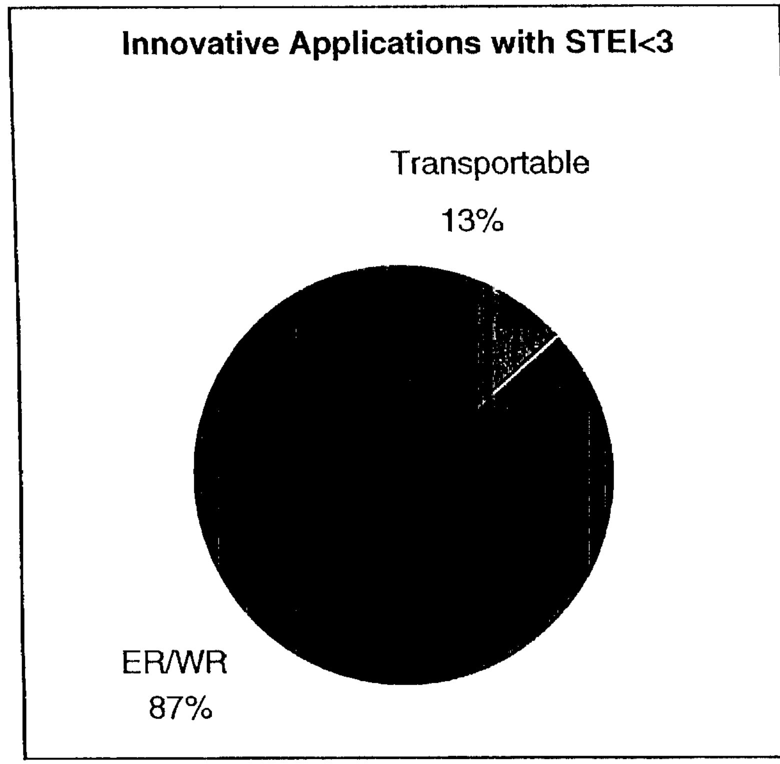
Innovative Applications by Sectors: LEO Weight Thresholds

A further breakdown of the LEO weight threshold by sectors is provided in this figure. All sectors have a significant number of missions in the medium-, heavy-lift weight classes. About one-fourth of the traffic in each sector is in the very heavy-lift class (>60K lb) and a significant factor (16-34%) of the traffic in the 40-60K lb class. Little innovative mission commercial traffic is projected in a small (10K lb and below) payload class.

Threshold Characteristics: Launch Facilities

(% breakdown based on total weight to LEO per year)





- Present launch pads acceptable for majority of applications
- Need for airport type of launch facilities as well

- Present launch pad locations acceptable to most applications

Threshold Characteristics: Launch Facilities

Launch facilities and range requirements are shown here. The majority of STEI<3 missions can probably be launched from Eastern and Western Ranges. They require no substantial departure from the facilities and range support typically provided at today's launch ranges. The Military spaceplane may require transportable, austere launch support capability for downrange or in-theater operations.

While a large fraction of the applications, such as passenger or package transport and space tourism, require facilities and services similar to conventional airports, the majority of missions in the entire innovative set would find launch from ER/WR acceptable. Note that this data does not imply that most of the applications require present ER/WR type of launch facilities. It is likely that many of the applications would find other forms of launch facility support more economical.

Existing Facilities Launch Capacity

	Delta II (flights/year)	Atlas II/A/AS (flights/year)	Titan + Shuttle (flights/year)
Eastern Range Current Capacity	12	12	12 (4 + 8)
Aggregate Eastern Range Flight Rate (Innovative Apps)	61 (49% dual manifested)	21	79
Western Range Current Capacity	6	3	2
Aggregate Western Range Flight Rate (Innovative Apps)	57 (53% dual manifested)	0	0

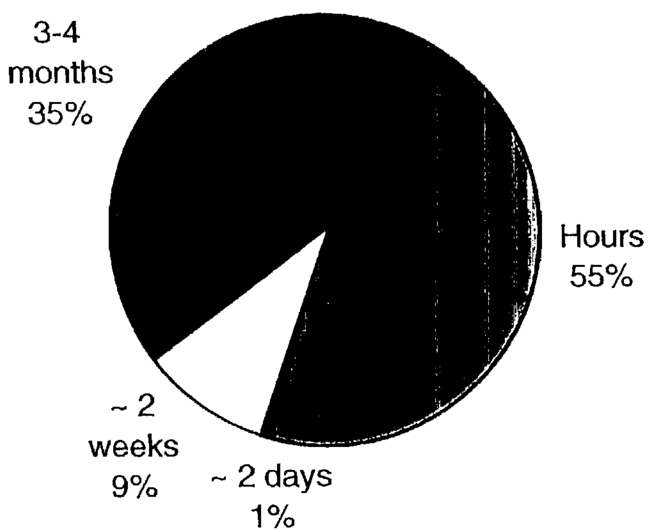
- Aggregate launch rates from Innovative Applications with STEI < 3
- Payloads under 5000 lb dual manifested on Delta II launches
- Applications with STEI < 3 requiring special launch services or with payload requirements greater than 60,000 lb excluded

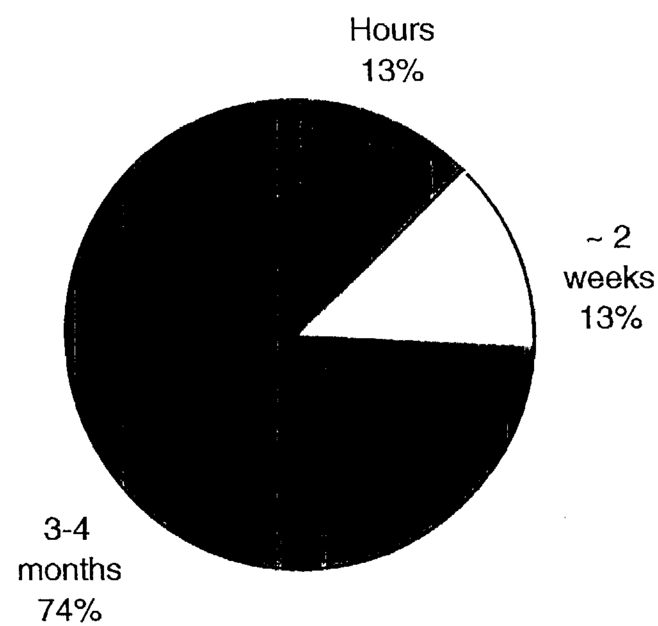
Existing Facilities Launch Capacity

Aggregate launch rate requirements for innovative applications with STEI<3 far exceed the current launch facility capacity at ER/WR. Although a large fraction of the near-term innovative applications' launch requirements could be satisfied by today's launch sites, existing systems and launch capacity at these sites are sufficient to service only a small fraction of these missions. This table shows the current launch throughput capacity at ER and WR, compared with the required launch rates in the innovative database, assuming dual manifesting of medium class payloads.

Threshold Characteristics: Mission Turnaround Time

(% breakdown based on total weight to LEO per year)





- Strong need for rapid turnaround capability

- Present turnaround time is acceptable for majority of applications
- Some need for rapid turnaround capability (MSP)

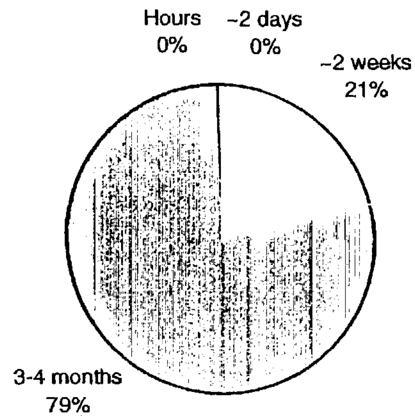
Threshold Characteristics: Mission Turnaround Time

Mission turnaround time requirements are compared in the facing chart. A large fraction of STEI<3 missions have no rapid processing or turnaround time requirements. Mission turnaround time on the order of 3-4 months is acceptable. Military spaceplane is an exception that requires vehicle turnaround in a matter of hours.

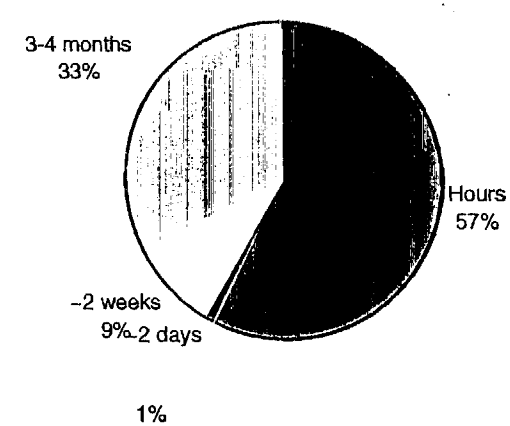
For the entire database, however, a majority of missions require vehicle turnaround time on the order of hours. Rapid passenger and cargo transport are representative of missions in this class. Still, even in the complete data set there is still a significant portion that can live with turnaround time of months.

Innovative Applications by Sectors: Turnaround Time

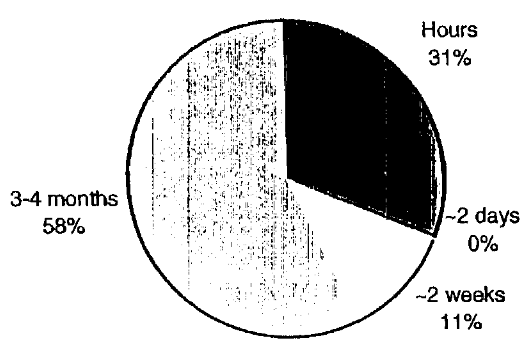
Civil Applications



Commercial Applications



Military Applications



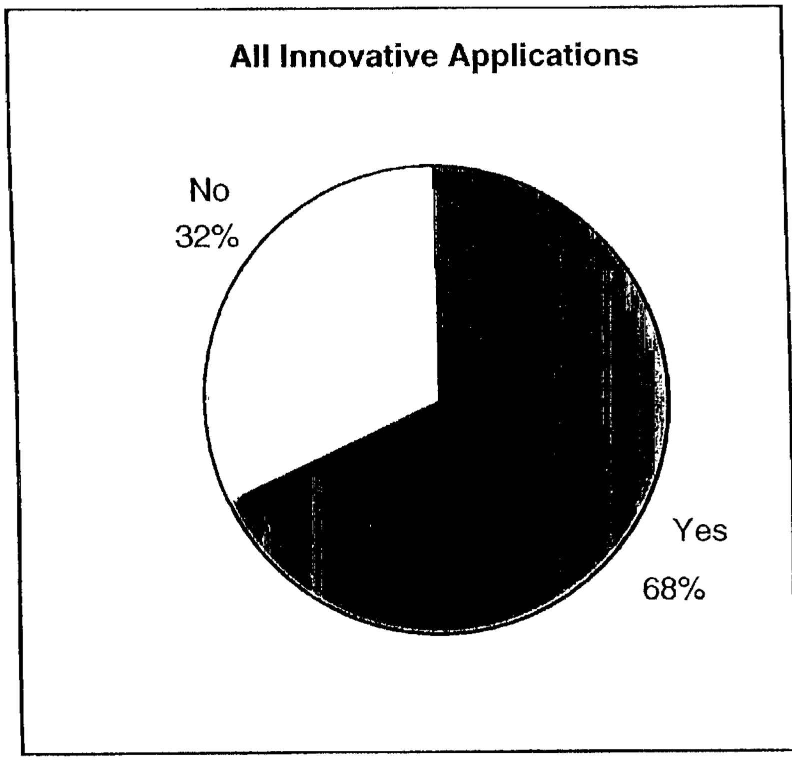
- **Only a small fraction of civil sector requires faster than present (2 week) turnaround time**
- **Commercial sector requires mix of present and fast (weeks) and very fast (hours) turnaround time**
- **Military sector requires mix of present and fast (weeks) and very fast (hours) turnaround time**

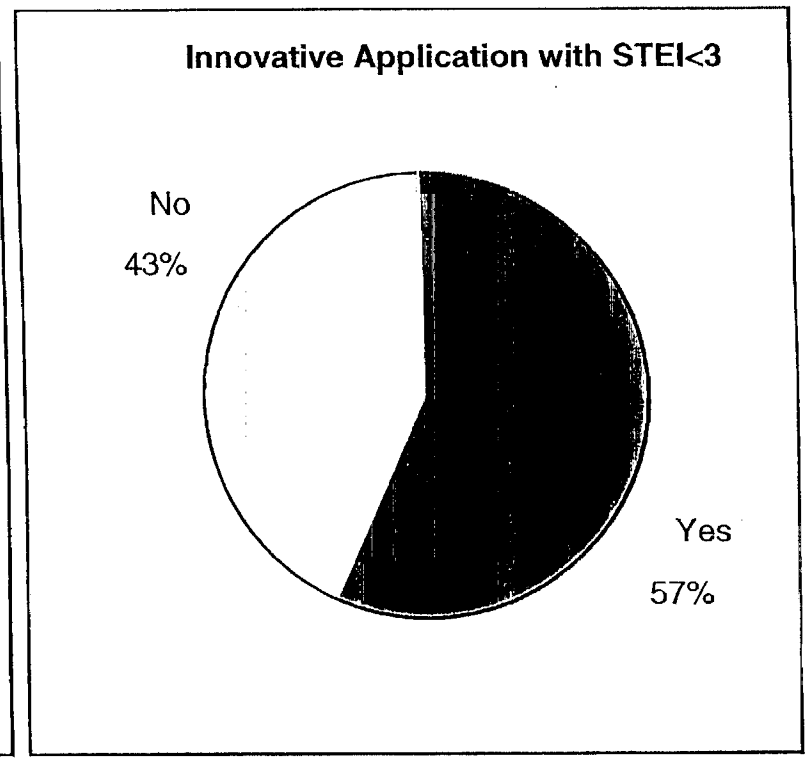
Innovative Applications by Sectors: Turnaround Time

Mission turnaround time requirements are shown here by sector. Only a small fraction of innovative civil sector missions require faster than present (2 week) turnaround time. Most of the other civil missions deem present turnaround time of 3-4 months to be adequate.

Both the commercial and the military sectors require a mix of present and fast (weeks) and very fast (hours) turnaround time.

Threshold Characteristics: Upper Stage Required?





– Upper stage required for large proportion of missions

– Upper stage required for large proportion of missions

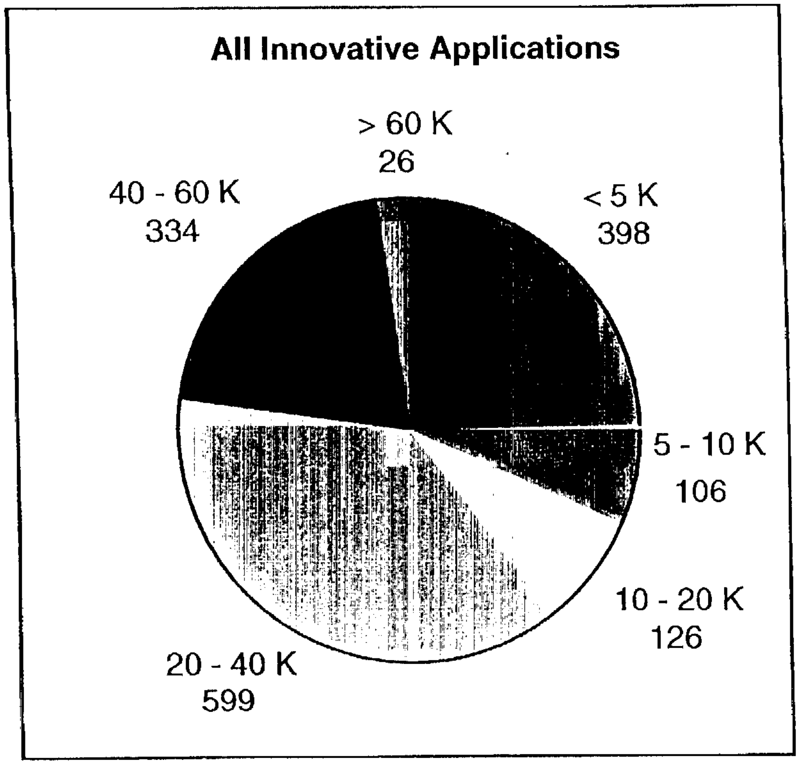
* Specific upper stage requirements not addressed, may require several different types and sizes

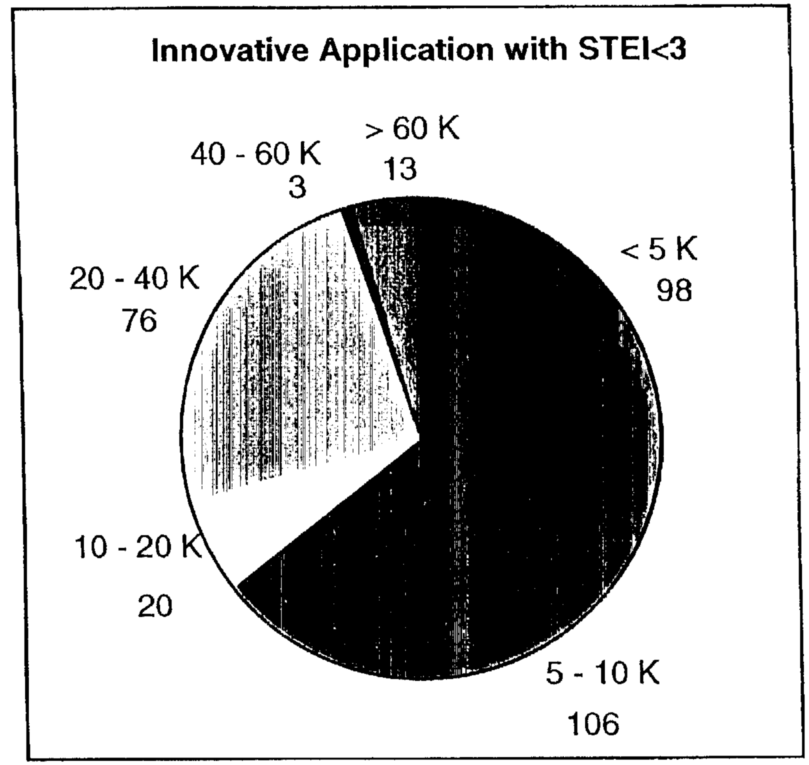
Threshold Characteristics: Upper Stage Required?

The need for an upper stage to be used to extend the LEO capability to meet specific mission requirements was investigated. The results depicted here were derived from the orbital characteristics of the missions. Those missions whose final orbit was higher than LEO were assumed to require an upper stage. For both the entire database, and the STEI<3 subset, it appears that a large proportion of the missions require an upper stage or a launch system with considerable on-orbit altitude and plane change capability.

Whether or not a particular mission requires an upper stage will actually depend on the specifics of the launch vehicle implementation including engine restart capability. Some missions could be done with or without an upper stage.

Aggregate Flight Rate by LEO Weight Class





- Approximately 1,600 total missions/yr
- >300 missions/year for very small, medium, and heavy classes

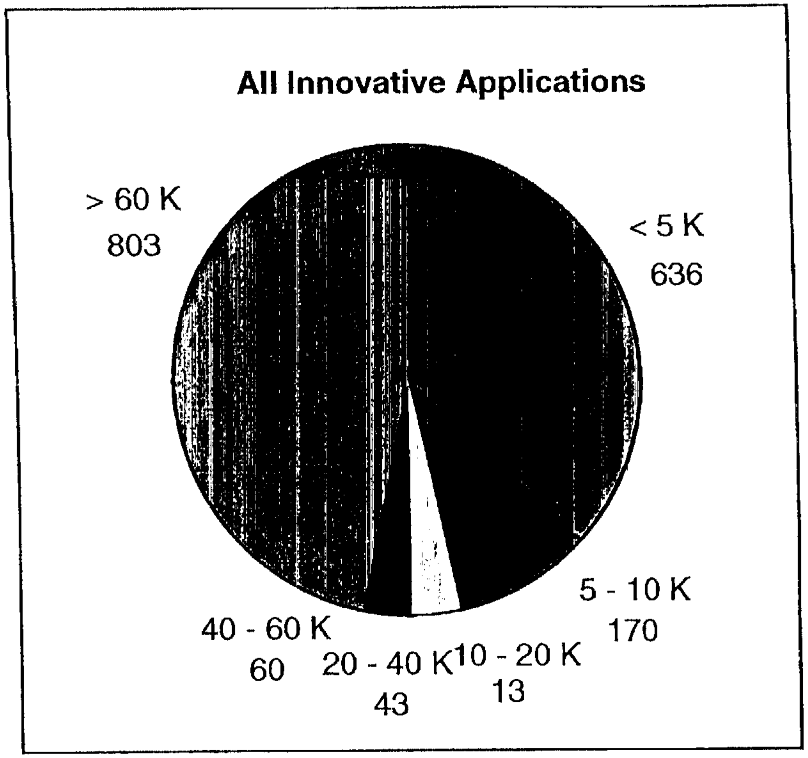
- Approximately 300 total missions/yr
- ~100 missions/year for very small, small, and medium classes

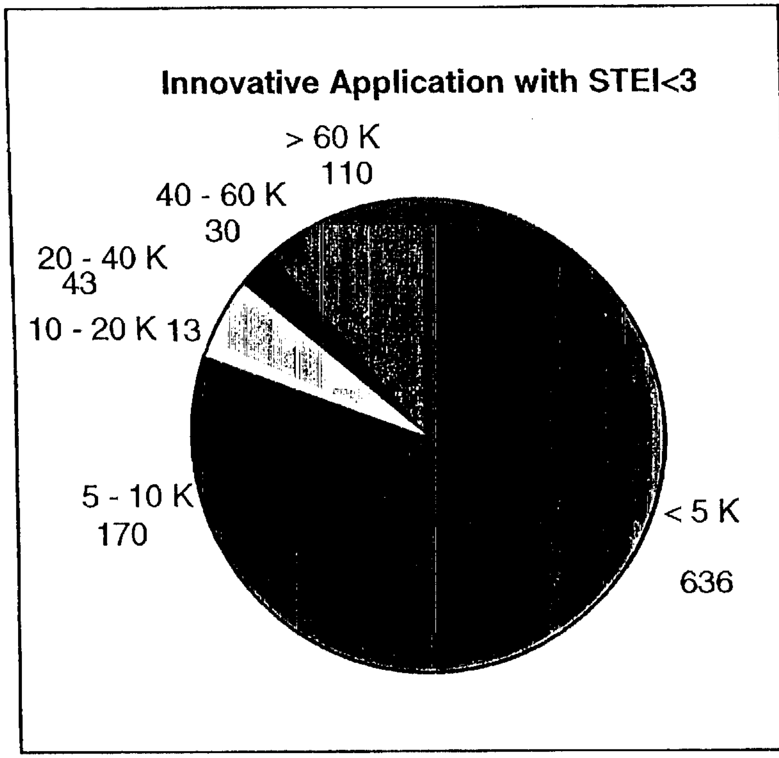
Aggregate Flight Rate by LEO Weight Class

Flight rate data requirements for the various spacelift system weight classes are depicted here.* There are a large number of applications with very small, small and medium class payloads for STEI<3 mission. For the entire database, in addition to the small and medium missions, there are a large number of heavy class payloads.

*This chart reports only on the recurring flight rates - see next chart for the deployment-only missions.

Aggregate One-time Deployment Flights by LEO Weight Class





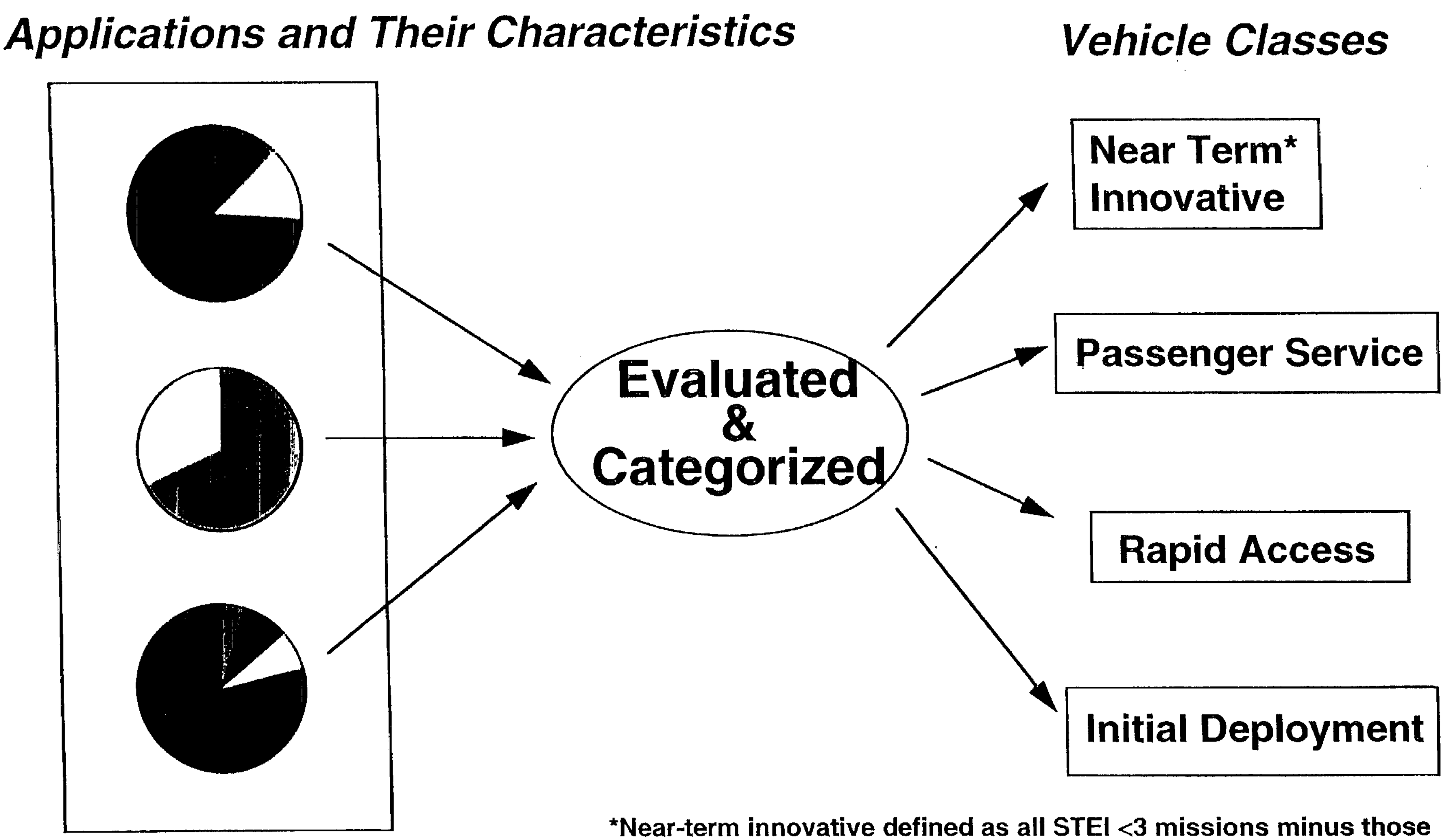
- Approximately 1,700 total missions/yr
- Many ultra heavy deployment missions
  (Space Utilities deployment, Mining)
- Many small deployment missions
  (Comm. mobile sat, Global surveillance, MSP, other military missions)

- Approximately 1,000 missions/yr
- Many small deployment missions
  (Comm. mobile sat, Global surveillance, MSP, other military missions)

Aggregate Initial Deployment Flights by LEO Weight Class

Initial deployment flight data is depicted. For the STEI<3 missions, the deployment flights are dominated by the small payload applications. These missions are for the initial population of proliferated communication or surveillance systems. Multiple manifesting of 4-8 payloads per launch would greatly reduce the launch rate. For the entire database, in addition to the small payload missions, there are a large number of ultra heavy deployment missions for the establishment of space utilities, mining and other applications requiring large facilities and/or equipment.

Spacelift Attributes from Application Characteristics



*Near-term innovative defined as all STEI <3 missions minus those missions that belong in other 3 categories

Spacelift Attributes from Applications Characteristics

Spacelift attributes were derived from an evaluation of threshold requirements of the various innovative applications and naturally grouped into mission classes. Although key mission threshold characteristics have been individually presented in the previous charts, it is important to realize that a simple statement characterizing the spacelift requirements cannot be made because the stressing or most demanding attributes don't necessarily apply to the same application. To derive the launch vehicle spacelift attributes, the data was correlated and categorized into four mission classes to capture most of the requirements of the innovative applications. The four launch mission classes are:

- Near Term Innovative - attributes that are near term extensions of today's launch system capabilities
- Passenger Service - highly reliable, high flight rate, reusable
- Rapid Access - military spaceplane like, with other applications such as rapid package delivery
- Initial Deployment - heavy lift capability (~100,000 lb to LEO)

Threshold Attributes Summary

		Near Term Innovative	Passenger Service	Rapid Access	Initial Deployment
Performance	LEO equiv wt (lb)	up to 60 K	40 K	5 K - 20 K	100 K
	Types of Cargo	Satellites	Passenger	Crew/cargo	Cargo/Sats
	Launch rate	< 50 /yr	> 300 /yr	100 - 500 /yr	< 50 /yr
	PL Fairing size	Present	Special	Small	Large
	Passenger service	No	Yes	No/emergency	No
	Multi-Azimuth	No	No	Yes	No
Reliability	Reliability	1 x - 3 x	> 100 x	> 100 X	> 3 x
Safety	Safe Abort	Optional	Mandatory	Mandatory	Optional
Reusability	Return payload	No	Yes	Yes	No
	ELV vs. RLV	ELV/RLV	Reusable	Reusable	ELV/RLV
	Manned ?	Optional	Manned	Optional	Unmanned
Operability	Turnaround time	Monthly	Days	Hours	Monthly
	Multiple Manifest	Optional	No	No	Optional
	Order To Launch	Months	Weeks	Days	Months
	SC Time on Pad	Days	Hours	Hours	Days
	Facilities	Present	Airport-Like	Airport-Like	Present
Affordability	Insurance/Liability	Same	More	More	Same
	LEO Cost	3 x	10 x - 100 x	3 x - 10 x	10 x - 100 x
Environments		Present	More Strict	More Strict	Present
Typical Missions		Comm Sats	Tourism	MSP	Space Utility
		S S Support	UHSCT	Rapid Package	Human Planetary
		Big LEO	Space Medical	Big LEO Replenishment	Weapons
		Remote Sensing			Business

Threshold Attributes Summary

Threshold attributes were derived for four launch system mission classes. Key characteristics in the areas of performance, reliability, reusability, operability, affordability, and environments are summarized in this chart for each of the four launch system classes. These attributes capture nearly all of the mission requirements in the innovative applications database, recognizing that there is some overlap in the capture of various missions by different vehicle classes. For example, a passenger service vehicle could probably perform a majority of near-term innovative class missions, as well as some of the rapid access missions. The objective here is the identification of vehicle classes and their required attributes, not to recommend a particular vehicle configuration.

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Alternative Futures

Alternative Launch Futures

Driving Requirements
- Flight Rate
- Crew Rating
- Payload Weight
- Cost Reduction Factor
- Reliability Requirement

Current + EELV + Space Shuttle

Conventional

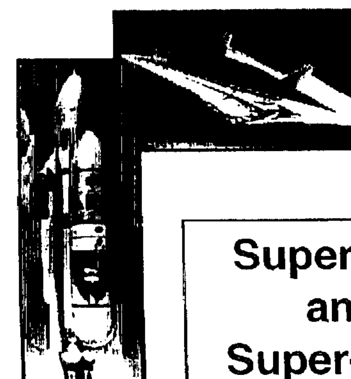
RLV + Low Cost Commercial

Near Term Innovative

Rapid Access

Military Spaceplane

Passenger Service / HLV



Super HLV and Super-Low-Cost Medium

Current — 2005 — 2010 — Future

Alternative Launch Futures

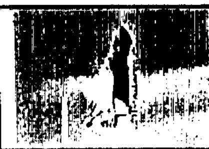
The groups of spacelift attributes determined in the previous section can be mapped to an evolutionary set of space launch systems or alternate futures.

The initial group is made up of current systems including initial EELV operations, the Space Shuttle, and current expendable systems. The Near Term Innovative category maps into a group of launch vehicles on the horizon including NASA's X-vehicles, Lockheed Martin's RLV Program, U.S. launch startups (Kistler, Kelly, Pioneer), and perhaps a few current launch systems that may be price competitive such as the Chinese and Russian launchers.

The next group is a low- to medium-lift, quick turnaround vehicle with attributes like that of the proposed Air Force Military Spaceplane. This family would be targeted at very quick turnaround missions not specifically requiring significant additional improvements in launch characteristics.

Finally, a hypothetical set of vehicles is defined and analyzed separately and as a family. The Super HLV and Super Low Cost MLV are defined to capture the spacelift attributes designated HLV and Passenger Service categories. The development schedule will be determined by market forces or national need.

Alternative Launch Futures Characteristics

	Current, EELV, STS	RLV + New Commercial	Military Spaceplane	Super Heavy	Super Low Cost Medium
					
Payload Equivalent Weight to LEO	< 60,000 lb	< 60,000 lb	5-20,000 lb	100,000 lb	40,000 lb
Cost Factor	Current Prices	3x Cost Reduction	3x Cost Reduction	10x Cost Reduction	100x Cost Reduction
Reliability Improvement	Current Reliability	3x Better Reliability	100x Better Reliability	10x Better Reliability	100x Better Reliability
System Flight Rate (per year)	50	100	200	240	5000

Alternative Launch Futures Characteristics

Payload weight, launch price, reliability, flight rate, and crew rating were the primary factors used to determine the compatibility of the Innovative Applications with the characteristics of the five Alternative Space Launch Futures defined here. Current vehicle attributes are those exhibited by launch systems today, while the future systems are either based on system requirements or characteristics as they are known today (RLV and MSP) or on Innovative Application requirements (Super HLV and Super Low Cost MLV).

The RLV and new commercial vehicles set, as indicated, includes the Venture Star type system and innovative reusable launch vehicle start-ups, as well as any price competitive expendable launch systems which may be operating in that time period. RLV and these new reusable systems are expected to produce a factor of 3 cost reduction from today's commercial price, while higher launch rates of the expendables should produce similar reliability improvements in the far term.

The Military Spaceplane type system requirements are largely drawn from the AFSPC draft System Requirements Document dated 11/1/96. The factor of 3X cost reduction is assumed due to improvements learned from RLV and may be closer to 5-8 times depending on flight rate and possible commercial uses. MSP is not expected to achieve a factor of 10X cost reduction which is our next threshold. A baseline launch rate for all payloads of at least 200 flights per year was assumed due to the MSP mission model and possible commercial spin-offs.

The hypothetical Super HLV vehicle was created to meet a large section of innovative applications requiring on the order of 100,000 lb to LEO lift capability. It was assumed to yield another level of cost and reliability improvements. This vehicle type would essentially be considered a "space truck" and would not necessarily carry crew or be able to perform auxiliary missions.

Finally, the Super Low Cost Medium lift vehicle was defined to be the workhorse of a booming commercial launch industry. Its 100x cost and reliability improvements and high flight rate provide a nearly aircraft-like service to many Innovative Applications.

Relationship of Key Attributes to Achieve Lower Cost/Flight

Cost Reduction Factor	Present (STS)	10X	100X
Required Flight Rate (Fleet)	10 per yr	240 per yr	5000 per yr
Required Vehicle Life	50 flts	1000 flts	15,000 flts
Required Reliability	0.99	0.9995	0.99996
Required Maintenance	240,000 hrs/flt	10,000 hrs/flt	875 hrs/flt

10X & 100X Cost assumptions:

- RDT&E = $10 billion (3-year payback)
- Unit production = $1 billion/vehicle
- Infrastructure = $500 million/year
- Propellant = $1 million/flight
- Failure = $2 billion/failure
- Maintenance = $100/hour

Significant (5,000 per year) flight rate required for commercially-developed vehicle to achieve 100 X cost reduction

Relationship of Key Attributes to Achieve Lower Cost/Flight

Very high flight rates are required to amortize non-recurring costs and yield a low-cost flight. A simple cost model was developed to determine the characteristics of a generic reusable launch vehicle designed to achieve 10X and 100X cost reductions over today's launch costs. The conclusions that can be drawn from this simple costing exercise are very important, especially with regard to high flight rates and low operability costs.

The characteristics in the "present" column are representative of the current space shuttle. The characteristics in the "10X cost-reduction" and "100X cost-reduction" columns were computed from the cost model. In each case, a total cost per flight "budget" ($500 per lb for 10X reduction, $50 per lb for 100X reduction) were allocated among the different cost elements. The percentage allocations assumed in each case are as follows:

Cost Factor	10X	100X
Development	70%	33%
Production	5%	3%
Maintenance	5%	4%
Infrastructure	10%	5%
Insurance (failure)	5%	4%
Fuel	5%	51%
	100%	100%

(The fuel cost could be reduced by assuming a more efficient payload mass fraction, for example, but lower structural margins would likely increase reliability and maintenance costs.) Some key observations can be made on the basis of this data:

1. Very high flight rates are required to achieve 10X or better cost reductions. This is the most important enabling characteristic.

2. Extremely high reliability requirements are driven by the need to reduce failure (insurance) costs, and not by particular mission requirements, which, except for commercial passenger service, do not require such high reliabilities.

3. Vehicle life must be extended by 20 to 300 times over the present STS.

4. Vehicle maintenance hours per flight must be dramatically reduced compared to the STS.

These characteristics, of course, describe aircraft-like operability requirements. The high flight-rate requirements in particular imply that proposed innovative applications that have low flight rates (less than, say, 50 per year) will not be drivers of a commercial RLV development. (The government may develop specialized launchers for low flight-rate missions, such as the Apollo program, for example.) The space transportation economic index (STEI) defined in this study is based largely on the fact that high flight rate is a necessary enabler for commercial RLV development.

Derived Operational Tempos

Cost Reduction Factor	Present	10X	100X
Required Vehicle Flight Rate	2.5 per yr	48 per yr	714 per yr
Required Fleet Size	4	5	7
Failures in 20 Years	2	2	4
Propellant Consumption	2×10^7 lb/yr	5×10^8 lb/yr	10^{10} lb/yr

Operational assumptions:

- Vehicle operational life = 20 years
- Propellant per flight = 2 million lb
- (90% fuel fraction, 2.2 million lb GLOW)

Derived Operational Tempos

Aircraft-like operability is required to achieve very high flight rates. This chart lists various operability and tempo factors derived from the key attributes identified in this study. A typical scenario to achieve a 10X cost reduction, and 240 flights per year calls for a fleet of 5 RLVs, each flying approximately once a week. By comparison with today, each of a fleet of four STS flies about twice per year.

To achieve a 100X cost reduction, which is required to enable many of the innovative applications, requires that each vehicle make two flights daily. The huge amount of propellant consumed annually with such high flight-rate scenarios may raise environmental concerns.

Key	
Not useable for this application	R
Meets most requirements - has deficiencies	Y
Meets or exceeds all requirements	G

Innovative Missions with STEI < 3

In Order of Space Transportation Economic Index (STEI)

(Page 1 of 2, 43 Missions)

Id	Application	Cost Reduction	Equivalent payload weight to LEO	EELV + STS	RLV/Commercial	Military Spaceplane		Low Cost Ultra Heavy	Super Low Cost Medium
1.1	Global Surv, Recon, and Targeting System - servicing flight	Present prices	less than 5,000 lb	Y	Y	G	Y	G	G
21	KEW Kinetic Energy Weapons	Present prices	less than 5,000 lb	G	G	G	R	G	G
30	Remote Sensing	Present prices	less than 5,000 lb	G	G	G	R	G	G
50	Space Burial	Present prices	less than 5,000 lb	G	G	G	R	G	G
1	Global Surv, Recon, and Targeting System - deployment	Factor of 3 reduction	less than 5,000 lb	Y	Y	G	Y	G	G
27	Communications - Mobile Satellite Service - deployment mission	Factor of 3 reduction	less than 5,000 lb	R	G	G	Y	G	G
27.1	Communications - Mobile Satellite Service - servicing flight	Factor of 3 reduction	less than 5,000 lb	R	G	G	Y	G	G
7	Space Surveillance	Present prices	less than 5,000 lb	G	G	G	Y	G	G
22	Super GPS	Present prices	less than 5,000 lb	G	G	G	Y	G	G
60	Nanosat Applications	Present prices	less than 5,000 lb	R	R	G	R	G	G
25	Communications - Fixed Satellite Services	Present prices	20 Klb to 40 Klb	G	G	R	Y	G	G
49	Space Advertising	Factor of 3 reduction	less than 5,000 lb	R	G	G	R	G	G
2	Hyperspectral	Present prices	less than 5,000 lb	Y	Y	G	Y	G	G
26	Communications - Broadcast Satellite Services	Present prices	20 Klb to 40 Klb	G	G	R	Y	G	G
4	Military Spaceplane	Factor of 3 reduction	5 Klb to 10 Klb	R	R	G	R	G	G
28	Communications - Positioning Satellite Services	Present prices	5 Klb to 10 Klb	G	G	G	Y	G	G
6	Space Mine	Factor of 3 reduction	less than 5,000 lb	Y	Y	G	Y	G	G
8	Space Traffic Control	Factor of 3 reduction	less than 5,000 lb	R	G	G	Y	G	G
23	Communications	Present prices	20 Klb to 40 Klb	G	G	R	Y	G	G

Alternative Futures - Compatibility with Innovative Applications

Each of the alternative futures was compared to the set of Innovative Applications to measure launch compatibility. If the system could meet all of the primary launch requirements of an applications, the launch system was rated "GREEN". If additional assumptions needed to be made in order to make launch of that application on a system practical (for example, multiple manifesting or additional obvious minor changes in system or mission requirements), the system was rated "YELLOW". If the launch system was essentially incompatible with the application payload, it received a "RED".

The results of the assessment of alternative futures for the set of 43 Innovative Applications with STEI<3 are shown here. The missions are sorted in order of increasing STEI and also provide some insight into the set of applications with STEI<3. Cost reduction factor and LEO payload weight are listed for reference.

Current systems receive a large number of YELLOWs and REDs, indicating launch incompatibilities. Super HLV is also incompatible with most payloads, unless the assumption of multiple manifesting or a reusable crew return vehicle is permitted. The RLV and MSP categories do very well for STEI<3.

Super Low Cost MLV is very attractive (almost a universal carrier) for applications with STEI<3. It is only limited by payload weight to orbit and couples nicely with Super HLV as a family of launch systems.

Id	Innovative Missions with STEI < 3 Listed in order of Space Transportation Economic Index (Page 2 of 2, 43 Missions) Application	Cost Reduction	Equivalent payload weight to LEO		EELV + STS	RLV/Commercial	Military Spaceplane	Low Cost Ultra Heavy	Super Low Cost Medium
40	Entertainment - Digital Movie Satellite	Present prices	20 Klb to 40 Klb	G	G	R	Y	G	G
15	Interceptors	Factor of 3 reduction	5 Klb to 10 Klb	R	G	G	Y	G	G
38	Transportation - Space Rescue	Present prices	less than 5,000 lb	G	G	G	R	G	G
33	Government - Space Science Outwards	Factor of 3 reduction	10 Klb to 20 Klb	R	G	G	R	G	G
9	Missile Warning	Present prices	10 Klb to 20 Klb	G	G	G	Y	G	G
12.3	Planetary Defense -- System Development	National Will	20 Klb to 40 Klb	G	G	R	G	G	G
31.1	Government Missions - Space Station Missions - servicing flight	Present prices	20 Klb to 40 Klb	G	G	R	R	G	G
14	Force (PGM) Delivery from Space	Present prices	Greater than 60 Klb	R	R	R	G	R	G
3	Light, Affordable, On-demand Surveillance Sats	Factor of 3 reduction	less than 5,000 lb	Y	Y	G	Y	G	G
5	Space Control	Factor of 3 reduction	5 Klb to 10 Klb	R	G	G	Y	G	G
12.1	Planetary Defense -- Sky Survey	National Will	10 Klb to 20 Klb	G	G	G	Y	G	G
39	Transportation - Space Servicing and Transfer	Factor of 3 reduction	20 Klb to 40 Klb	R	G	R	Y	G	G
45.1	Space Utility - GEO - servicing flight	Factor of 3 reduction	20 Klb to 40 Klb	R	G	R	Y	G	G
31	Government Missions - Space Station Missions - deployment	Present prices	40 Klb to 60 Klb	R	G	R	G	R	G
10	Bi-Static Radar	Factor of 3 reduction	10 Klb to 20 Klb	R	G	G	Y	G	G
18.1	Solar-Powered High Energy Laser System. - servicing flight	Factor of 3 reduction	10 Klb to 20 Klb	R	G	G	Y	G	G
20	Ground-Based High Energy Laser System - deployment mission	Factor of 3 reduction	20 Klb to 40 Klb	R	G	R	Y	G	G
20.1	Ground-Based High Energy Laser System - servicing flight	Factor of 3 reduction	10 Klb to 20 Klb	R	G	G	R	G	G
12.2	Planetary Defense -- Sky Guard	National Will	20 Klb to 40 Klb	G	G	R	G	G	G
13	Global Area Strike System (GASS)	Factor of 3 reduction	5 Klb to 10 Klb	R	G	G	Y	G	G
48	Space Utility - Space-to-Space Power Beaming	Factor of 3 reduction	Greater than 60 Klb	R	R	R	G	R	G
52	Space Product Demonstration	Factor of 10 reduction	less than 5,000 lb	R	R	G	R	G	G
19.1	Space-Based High Energy Laser System - servicing flight	Factor of 3 reduction	40 Klb to 60 Klb	R	G	R	G	R	G
47	Space Utility - Lunar - deployment mission	Factor of 3 reduction	Greater than 60 Klb	R	R	R	G	R	G

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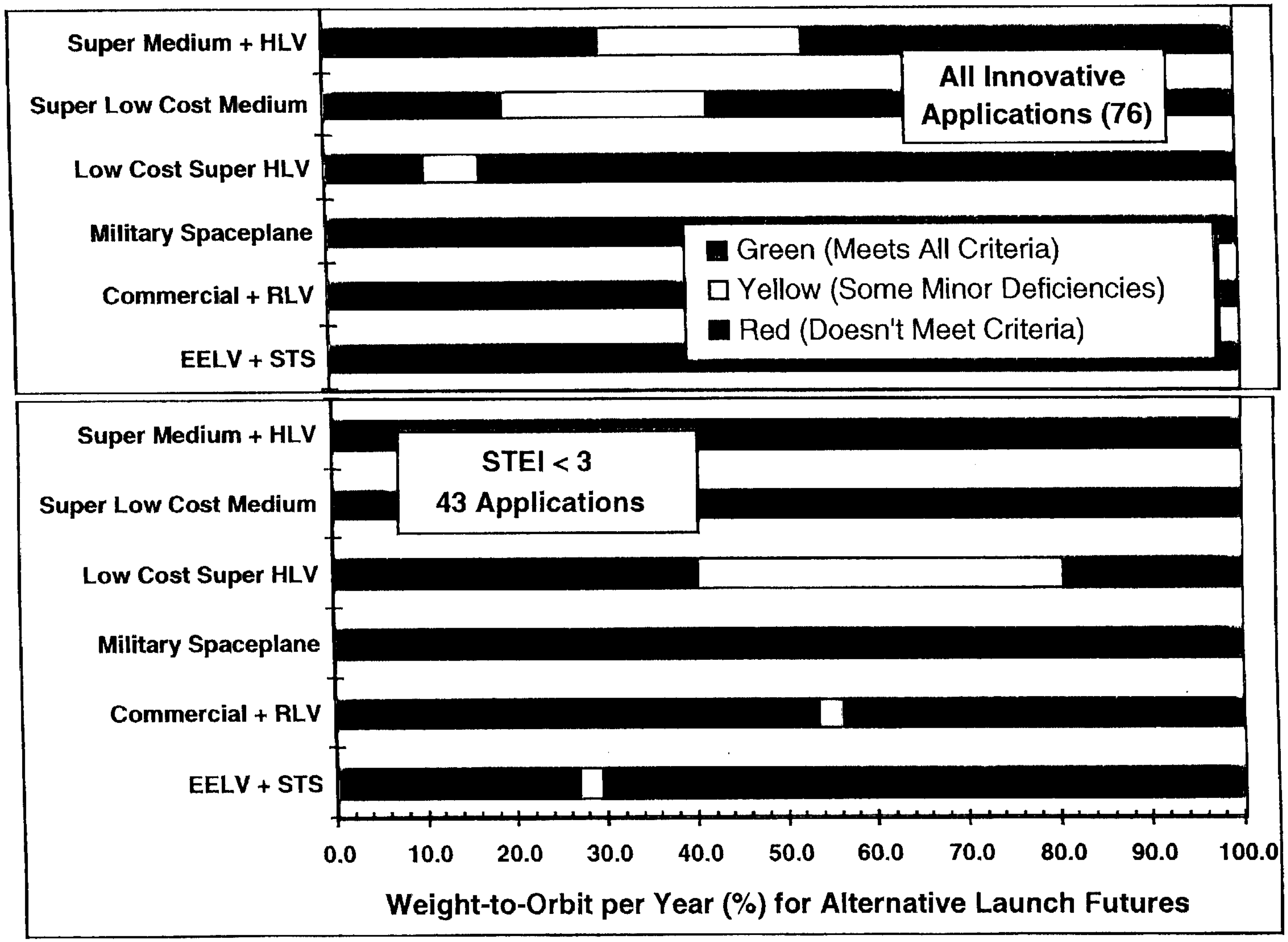
Mission Weights for Launch Futures



Mission Weights for Launch Futures

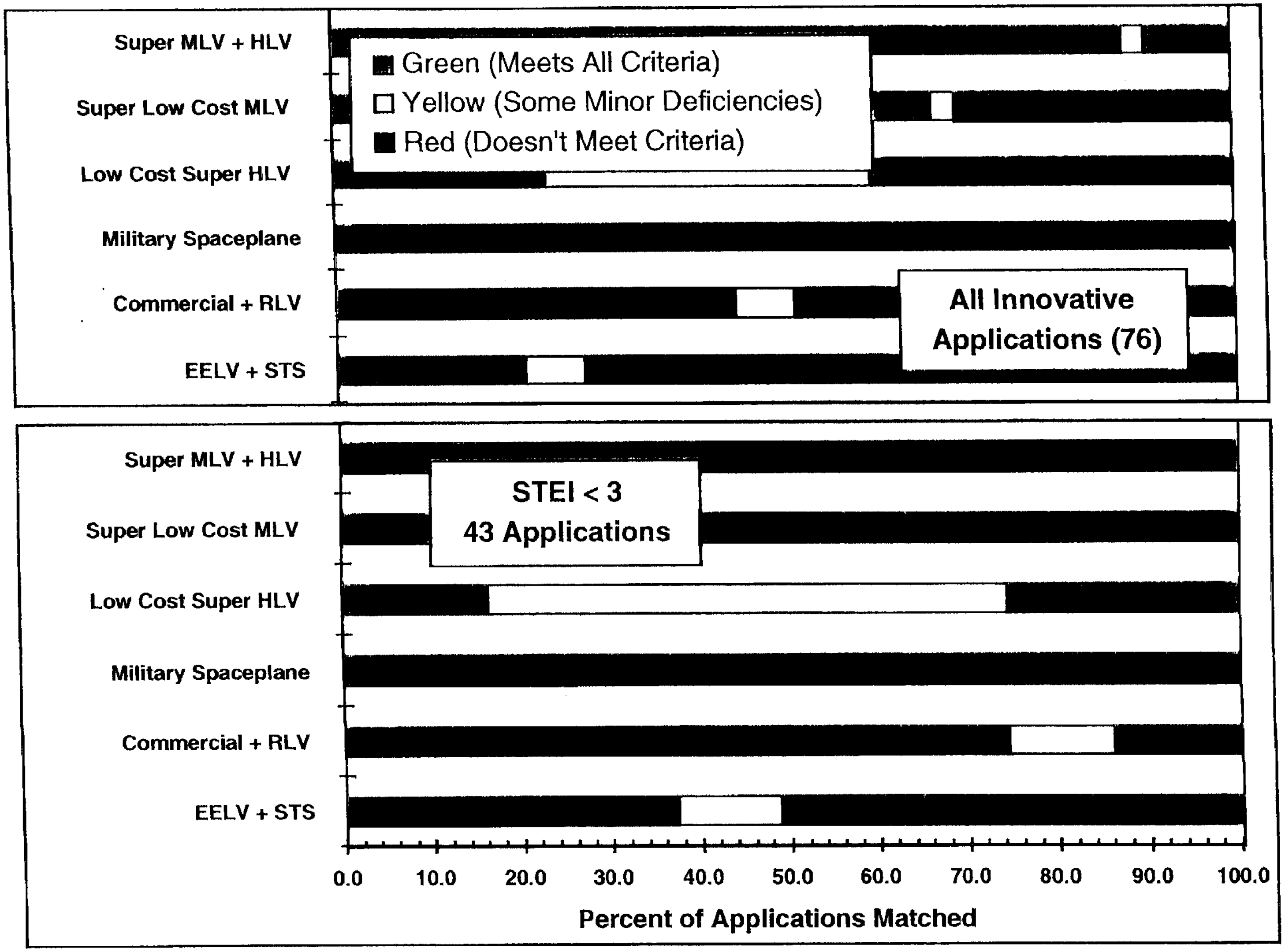
The next two charts provide a summary insight to the compatibility of the launch futures and the Innovative Applications. This chart shows the percentage of total weight to orbit captured by each launch future using the GREEN-YELLOW-RED rating system described previously. Additionally, the applications with STEI<3 and all Innovative Applications are analyzed separately to provide a contrast.

Assuming the existing EELV+STS infrastructure could handle the number of launches, up to 28% of the mission weight of STEI<3 missions could theoretically be captured. The potential launch weight that might be captured will almost double with the advent of the RLV and low cost commercial launch family. However, if cost per lb to orbit is reduced by a factor of 3 and only results in a doubling of weight to orbit delivered, a net loss of revenue of 33% would result. This indicates an economic "hurdle" that must be overcome for this launch family to be successful.

A similar trend is seen in the "all applications" part of the chart. The EELV+STS line is reduced to 5% of the total launch weight because the STEI>3 applications contain missions with generally heavier payloads and with high flight rates. However, the advent of Commercial+RLV systems will also double the weight of "all innovative applications". Again, the loss of revenue in this model must be considered.

The Super HLV can double its launch weight if logical assumptions are made about multiple manifesting lighter payloads. The Super Low Cost MLV captures all of the STEI<3 missions other than those captured by the Super HLV, so a family of these two is a potentially attractive combination. Another possibility not considered here is that the HLV payloads are broken into smaller pieces and launched on the MLV.

Number of Missions Matching Launch Futures



Number of Missions for Launch Futures

This chart shows the percentage of number of applications captured by each launch future using the GREEN-YELLOW-RED rating system described previously. Additionally, the applications with STEI<3 and all Innovative Applications are analyzed separately to provide a contrast.

The EELV+STS future could capture about 40% of STEI<3 missions. As with weight to orbit, RLV+Commercial would approximately double this number of missions capturing about 80% of the 43 applications. The remaining 20% of the applications are not captured due to weight, flight rate, and cost.

Although Military Spaceplane only captured 25% of mission weight, it promises to be a versatile platform capable of launching 60-70% of STEI<3 innovative applications. Again, the missions not captured include larger weight and higher flight rate applications.

Super Low Cost MLV once again captures most applications both STEI<3 and all innovative. The missions that it cannot launch are primarily due to launch weights (heavy application deployment missions) which are uniquely captured by Super HLV. The few "all innovative" missions that Super HLV and Super Low Cost MLV cannot launch are the extremely high flight rate and payload weight missions with 100x cost reduction requirements. These missions include space settlements.

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Technology Assessment

Assessment of Current Technology Programs

- Current technology programs address near-term goals
  - 3X to 5X cost reduction on target
  - Path to 100X cost reduction (high flight rates, airport-like operations) not well defined
- Systems engineering and integration are key to achieve 100X cost reduction
  - Define technology integration goals
    - » Robust structures and reusable engines, durable TPS
    - » Propulsion performance, light-weight materials
  - Focus on operations technology for rapid turnaround
    - » Crew and ground support equipment, launch facilities
    - » Integrated health monitoring sensors and systems, on-board processing to support reuse and maintenance

Assessment of Current Technology Programs

The DOD and NASA core technology programs were reviewed as an input to the technology assessment. DOD laboratories have about 100 S&T programs in the spacelift area -- FY97 funding was about $50M, the lion's share in boost/OTV propulsion under a DOD/NASA/Industry coordinated program titled Integrated High Payoff Rocket Propulsion Technology (IHPRPT). NASA's core technology is in the Advanced Space Technology Program (ASTP), which also had FY97 funding of about $50M. Advances in spacelift operability, reliability, and affordability are also being fostered by DOD's programs for EELV ($2B) and Range Standardization and Automation ($150M/year) and NASA's RLV programs ($1.4B).

While **current technology programs address near-term goals** and were judged to be generally on track to provide a cost reduction factor of 3 to 5X, there is little basis for confidence in applying this technology base in achieving a 100X cost reduction. Many individual technology areas have goals which may support this far-term goal, but the overall picture is characterized by a lack of cohesive effort toward technologies which would allow launch systems to achieve the high flight rates and airport-like operations needed to enable the more innovative spacelift applications identified in this study.

A **systems engineering approach** is called for that defines technology needs and goals and that **integrates** engineering operations required to achieve the synergistic advances in reusability, durability, operability, and efficiency. Propulsion performance advances in say, Isp or thrust/weight, need not be pushed to the limits. Rather, those advances need to be maintained while integrating the demands of rugged, long-life reliable engines and airframes.

Focus on the operations technology goals for 100X or greater levels of cost reduction would bring technology efforts to bear on low-maintenance, long-life, durable components with robust margins; innovative cargo handling and crew/passenger systems; "intelligent" ground support equipment and health monitoring systems; and low-cost propellants and other consumables.

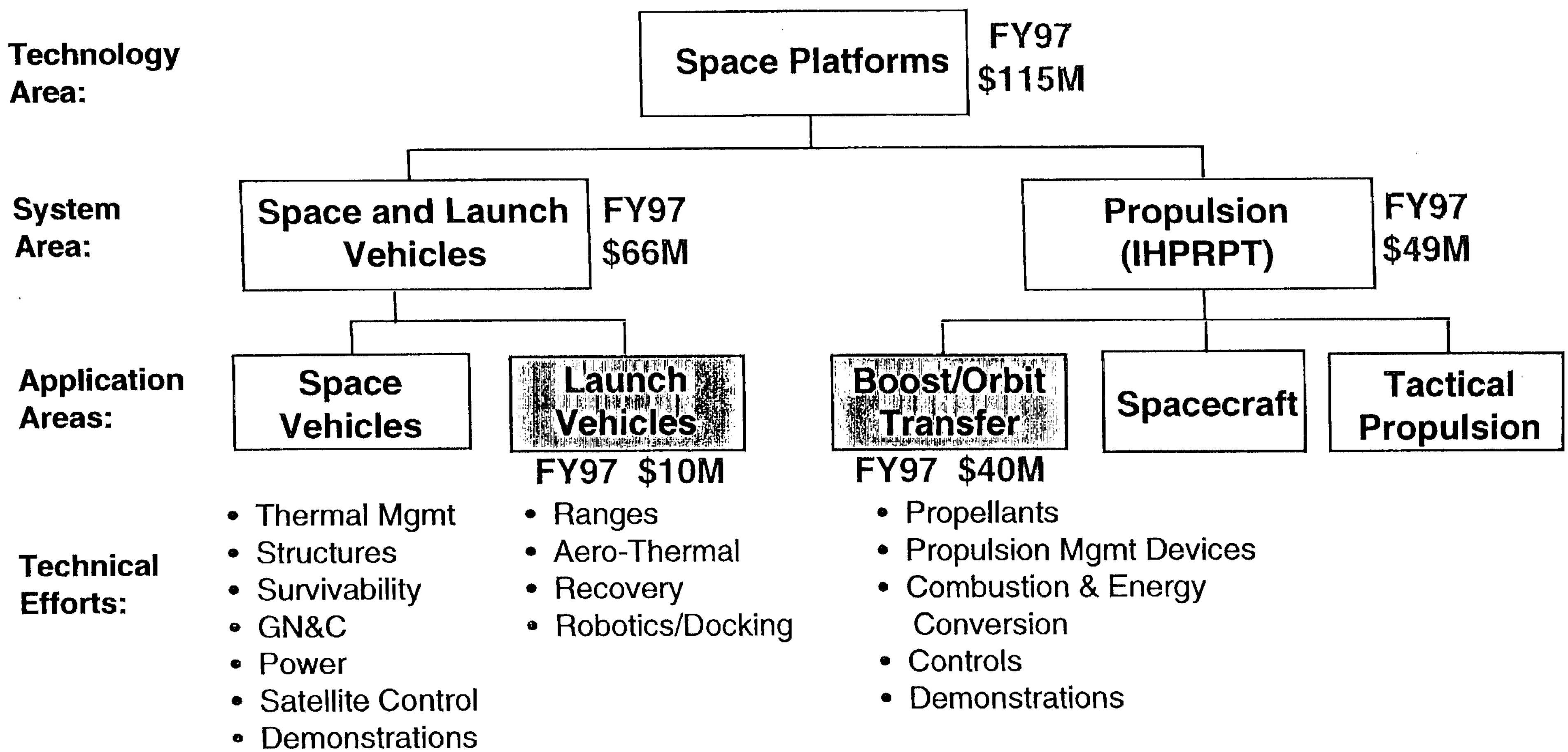
Spacelift Technology Features

Mission Characteristics	Near-Term Innovation	Ultra Heavy	Rapid Access	Passenger Service
Desired LV Features	Expendable or Reusable Present and planned LV OK	Expendable or Reusable SSTO or Multi Stage	Reusable SSTO or TSTO	Reusable SSTO or TSTO
Technology Features SE&I	Present to higher reliability	Robust design margin High reliability	Robust design margin Crew support optional Higher reliability	Robust design margin Passenger support system Highest reliability
Structures	Current technology OK	High performance materials	Lightweight materials High temp. alloys	Lightweight materials High temp. alloys
Thermal Protection		Robust cryogenic insulation	Durable TPS (> 500) Rapid cool TPS	Durable TPS (> 300) Rapid cool TPS
Propulsion		Low cost, heavy lift Leak proof joints	Highly reusable engine Leak proof joints Lower fuel cost	Highly reusable engine Leak proof joints Lowest fuel cost
OTV		Low cost	On-orbit operations/Docking Telerobotics capability	On-orbit operations/Docking Reusable
Avionics		Fault tolerant avionics	Fault tolerant avionics	Fault tolerant avionics Eliminate crit 1 failures
Range		Surge flight rate of 2x	All weather capability Rapid turn around Airplane like operations Surge flight rate of 2 to 3x	All weather capability Rapid turn around Airplane like operations

Spacelift Technology Features

The key technology features for each of these spacelift classes to reach their enabling thresholds are shown with the requirements generally becoming more stringent moving from the near-term innovative missions to the more far-term passenger service missions. Current technologies are generally adequate to enable the near-term innovative missions, although Systems Engineering and Integration (SE&I) efforts for longer life and better reliability and operability characteristics are needed. As noted in the passenger service column, these missions require technology features that will deliver the highest reliability, lightweight materials, high temperature alloys, durable (>300 missions) and rapidly cooling thermal protection systems (TPS), and fault tolerant avionics incorporated into designs that eliminate Criticality 1 failures (catastrophic; complete loss of vehicle) to allow for safe abort of missions. This, in combination with launch system designs and range enhancements which will enable all weather, airplane-like operations are additional technology "needs" of future space transportation systems.

Current DOD S&T Program



IHPRPT: Integrated High Payoff Rocket Propulsion Technology

Current DOD S&T Program

The **current DOD Science and Technology (S&T) program** supporting spacelift is organized to reflect DDR&E emphasis on coordinated planning and the National Defense S&T Strategy.

Space Platforms is one of the ten Defense Technology Areas; examples of other areas are Air Platforms; Materials/Processes; Sensors, Electronics and Battlefield Environment; and Information Systems and Technology.

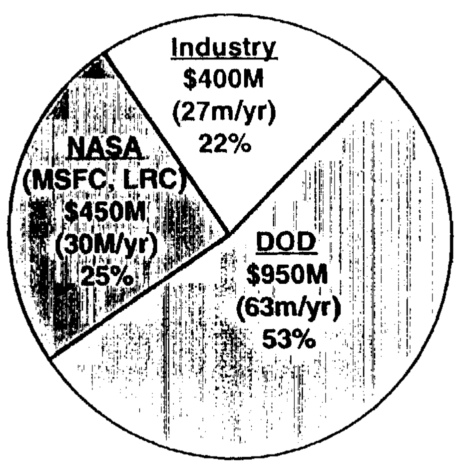
Propulsion technologies are coordinated among DOD, NASA and Industry under the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) program which started in FY94, with primary program impacts for DOD and NASA beginning in FY95. Boost/Orbit Transfer programs amounting to $40M in FY97 directly support spacelift objectives, although IHPRPT also manages exploratory and advanced development efforts in spacecraft and tactical propulsion.

Space and Launch Vehicles complement the propulsion programs and are comprised of the technologies shown for projects managed by Phillips Laboratory and the Naval Research Laboratory. Coordination of a National plan for this area began in FY96 and is continuing.

The **Launch Vehicles** application area has about $10M of FY 97 funding for programs in the following technical efforts (listed in order of funding amounts):

Structures
Range
GN&C
Aero/Thermal
Power

Integrated High Payoff Rocket Propulsion Technology (IHPRPT)



Goals Relative to 1993 Baseline
15 year program for $1.8B
~68% Boost/OTV ($1.2B)

Technologies

- Propellants
  (Solid, Liquid, Gels, Liners)
- Propulsion Management Devices
  (Tanks, Feed Systems, Bladder, Turbomachinery, Cases, Insulation)
- Combustion and Energy Conversion
  (Injector, Nozzles, Igniter, Combustion Chamber, Gas Generator)
- Control Systems
  (Health Monitoring, Actuators, Valves, Ordnance Devices)
- Demonstrations
  (Test Beds, Subscale Systems, Combustion Devices)

Boost/OTV Goals for 2010

- Reduce Failure Rate by 75%
- Increase Mass Fraction by 35%
- Increase Isp by 26 seconds
- Reduce Hardware and Support Costs by 35%
- Increase Thrust/Weight by 100%
- Reusable Life to 100 Missions

System Payoffs for 2010

- Increase payload for ELV by 50% and RLV by 150%
- Reduce launch/O&S costs for ELV by 60% and RLV by 90%
- Cost savings of $1.8B/year

Integrated High Payoff Rocket Propulsion Technology (IHPRPT)

The IHPRPT program established a 15 year National plan, with Boost/Orbit Transfer efforts accounting for $1.2B over that period. DOD contributions are to be over one-half the total; NASA's Marshall Space Flight Center and Lewis Research Center efforts will provide one-quarter of the National effort, and Industry will make up the balance. Army and Navy participation is chiefly in the area of Tactical Propulsion.

Technologies are comprehensive; additional information on planned demonstrations is provided on the following chart.

While **Goals and System Payoffs** are only shown for 2010 here, they were established for 2000 and 2005 as well (see below). Note that the expected 2010 system payoff of annual cost savings matches the outlay for the entire IHPRPT Program.

Boost/OTV Goals for 2000

- Reduce Failure Rate by 25%
- Increase Mass Fraction by 15%
- Increase Isp by 14 seconds
- Reduce Hardware and Support Costs by 15%
- Increase Thrust/Weight by 30%
- Reusable Life to 20 Missions

System Payoffs for 2000

- Increase payload for ELV by 17% and RLV by 50%
- Reduce launch/O&S costs for ELV by 20% and RLV by 30%
- Cost savings of $630M/year

Boost/OTV Goals for 2005

- Reduce Failure Rate by 50%
- Increase Mass Fraction by 25%
- Increase Isp by 21 seconds
- Reduce Hardware and Support Costs by 25%
- Increase Thrust/Weight by 60%
- Reusable Life to 40 Missions

System Payoffs for 2005

- Increase payload for ELV by 34% and RLV by 100%
- Reduce launch/O&S costs for ELV by 40% and RLV by 60%
- Cost savings of $1.26B/year

IHPRPT Demonstrations

- Integrated Powerhead Demonstration (IPD)
  - Mixed Preburner Staged Combustion Cycle
    - Enables Phase I Reliability Weight Goals
  - Unique Oxygen Preburner
  - Configuration/Fabrication Technologies Reduce Weight & Cost and Enable Ox-Rich Cycle
  - Oxygen Turbopump Incorporates Hydrostatic Bearings
    - 14% Reduction in Specific Weight
    - 9:1 Reduction in Parts Enables Phase I Reliability Goals
    - 5:1 Cost Reduction
  - Advanced Oxidation Resistant Materials Enables Ox-Rich Cycle
  - Hydrogen Turbopump Incorporates Hydrostatic Bearings
    - 33% Reduction in Specific Wt
    - 7:1 Reduction in parts Enable Phase I Reliability Goals
    - 4:1 Cost Reduction
  - Hydrogen Preburner Fabrication Technologies Meet Phase 1 Weight and Cost Goals
- Cryogenic Booster Phase II Demo
  - Brassboard, Full Flow Combustion Cycle
    - Lower turbine temperature
    - Hydrostatic bearings
    - Lightweight turbine/pump housings
    - Lightweight chamber/nozzle
  - Increase Isp (2%), T/W (60%)
  - Reduce Hardware/Support Costs (25%) and Failure Rate (50%)
- Advanced Combustion Devices
  - Demo H2 and O2 rich preburner
  - Demo/Evaluate ceramic foam H2/O2 injector
  - Increases component reliability (turbo pumps)

IHPRPT Demonstrations

The Integrated Powerhead Demonstration (IPD) is one of the keys to achieving IHPRPT objectives in weight and cost reduction as well as reliability gains. Components to be demonstrated in Phase I during FY99 are preburners and turbopumps for both hydrogen and oxygen; the mixed preburner staged combustion cycle is enabled through its unique configuration and fabrication technologies including the use of oxidation resistant materials.

Phase I Goals: Increase Isp 1%
Increase Thrust-to-Weight 30%
Reduce Hardware Costs 15%
Reduce failure Rate 25%

The Cryogenic Booster Phase II Demonstration in FY03 will consist of a brassboard model of the full flow combustion cycle engine operating at lower turbine temperature and implemented with hydrostatic bearings and lightweighted housings for the turbine and pumps, combustion chamber and nozzle.

Phase II Goals : Increase Isp 2%
Increase Thrust-to-Weight 60%
Reduce Hardware and Support Costs 25% each
Reduce Failure Rate 50%

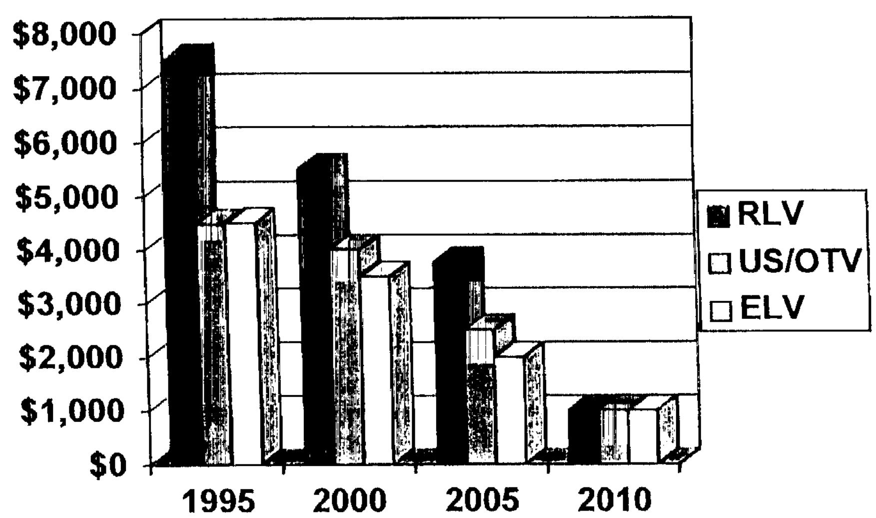
The Advanced Combustion Devices projects will demonstrate jet-stirred hydrogen- and oxygen-rich preburners to induce more efficient mixing. Dense-pore refractory ceramic foam will be used in fabricating hydrogen and oxygen LRE injectors for demonstration and evaluation of their performance. Carbon-Metal-Carbon (CMC) and Carbon-Carbon (CC) high temperature composite thrust chambers will also be demonstrated.

Goals: Increase turbopump component reliability
Reduce component weight
Increase system Isp by increasing power to the turbine

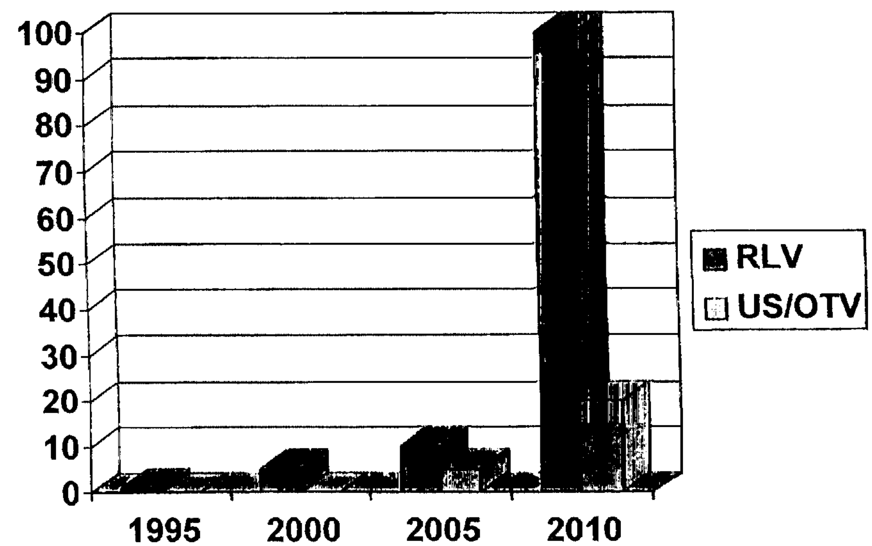
Launch Vehicle Technology Projections

- 1996 Launch Vehicle Technology Development Approach (TDA)
  - Directed by DDR&E to complement IHPRPT
  - Part of Space Platforms Defense Technology Area
- Technology Projections Used to Determine Benefits of S&T Programs

Cost Payoff:
$ per pound mass delivered



Reusability:
Number of flights between refurbishments



Launch Vehicle Technology Projections

Launch Vehicle technologies target reducing the cost of launch, making launch schedules more responsive to user requests, improving the flexibility and operability of the range to support multiple users while significantly reducing operating costs, improving the ability to reposition on-orbit assets, and improving the ability to recover, repair, replenish and deploy on-orbit assets.

In 1996, a **Launch Vehicle Technology Development Approach** (TDA) was directed by DDR&E to complement the IHPRPT initiative in propulsion technologies. The TDA requires development of goals for supporting technical efforts, focusing the efforts, and to serve as metrics of progress. Additionally, system payoffs are computed from the goals and projections made for the time frames 2000, 2005 and 2010. The Launch Vehicle TDA is part of the Space Platforms TDA; coordination with Industry has been initiated to review goals and begin formulation of a National plan -- expected to be finalized in FY98.

The TDA **technology projections** are used to determine the benefits of S&T programs as a basis for funding decisions. The charts illustrate the cost reduction payoffs and reusability increases projected for the Launch Vehicle technical efforts. The table below gives the data from the TDA, including the mass fraction projections; mass fraction is the ratio of dry weight of the launch vehicle to gross lift-off weight, less payload. Very ambitious and challenging mass fraction goals have been set for all systems.

System Timeframe	**$/pound of Mass Delivered**	**Number of Flights between Refurbishments**	**Mass Fraction**
RLV			
1995	7525	1	0.155
2000	5500	5	0.093
2005	3750	10	0.070
2010	1000	100	0.039
Upper Stage/OTV			
1995	4478	N/A	0.148
2000	4000	N/A	0.089
2005	2500	5	0.067
2010	1000	20	0.037
ELV			
1995	4504	N/A	0.097
2000	3500	N/A	0.058
2005	2000	N/A	0.044
2010	1000	N/A	0.024

NASA RLV Technology Programs

- A Change in Direction
  - Prime Objective ► Low Cost
  - Leapfrog Technology
  - Partnership with Industry
  - Commercial Operations

Improve
Reliability
Operability
Reusability

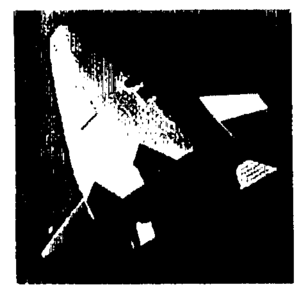
DC-XA

- Operations (Subsonic)
- Advanced Technology
- 42,000 lb, $30M
- Four Flight Tests Concluded

X-34

- Flight Ops (Mach 8)
- Advanced Systems
- 43,000 lb, $60M
- 1998 Flight Test

X-33



- Flight Ops (Mach 15+)
- Demo SSTO (Grd & Flt)
- 273,000 lb, $1130M
- 1999 Flight Test

RLV

- Commercial System
- 45,000 lb to LEO
- 25,000 lb to Sun Sync
- 13,000 lb to GEO w/US
- 2004 Flight Test

Core Technologies

- Reusable Cryogenic Tanks
- Graphite Composite Primary Structure
- Advanced TPS
- Advanced Propulsion
- Avionics/ Operable Systems

NASA RLV Technology Programs

The NASA reusable launch vehicle (RLV) technology program has a prime objective of drastically reducing the cost of routine access to space by a factor of ten or more; i.e., cut the cost of payload to orbit from $10,000 to $1,000/pound by 2010. Stimulating commercial enterprise through partnership with industry and the application of revolutionary technologies will require program focus on technology development and demonstration of improvements in reliability, operability and reusability.

DC-XA advanced technologies included Al-Li O_2 tank, composite H_2 tank, composite intertank, composite lines and valves. Operability enhancements consisted of automated mission planning, redundancy management, differential throttling, rapid turnaround plus small ground and flight crews. Primary goals were met.

X-34 is a test bed demonstration vehicle for technologies applicable to RLVs. The key technologies include composite primary and secondary airframe structures; composite reusable propellant tanks, cryo insulation, and low-cost simple propulsion system elements (the MSFC "Fastrac" 60K LOX/RP engine); hypersonic TPS and materials; low-cost avionics; integrated vehicle health monitoring system; and autonomous approach and landing.

X-33 is an advanced technology demonstrator planned for first flight in 1999. Horizontal processing, vertical lift-off, lifting reentry and horizontal landing are design features that will demonstrate technologies related to aircraft-like operations. Structural technologies considered are an aluminum LOX tank, composite LH2 tank, composite intertank structure, composite thrust structure and a composite payload container. The linear aerospike LOX/H2 engine is planned with throttling from 40% to 120% thrust. The vehicle design uses a standoff aeroshell.

The vision for a **commercial RLV system** capable of delivering 45,000 pounds to low Earth orbit calls for first flight in 2004.

Core technologies are discussed in the following charts.

NASA Advanced Space Transportation Program

Total FY97 Funding: $50M

Advanced Reusable Transportation Technologies

- Target: Medium launch capability
- Goal: Two orders of magnitude reduction in current launch cost (100x cost reduction)
  - Maintain U.S. lead in reusable transportation
- Technology:
  - Adv Al-Li Tank/Gr-Ep LOX Tank
  - RBCC propulsion

Low-cost Boost Technologies

- Target: ~500 lbm to LEO
- Goal: $1.5M per launch
  - Enable small payload transportation
  - Commercial launch technology spin-off
- Technology:
  - LOX/RP engine testing in 1998-1999
  - LOX/LH_2 upper stage test in 1999

Space Transfer Technologies

- Target:
  - High efficiency upper stages
- Goal: Order of magnitude reduction in cost
  - Shorter planetary mission times
- Technology:
  - High temperature engine

NASA Advanced Space Transportation Program

The Advanced Space Transportation Program (ASTP), led by MSFC, addresses future technologies for transportation at NASA. The objective is to reduce payload transportation cost to LEO to approximately $100/pound by 2020 and enhance U.S. commercial launch competitiveness.

Advanced reusable transportation technologies target medium launch capability systems with a goal of reducing launch costs to 1% of current cost. It should be noted that NASA has a different cost baseline (higher) than that used in this study so the NASA 100X reduction (to about $100/pound to orbit) doesn't precisely align with the study's 100X reduction factor. NASA uses today's Space Shuttle as a baseline versus the use of today's best expendable cost of about $5,000/pound in this study. The current principal technology efforts are the advanced Aluminum-Lithium tank, graphite-epoxy liquid Oxygen (LOX) tank, and Rocket Based Combined Cycle (RBCC) systems planned for flight test of critical components in 2000 and a large-scale integrated flight test in 2005.

Low-cost boost technologies are directed toward small payload transportation. The goal is to use current and emerging technologies to achieve a launch system which can put approximately 500 pounds in orbit for $1M to $1.5M per flight. Plans call for a simple robust design with advanced low cost manufacturing and streamlined processes leading to flight demonstrations of the Bantam Booster in 2000 with spin-offs for commercial low-cost launches targeted for 2002. X-34 flight tests are scheduled for 1998 using the Fastrac 60K engine with low-cost features such as a simple cycle LOX/RP (Gas Generator) design based on the low-cost Fastrac I & II thrust chamber assemblies and a Simplex Turbopump. Reduced part count, commercial manufacturing techniques (silica-phenolic ablative chamber, non traditional suppliers) and early participation by fabrication contractors will also be used to achieve the stated goals.

Space transfer technologies are to provide high efficiency upper stages that will reduce planetary mission times as well as lower costs. Technologies include advanced control systems, low-mass structures, high-temperature materials, propellant technology, non-chemical propulsion research and advanced propulsion physics. A solar thermal stage flight experiment is planned for 1998 with advanced thrusters and orbit transfer stages to follow.

ASTP RLV Technologies

- **Goal: Two orders of magnitude reduction in launch cost (medium payload weight)**
- **Technology: Increase performance margin of next generation RLV; longer life, reduced maintenance, lower cost.**

  <u>Technologies</u>
  - Composite Structures
  - Advanced TPS
  - Simple Avionics
  - Improved Rocket Propulsion
  - Combined Airbreathing Rocket Propulsion
  - Advanced High-Risk Launch

  <u>Applications</u>
  - Medium Cost Payloads
  - Shuttle Improvement
  - Medium Commercial Launchers

- **Milestones:**
  - 2000, RBCC POC Flight Test
  - 2002, RBCC Testbed, Sub-scale Flight Demo
  - 2005, RBCC Small Scale Flight Demo
  - ~2015, Commercial RBCC Flight Vehicle

<u>TPS</u>

X-34 Acreage
- Toughened Tiles
- Blankets-Organic, Ceramic

X-33 Acreage
- Metallic Honeycomb Standoffs

X-33 Leading Edge/ Nosecap
- C-C Nosecap

Inspection/NDE Supporting Technologies
- Complex Geometry Inspection Techniques
- Health Monitoring
- NDE for Metallics and Composites

Acreage Alternative Technologies
- Advanced Ceramics
- Advanced Metallics

Leading Edge
- Advanced Ceramics, C-C, and CMC's
- Reusable Ablators
- Attachment and Sealing Methods

Advanced Acreage
- Advanced Flexible Blankets
- Refractory Composites
- Advanced Metallics

Hot Control Surfaces
- Fab Methods and coating dev. for Ceramics

ASTP RLV Technologies

Thermal Protection System (TPS) technologies are aimed at increasing lifetime of TPS materials while providing lower cost fabrication and simple attachment and integration methods. Labor-intensive manufacturing and space vehicle integration are currently TPS hurdles to multi-fold cost reductions for RLVs at large. A variety of new TPS technologies are currently being explored under both NASA and DOD efforts (see later TPS chart).

Applications of RLV technologies listed here are currently projected for Shuttle improvements and commercial launchers along with the NASA experimental vehicles. In particular, the TPS technologies planned for the X-planes are also applicable to DOD missile re-entry vehicles.

Milestones for the Rocket Based Combined Cycle vehicle are indicated. The NASA X-33 experimental space vehicle's use of advanced leading edge and nosecap TPS materials will provide insight into the success of the TPS technology advancements in 1999.

ASTP Structures and Tanks Technologies

Primary Structures

Noncircular Shell Thrust Structure/Intertank
- Advanced PMC Materials/Processing
- Bonded Joint Design/Analysis
- Composite Shell Analysis Tools
- NDE of Damage and Repair
- Life/Fatigue Damage Assessment

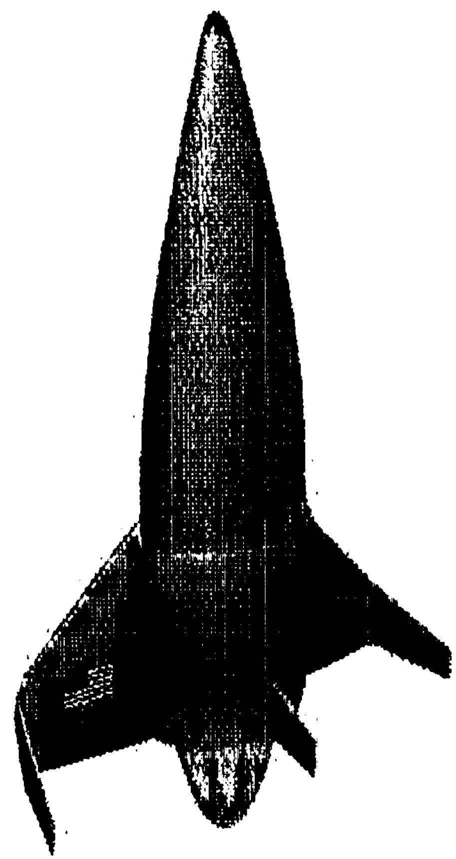
Integrated Primary Structure/TPS
- Subscale, Full-Scale Design/Fab/Test
- High Temperature PMCs

Hot/Cold Structural Interface (Fins/Cold Structure)
- Mechanical Joint Development
- Advanced Intermetallics

Hot Wing Structure/Fins
- Advanced MMC Structure/Materials
- High Temperature Alloys
- Joining Methods for MMC

Design/Analysis Supporting Technologies
- Multi-Discipline Design Optimization
- MMC Landing Gear Design
- Materials Design Allowables

X-33 Phase 1
- Composite Thrust Structure, Intertank, Wing Box



Commercial RBCC Flight Vehicle (~2015)

Cryotanks

Gr-Ep Lox Tank
- Lined/unlined Tank
- Thermal Spray Processing
- Lox-Compatible Materials
- Improved Stringer Adhesion
- Debris Impact Resistance
- Low-Cost Automated Manufacturing
- Adv. Al-Li Tank

Advanced Design and Analysis
- Impact Damage Analysis Code
- Automated Finite Element Mesher
- Fracture of Advanced Material Joints
- Fracture of Advanced Materials

Integral TPS/Cryostructure LH_2 Composite Tank
- Composite Sandwich Structure
- Ti Honeycomb Core Sandwich

Nonautoclave Composite Tank
- Integrated TPS/Insulation Cryotank
- Composite Y-Joint
- Bonded Splce Joint
- Composite Seals
- E-Beam Cure
- Automated Fiber Placement
- Dry Prepreg Forms

Alternate Technology Tank
- Hot-to-Cold Structural Joints
- Al-Be, Al-Mg Alloys
- Aerogel Cryo Insulation
- NDE of Repaired Structures
- Advanced Cryo Insulation Coatings

ASTP Structures and Tanks Technologies

Elements of ongoing and proposed NASA technology development for **primary structures** and **cryotanks** are summarized in this chart. The efforts focus on a reusable vehicle with lifting body and/or wings. All technologies aim to reduce structure weight, increase damage tolerance and life, reduce thermal protection requirements, and reduce manufacturing and design cost. These programs build on past government work on RLV, SSTO, NASP and ongoing efforts under X33.

Current Technology Programs Assessment

Cost Reduction		3X					10X					100X				
Technology		Performance	Operability	Reliability	Affordability	Reusability	Performance	Operability	Reliability	Affordability	Reusability	Performance	Operability	Reliability	Affordability	Reusability
SE&I	Systems Analysis						Y	Y	Y	Y	Y					
	Modeling/Tool Development								Y	Y	Y	Y				
Structures	Composite Structures/Tanks						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Composite Tanks (Conformal)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Advanced Metallics						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Thermal	High Temp Alloys						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Protection	Ceramics						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Active TPS															
Propulsion	LOX/LH2 IPD Engine						Y	Y	Y	Y	Y		Y	Y	Y	Y
	LOX/LH2 (Aerospike)						Y	Y	Y	Y	Y		Y	Y	Y	Y
	LOX/RP IPD						Y					Y	Y	Y	Y	Y
	LOX/CH4 IPD						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Combined Cycle Propulsion						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Ultralow Cost Engines								Y							
	HEDM							Y	Y	Y	Y		Y	Y	Y	Y
OTV	Reusable Transfer Stages	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y			Y
	Low Cost Expendable	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y			
Avionics	GN&C/Health Monitoring							Y	Y				Y	Y		
Range	In-flight Refueling	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Containerized Payload System									Y			Y	Y		Y
	Flight Ops Control Center							Y	Y	Y						
	Range Standardization/Turn Time							Y	Y	Y						

	Tech efforts focused on goals or no tech required
Y	Marginal, may achieve goals with shift in emphasis, or underfunded
	Current tech base inadequate or no program

Current Technology Programs Assessment

An assessment was made of how well the current programs are addressing the desired spacelift attributes. As stated earlier, the current DOD and NASA technology programs are judged to be adequate for meeting the cost reduction goals of 3X and slightly beyond. However, the focus is on launch characteristics for 3 to 10X cost reduction: NASA technology efforts reflect X-33, X-34 objective characteristics of 99.9% reliability, 4 to 7 day turnaround, 50 flights/year, $1000 to $2000/pound, 700 nmi crossrange; DOD is focused on the MSP with slightly more stringent military-type operations goals of 99.95 to 99.98% reliability, 2 to 8 hour turnaround, up to 300 flights/year, costs of $100 to $1000/pound, and 1200 to 2400 nmi crossrange with significantly reduced lift requirements in comparison to NASA. The technology assessment for 100X cost-reduced systems also reflects the earlier comment that systems analysis and integration tools have not yet been brought to bear on designs with highly operable, reliable and durable attributes. In addition to shifting emphasis to operability and reliability goals over performance, several required technology efforts such as active TPS, OTVs, ultra low cost engines and range enhancements do not exist or are not adequately supported by current plans. Active TPS may be required to support rapid vehicle turn times, OTVs to provide affordable orbit-to-orbit transport, ultra low cost engines to reduce the cost of expendable boosters and upper stages, and range enhancements to facilitate more operable and safer ranges.

SE&I: Systems analysis -- Current situation is that each concept requires unique systems analysis; tools are needed that can span different concepts for comparative in-depth analyses to evaluate designs and to eliminate all critical failure modes and provide safe shutdown before impending failure. Design requirements need to focus on operability, reliability and low cost per flight. High reliability should be sought through selection of design margins, operable subsystems, certification processes, in-flight health management systems, and techniques to eliminate Criticality 1 failures and provide safe abort. For rapid turnaround and long life there should be additional consideration for operable fuels and access provisions for maintenance and servicing. Low cost goals should be established through consideration of the complete system -- vehicle and support systems.

Modeling/Tool Development -- The Marshall Space Flight Center has a promising approach to RLV operations technology needs. For example, in addressing rapid vehicle turnaround for reflight, it's proposed to use early design analysis to assure maintainability with minimum crew and ground support equipment. The concept envisions immediate access to vehicle data by geographically dispersed engineering teams and analysis tools to support rapid servicing requirements. Key elements of the MSFC approach are:

Centralized database with remote access to vehicle design, engine component sensor, avionics status and test, electrical power system (EPS) status and test, TPS and structure sensor, vehicle health, and ground support systems (GSS) data;

Operations expert system for vehicle analysis;

Human factors engineering and computer-based tools for design analysis, operational procedures development and training.

Structures Technology Assessment

App.	Component	State-of-the-art	Applicable technologies and approaches	Component weight reduction potential	Component cost reduction potential
RLV, ELV, OTV	Liquid Propellant Tanks	grid/rib or pressure stiffened cylindrical metallic, no or separate TPS, "hand" inspection	lined and unlined composites or other advanced materials, integrated TPS, bonded or jointless design, advanced manufacturing (spin forming, welding, non-autoclave composite), automated/autonomous NDE	2005 - 25% 2015 - 40%	2005 - 10% 2015 - 25%
ELV, OTV	Solid Propellant Motor Cases	monocoque wound composites, integral skirts, separate TPS and insulation, ring/bolted joints	advanced materials (high strength/stiffness composites, high temp resins), grid stiffened designs, integrated TPS and insulation, advanced manufacturing (automated tape placement, non-autoclave composite), bonded joints	2005 - 10% 2015 - 20%	2005 - 10% 2015 - 20%
RLV, SP	Primary Structures	separate lifting surfaces, spar/stringer wingbox construction, metallic and composite , separate TPS, "hand" inspection	integrated tanks and lifting surfaces (conformal tanks), integrated TPS and ablators, high temperature materials, automated/autonomous NDE, advanced manufacturing (automated tape placement, non-autoclave composite)	2005 - 20% 2015 - 40%	2005 - 10% 2015 - 20%
RLV, ELV	Primary Structures (shroud, interstage)	skin/stringer metallic or composite honeycomb, ring/bolted joints, separate TPS	advanced materials (high strength/stiffness composites, high temp resins), grid stiffened designs, integrated TPS and insulation, advanced manufacturing (automated tape placement, non-autoclave composite), bonded joints	2005 - 15% 2015 - 30%	2005 - 10% 2015 - 20%

Structures Technology Assessment

This chart provides an overall assessment of the applicable NASA and Air Force technology developments related to structures. The table is organized by major components, or elements, of a typical launch vehicle's structures: liquid tanks, solid propellant cases, primary structures for lifting surfaces, and non-lifting surfaces (interstages, shrouds, etc.) The applicability of these structures and the associated technology development is indicated in the first column as expendable launch vehicle (ELV), reusable launch vehicle (RLV), orbital transfer vehicle (OTV), and space plane (SP). Corresponding to each class of structure is a description of the state-of-the-art and the advancements/innovations being pursued in various AF and NASA technology development programs. Based on the stated goals of these programs and consideration of the technology attributes, program funding, and current technology, an assessment of the potentials for cost and weight reduction is provided in the last two columns. Less significant weight reduction is projected for structures currently made of composites such as solid rocket motor cases, shrouds, and interstages. Advances in material properties, and innovative structural configurations enabled by new manufacturing techniques will yield some weight reduction in coming years. Cost reductions in all areas are expected to result from the benefits of increased production and supply of composite materials, new and efficient manufacturing methods, and reduced test and inspection time.

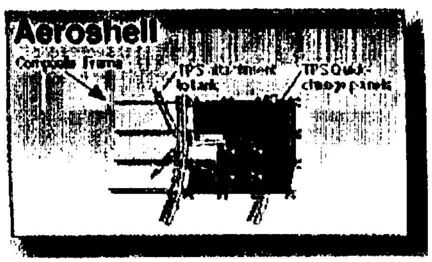
Composite Structures/Tanks -Several AF and NASA technology development programs are underway and many more are planned to exploit advanced composite materials and manufacturing methods for composite liquid propellant tanks. These programs have goals of 40% reduction in tank weight, more reusability (large number of load cycles), low-cost manufacturing and reduced inspection/refurbishment cost. Efforts are also underway to develop lightweight composite primary structures such as interstages, shrouds and wing boxes. Other programs are planned to develop hot structures and integral thermal protection to enhance weight savings by synergy with the thermal subsystem.

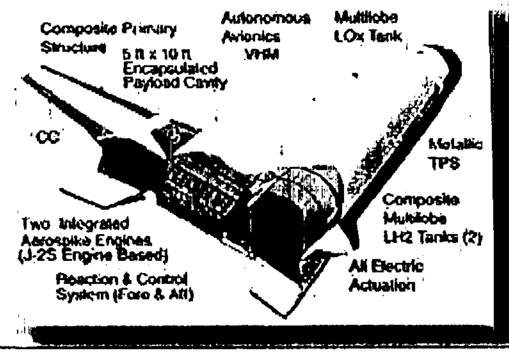
Composite Tanks (Conformal) -- Conformal (non-circular) composite tanks (LH2) are being developed for the X33 program which permit volume efficiency with the lifting body concept. Other conformal tank development programs have also been proposed and are structured to support combining the tank and wing/lifting body primary structures for enhanced weight savings.

Advanced Metallics -- AF technology development efforts directed towards non-tank structures are focusing on reusability of these structures. Aluminum-Lithium has been developed for tank structures, and further advances in manufacturing methods for this material are proposed. Metallic composite materials and advanced metal alloys are being investigated for application to tanks and primary structures, primarily in high temperature applications.

Aero/Thermal and Thermal Protection Systems (TPS)

Description: Advanced, reusable, hybrid concept Thermal Protection Systems for next generation RLVs and OTVs:





Objective: Develop highly reusable and cost effective Thermal Protection Systems.

- - Improved durability and operability
- - Reduced mass, reduced life cycle cost

Schedule:	**DOD**	**NASA**
Materials Ground Tests:	99 - 03	97 - 00
Flight Demonstrations	-	1999

Attributes

Performance:

- Weight Reduction: 10% TPS by 1999
- Ease of manufacturing,
- Flexible, Conformal TPS structure

Carbon Carbon: > 2000°F

Metallic: 900 - 1300°F

Gr/Ep/RSI (Nomex) < 900°F

Reusability: 1000% increase in lifetime over STS technology

Assessment

Application - RLV, OTV and Space Plane nosecaps, leading edges, hot structure control surfaces

Maturity - Demo concepts and materials ground tested. Aimed for X-34, X-33 flight demos - 1999

Good - Strong DOD and NASA programs with materials and tools development crosslink. Needs focus on TPS replacement times and methodologies

Aero/Thermal and Thermal Protection Systems (TPS)

NASA TPS Development Effort Highlights at Ames Research Center include:

A) Toughened Uni-Piece Fibrous Insulation (TUFI) upgrade for Shuttle's tiles,

B) Lightweight Ceramic Ablators that are easily machinable, low density and with variable composition, such as;

1) Silicone Impregnated Reusable Ceramic Ablators (SIRCA) for X-34 Leading Edges/Nosecap,

2) Phenolic Impregnated Carbon Ablators (PICA) (a candidate for the X-33 Aerospike Engine interior),

3) Secondary Polymer Layered Impregnated Tile (SPLIT) heatshield for the DSII Microprobe, and

4) Erosion Resistant Ceramic TPS, a thin layer of 3D C-C composite with existing ceramics,

C) DurAFRSI, a Hybrid TPS with flexible Ceramic blanket and Metal Foil, and

D) TPS Surface Characterization Studies (emittance, catalytic efficiency, and thermochemical stability).

At Langley Research Center, programs are planned in:

A) Thermal Insulation Development and Characterization;

B) Metallic and Refractory Composite TPS Concepts;

C) Carbon-Carbon composites that are low cost, long life and oxidation resistant;

D) Metallic Standoff TPS;

E) Titanium Multi-Wall SuperAlloy Honeycomb (0% Weight reduction from 80's designs); and

F) AeroThermal Heating Analysis and Testing.

DOD TPS Development Effort Highlights include:

A) Hot Structures/TPS;

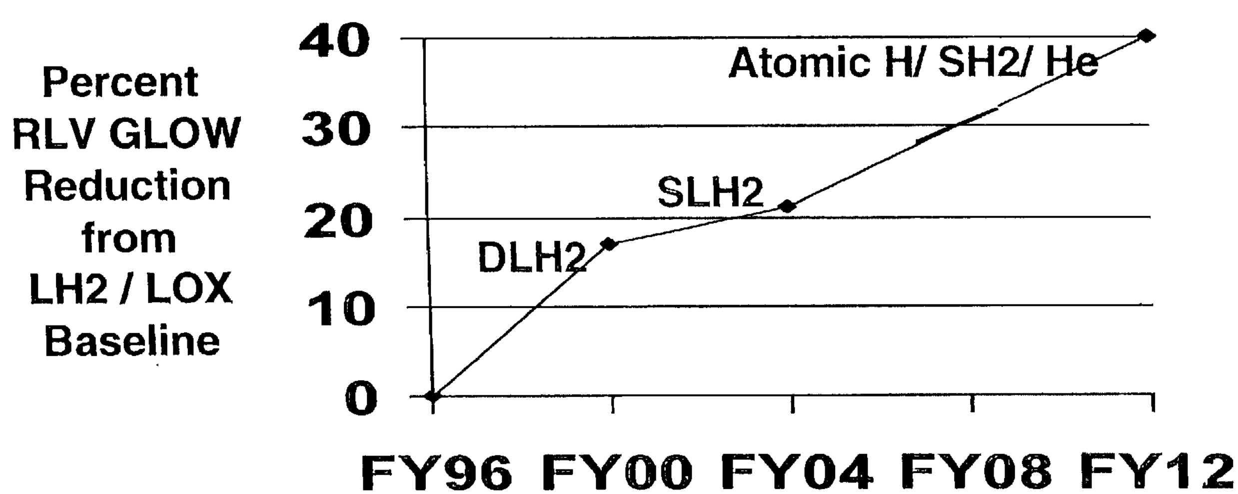
B) Aeromechanics Technology;

C) Boundary Layer Stability; Hypersonic Aero-Thermal Code; Real Gas Low Density Flowfields, and

D) 3D Design Optimization and Thermo-Mechanical Evaluation of Reentry Materials Follow-On.

Advanced Propulsion Technologies

- New World Vistas
  - Advanced Chemical Propellants
    - » High Energy Density Materials (HEDM)
  - Polymeric Rocket Propulsion Technology
- Magnetic lifters, power beaming



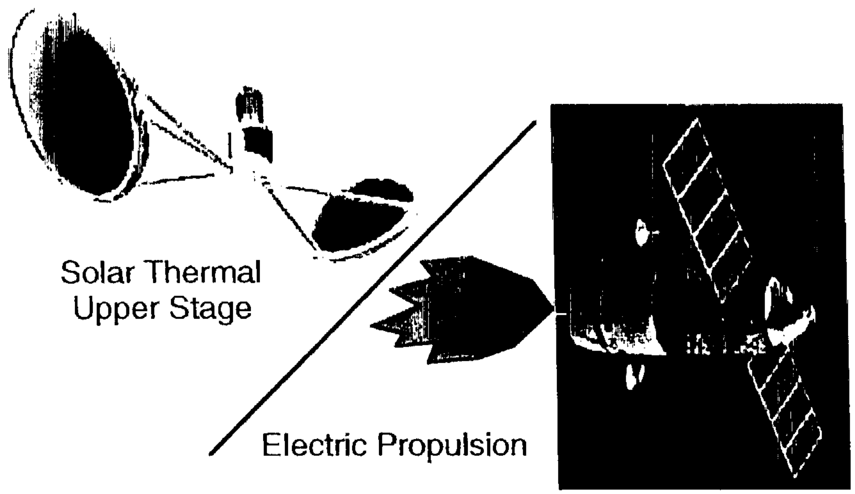
Advanced Propulsion Technologies

New rocket propellants developed in the AF **New World Vistas (NWV) advanced chemical propellants** program might provide much greater capability for a variety of AF missions. The range of new propellants under development is expected to result in modest improvements in cost and performance in 5 to 10 years and revolutionary improvements in 15 to 30 years. Double to quadruple payload increases for a fixed system size might be possible, resulting in greatly lowered cost and affordable access to space. Projects include efficient synthesis of a strained-ring hydrocarbon propellant with Isp 5% greater than RP-1, determination of combustion properties of a HEDM cryogenic solid in a hybrid rocket configuration, production and characterization of gram quantities of HEDM-doped solid hydrogen, determination of physical characteristics and demonstration of combustion characteristics of new liquid propellants, production and test of scaled-up quantities of HEDM propellants, and design, construction and testing of new combustion devices for these propellants. These efforts will lead to an advanced propellant booster demonstration in the 2006 to 2010 time frame.

The AF **Polymeric Rocket Propulsion Technology** program addresses IHPRPT objectives for lower component weights and manufacturing costs as well as the NWV goal of light weight integrated structures combining reusable cryo-storage, TPS, and self diagnostics to enable a responsive reusable launch capability. This joint program between PL and WL will develop the polymer blending methods, fabrication science and engine design methodologies needed to make rocket systems from ultra-light, neat plastics. Programs to develop ultra-lightweight ducting, pump housings, and case/nozzle systems will lead to testing and demonstrations in 2010.

NASA MSFC is sponsoring eight activities through the ASTP in advanced propulsion with little funding ($4M to $5M in FY97). **Maglev (magnetic levitation) and Launch Assist** is funded at about $1.2M with Pulse Detonation Engines, **Beamed Energy Transportation** (laser energy beamed from the surface to power a rocket), MagnetoHydroDynamics (LV propulsion by ionizing the external air and accelerating it with MHD), Fission/Fusion rockets and Anti-Matter Storage. Other activities such as solar thermal concentrators, tethers, catapults, micro-propulsion, gravity shielding/modification, anti-matter energy, energy from the vacuum, and worm holes are clearly just on this side of science fiction, even for the 2025 time frame. These offer substantial improvements in performance (thousands of seconds of Isp, not tens) and include concepts that may be feasible with advances in current engineering as well as concepts that require breakthrough physics. JPL is supporting anti-matter catalyzed fusion/fission and dense storage of hydrogen. LeRC has a joint program with PL in solid hydrogen research with test objectives to produce solid H2 / liquid Helium slurry, conduct flow and mixing studies, and characterize transport properties.

OTV (Orbit Transfer Vehicle)



Objective: Order of magnitude reduction in cost with high efficiency upper stages that increase payload to High Earth Orbit, on orbit lifetime, repositioning and shorter planetary mission times

Schedule: Components reach TRL 6 in 03 to 2010 time frame

Attributes

Performance: 10% Increase in Payload to GEO

25% Increase in Lifetime
200% Increase in Repositioning

Affordability: Cost Reduction, $4M/yr

Assessment

Application: High Earth Orbits; LEO with Repositioning and Planetary Missions

Maturity: Electric - Maturing

Solar Thermal - Long Way Off

Assessment: Electric - Good / Solar - Too Early to Tell

OTV

OTV: Reusable Transfer Stages can be considered a competitor to low-cost, expendable upper stages. Reusable transfer stages or space tugs have had a spotted history and one of the current concepts is Sandia National Lab's nuclear powered vehicle, which addresses autonomous rendezvous and docking, but will face an uphill political battle. Survivability will be crucial to these reusable assets; however, there is currently little if any funding available. Satellite control technologies are applicable, but RLV/OTV requirements do not seem to be addressed at this time.

Low Cost Expendable (storable and soft cryo) transfer stage programs stress performance more than affordability. **Solar Thermal Upper Stage (STUS)** propulsion technologies include Lightweight Large Concentrators (Fresnel lens and both rigid and thin film inflatable parabolic reflectors), High-Temperature Engine, and Long-Term Cryogenic Propellant Management which consist of mission specific requirements and long-term storage of cryogen in composite tanks. These technologies are being worked by NASA in the Shooting Star Flight Experiment, the Air Force in the Integrated Solar Upper Stage (ISUS) program and a NASA, AF, Industry Consortium in AITP. Additional technology and development work is required in concentrators, concentrator support structure, engines/thrusters, cryo propellant storage and management, navigation, control & pointing, and system demonstrations before an operational upper stage based on solar thermal propulsion is a reality. AF funding is in place to achieve a solar balloon experiment flight test demo and solar thermal component development in 2000, which will lead to a solar thermal flight demo by 2005. Isp increases from the current 290-450 sec. up to 1050 sec. by 2005 are expected from these efforts. **Solar Electric Propulsion** projects under AF funding range from the 30kW class Arcjet (1998) to Nanosatellite electric thruster development (2005). Efforts also include the High Performance Hall Thruster, pulsed plasma thruster on MightySat, and a 20kW Hall thruster development and ground demonstration. The NASA ion propulsion systems (Xenon gas) provide improved performance of planetary and Earth orbiting spacecraft primarily through reduced mass of the propulsion system. The ASTP funding augmentation supports the JPL/LeRC managed program. **Low Cost Transfer Stage** technologies to support missions to near-Earth bodies and planets include: engine technologies based on alternative propellants such as LOX/Ethanol, LOX/Methane; aerobrake technologies for aerocapture to reduce propellant requirements; and cryo-fluid management to provide long term storage and transfer of cryo propellants. **Tether Transportation Systems** provide passive transfer (no propellant) for near-Earth orbit and inclination changes. A flight experiment is scheduled for 2000 that will further define potential applications of tether systems.

Avionics

Description

Overall Objective: Increase performance, reliability, decrease cost, weight of sensors and actuators. Create integrated systems to use sensors for increased autonomy.

Objective

Decrease cost, increase reliability and performance of GN&C systems

-- Increased use of miniature solid state sensors/actuators (DOD)

-- Increased autonomy (NASA)

Attributes

System Payoffs (1998-on)

-- Performance: Increase accuracy

-- Affordability: Decrease manufacturing cost through use of micro-device manufacturing techniques. Increase vehicle autonomy.

-- Reliability/Safety: Increased use of solid state sensors and actuators.

Assessment

Applications: Expendable/Reusable LVs/ OTVs

Maturity: Demos defined for near-term developments

Marginal: No apparent overall coordination of ICBM/LV/Satellite GN&C programs

Avionics

GN&C/Health Monitoring -- DOD contributions are primarily in radiation hardening, miniature solid state actuators and sensors, including the use of GPS; technology projects are driven by aircraft and ICBM requirements, with IHPRPT engine monitoring work an exception. Phillips and Wright Laboratories have established cooperative projects in this area. NASA's projects have more of a focus on autonomy; for example, NASA Lewis Research Center (LeRC) work on health monitoring (HM) technology under their Controls and Dynamics Technology research includes:

> Intelligent control of reusable rocket engines with reconfigurable controls for fault accommodation, model-based fault detection, and real-time sensor validation with neural nets.
>
> Life-extending control concept.

Under LeRC Mechanical Systems Technology research are vehicle and engine HM systems to enable automated checkout and monitoring to reduce launch processing and operations costs. Examples are the Aerospike Health Management System; sensor validation -- comparing predicted to observed values; and Post Test Diagnostic System -- feature extraction, model-based data screening and sensor validation, analysis by heuristics and case-based reasoning. The latter system realizes an order of magnitude reduction in data analysis time and has event (pre-launch) and anomaly detection spin-offs.

The JPL Avionics Flight Experiment provides capabilities for monitoring and processing of X-33 critical mode flight data and GN&C functions [GPS-on-a-chip, INS]; miniature, distributed sensors for data bus diagnostics; real-time image processing using miniature sensors. Reliability is to be demonstrated through support to eight X-33 flights without ground maintenance.

JPL Vehicle Health Management efforts feature a wireless RF umbilical; beacon-based monitoring; a QWIPS (quantum well infrared photodetector and real-time software) in-flight TPS integrity monitor used for in-flight temperature profiling for insulation thermal leaks, external fluid leaks, and external TPS thermal profile; a MEMS (microelectro-mechanical system) moisture detector for the cryo distribution system; tunable diode laser (TDL) for on-board spectroscopy used as a hygrometer, hazardous gas leak detector, and spectral chemistry monitor; high-speed, high-resolution videogrammetry for external inspection(videogrammetry analysis software system automates external visual inspection with cross-correlated visual, spectral and ultrasonic imagery -- >10X reduction in external inspection time expected) of TPS, tires, brakes and engine wear; and an on-board structural health monitor. The structural health monitor algorithms and software are used for feature extraction and on-board data analysis; with an anomaly knowledge base, the system provides on-board engineering data summarization for impact reporting and informed maintenance, component failure propagation and global effects modeling, predictions of inspection period/frequency, and life expectancy tracking.

Range

Description

Comprehensive program of range improvement and modernization tasks under RSA; addresses mission and admin comm. GPS tracking proposed. Debris and weather projects.

Objective

Reduce Range and Launch Facility Operations costs through standardization and automation

Metrics

Performance:1.5 hour cold start

Operability:Reconfig <4 hours

Reliability:Auto FDI to 2 LRUs 95% of time

Affordability: LCC, manpower reductions. GPS investment of $50M to reduce range LCC from $25M/yr to $3M/yr.

Assessment

Application-All ranges

Maturity-Implementation underway

Priority-AFSPC determination

Good/Marginal/Minimal- Marginal since launch facilities outside purview (SPO responsibility)

Range

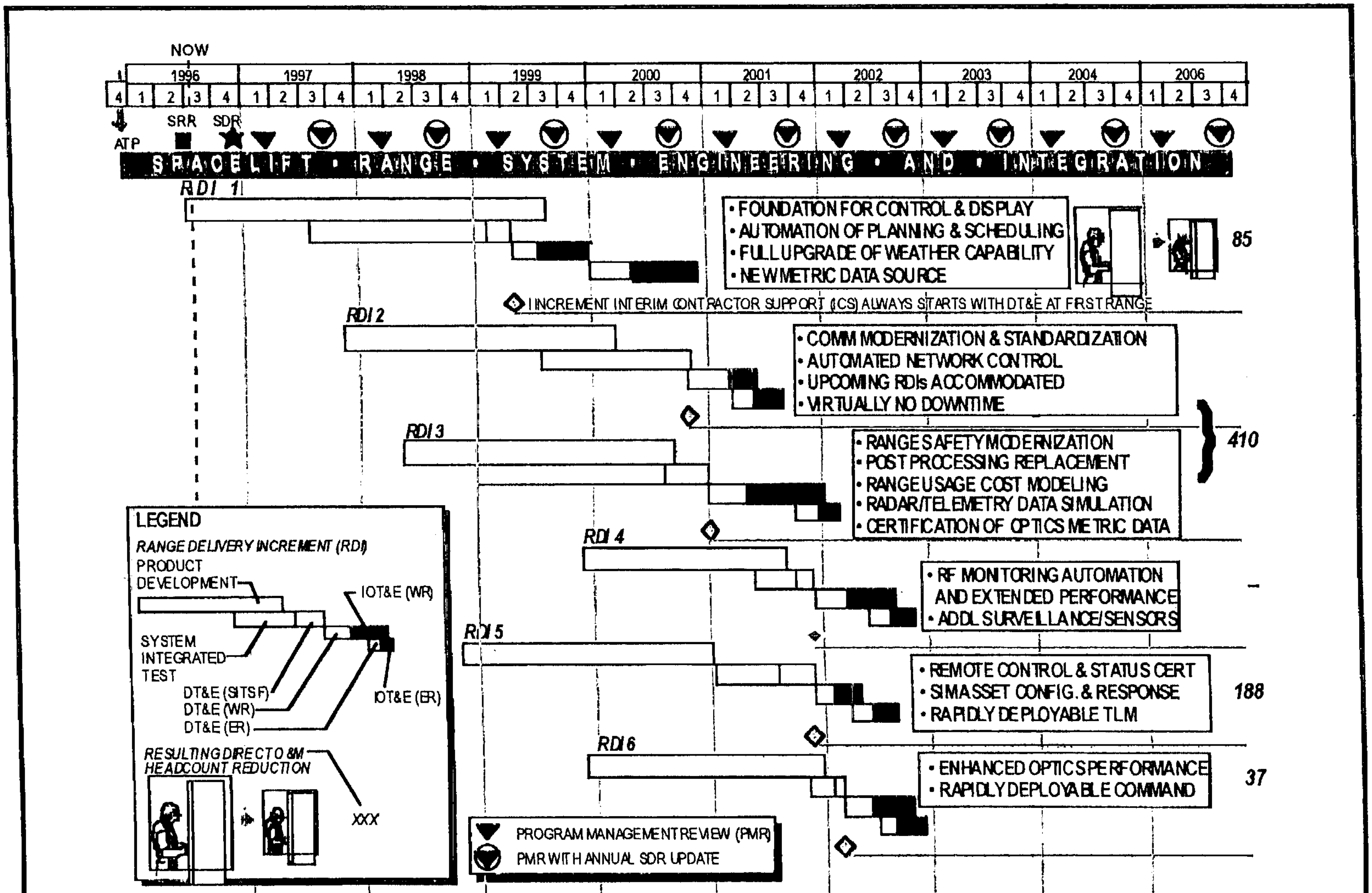
In-flight refueling -- Unique high payoff enables airport-like operations [subsonic and supersonic] and high performance [supersonic]. NASA programs are only considering subsonic refueling.

Containerized payload system -- Rapid payload changeout is essential for efficient RLV operations and turnaround.

Flight operations control center -- Mission needs beyond the first-generation RLV drive requirements for small teams, rapid mission replanning, and turn times.

Range standardization/turn time -- The DOD Range Standardization and Automation (RSA) program is enhancing the infrastructure at the the Eastern and Western ranges with AFSPC establishing priorities for the SMC program office efforts. The RSA requirements being addressed for the two ranges are for semi-automatic operations, remote control, status reporting, automated fault detection/isolation to two LRUs 95% of the time, 1.5 hours cold start time, simulation/dress rehearsal support capabilities, and a reconfiguration time of less than four hours. The RSA life cycle cost (LCC) reduction features emphasize standardized components, optimized scan and automated acquisition techniques, higher mean time between failures, and automated calibration. Additional cost reductions through implementation of a space-based range architecture (GPS tracking of launch vehicles vice ground-based radars) are being planned; AFSPC has established a 2000 target date. However, near-term efforts (RSA, GPS tracking) fail to address launch facility issues since these are considered the responsibility of the launch system program offices. Technology program applications are limited at present to debris analysis and collision avoidance tools for range safety and weather forecasting improvements. There is a critical need for a disciplined systems engineering approach to range cost reduction in order to define technology needs to meet operability, reliability goals.

RSA IIA RDIs OVERVIEW
(Range Deliverable Increments)



Range Standardization and Automation (RSA) IIA Range Deliverable Increments Overview

The RSA Range Deliverable Increments (RDIs) shown in this overview are directed toward range operability improvements and operations and maintenance (O&M) cost reductions. Completion dates for the RDIs are typically first at the Western Range (WR) with the Eastern Range (ER) following.

RDI 1 will provide the foundation for control and display enhancements, automation of planning and scheduling functions, a full upgrade of weather capabilities, and a new metric data source. Recent information from AFSPC indicates that the implementation of GPS-based tracking of launch vehicles will be accelerated to the 2000 time period.
Completion: WR 4Q 1999; ER 4Q 2000. **Goal:** O&M personnel reduction of 85.

RDI 2 targets communications modernization and standardization as well as automated network control. Infrastructure modifications to support upcoming RDIs will be enabled; goal is to virtually eliminate downtime.
Completion: WR 2Q 2001; ER 3Q 2001. **Goal:** O&M personnel reduction combined with RDI 3.

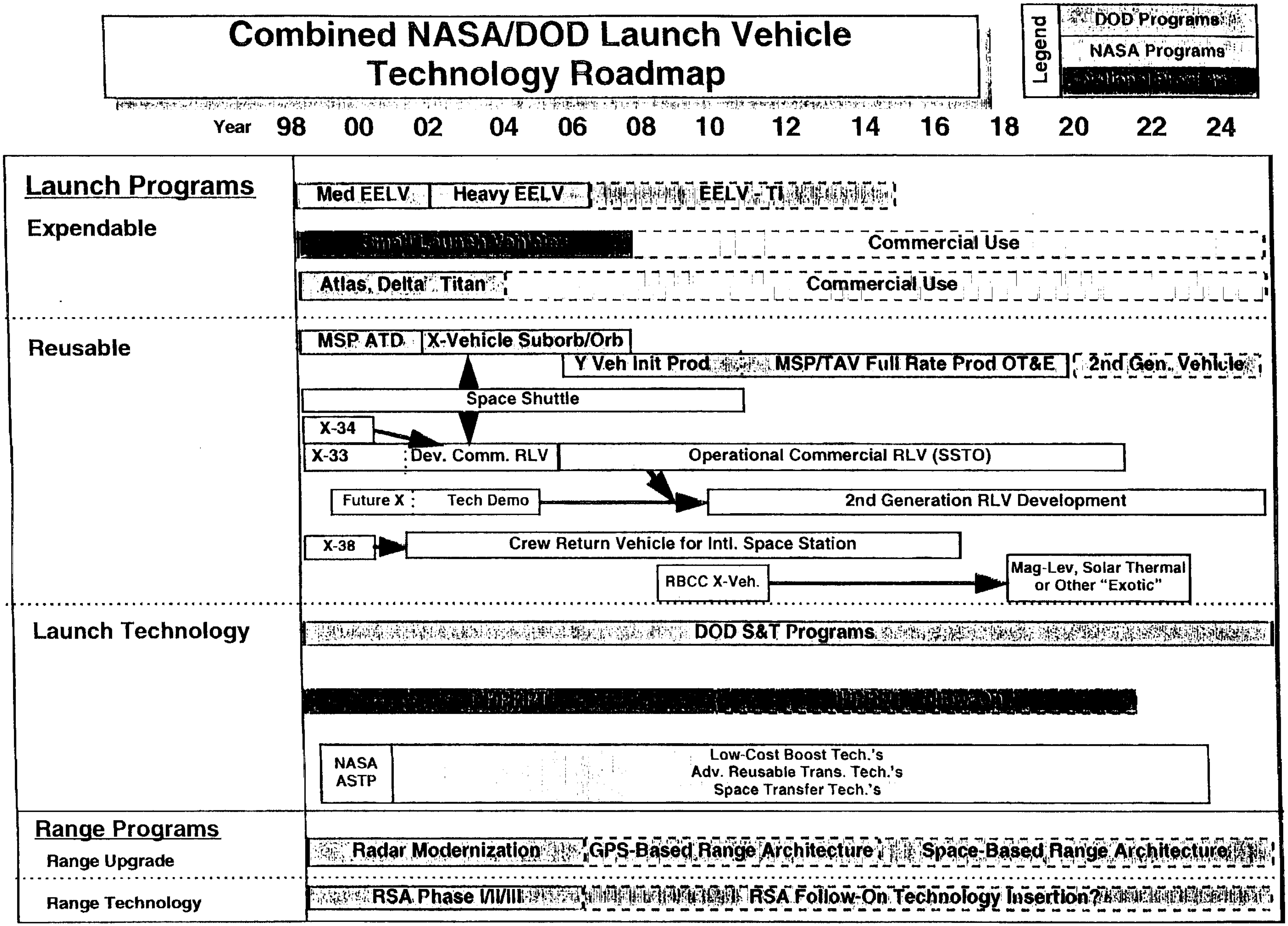
RDI 3 addresses range safety modernization, replacement of post-processing hardware and software, range usage cost modeling, simulation capabilities for radar and telemetry data, and certification of of optics metric data.
Completion: WR 4Q 2001; ER 1Q 2002. **Goal:** O&M personnel reduction of 410 combined with RDI 2.

RDI 4 concerns RF monitoring automation and performance extensions; additional surveillance systems and sensors are planned. **Completion:** WR 3Q 2002; ER 4Q 2002. **Goal:** No O&M personnel reduction assumed.

RDI 5 will provide certification for remote control and status systems, simulation capabilities for asset configuration and response, and rapidly deployable telemetry systems. **Completion:** WR 2Q 2002; ER 3Q 2002. **Goal:** O&M personnel reduction of 188.

RDI 6 is to enhance optics performance and implement rapidly deployable command systems. **Completion:** WR 3Q 2002; ER 4Q 2002. **Goal:** O&M personnel reduction of 37.

Combined NASA/DOD Launch Vehicle Technology Roadmap



Combined NASA/DOD Launch Vehicle Technology Roadmap

An overall launch system technology roadmap is illustrated here showing the interplay between the various RLV demonstrators. This future is driven by the need to make a decision on shuttle upgrade and life extension or replacement. Various "X" vehicles contribute to the technology integration and demonstration for "possible" RLV and MSP development.

Dotted lines indicate notional plans which may or may not come to fruition. In today's environment of coordinated planning and funding, these plans indicate the most logical progression from the current Five Year Defense Plan. ELV future is dependent on RLV introduction, capabilities, and price.

DOD S&T programs feed not only DOD programs, but cooperatively will feed into NASA and industry programs as well. The inverse also holds true as we rely heavily on commercial technology to support DOD programs in the future.

Range modernization is almost exclusively a DOD effort at this point. Program unique requirements without DOD application will most likely be cooperative programs with industry.

"National Programs" on this chart are loosely defined as programs with a wide variety of participation from government and industry. There are many new systems being developed within these areas with teaming arrangements too numerous to present here.

MSP development is in the earliest stages of definition, and we believe this area of the roadmap is the most subject to change. It is unclear how commercially viable RLVs will be and with NASA's long-term program hinging on industry participation, it will be in a constant state of flux in the near term as the X-33 program and the follow-on RLV evolves. The DOD MSP is leveraging the NASA effort and will necessarily have many "mid-course" corrections due to fall-out from the inevitable reprogramming, not unlike what has befallen the International Space Station effort.

Technology Assessment Summary

- Core NASA and DOD technology programs
  - Addressing needs for 3X to 10X cost reduction
  - Focus on characteristics for 100X cost reduction required
    - » Systems engineering and integration to enable higher flight rates and airport-like operations
    - » Technology and systems development emphasis on reliability, vehicle life and operability
  - NASA's next Future-X program could serve as pathfinder for 100X cost reduction efforts of NASA, DOD and industry
- Need exists for National Integrated Spacelift Roadmap
  - Launch facility and operability enhancements could be first targets for an IHPRPT-like program

Technology Assessment Summary

This assessment found that current individual evolutionary improvements in technology will likely yield only minor space transportation cost reductions. Revolutionary approaches are needed if the goals are to achieve high flight rates and airport-like operations. Incremental cost reduction steps will not produce a large increase in demand commensurate to that experienced in civil aviation -- that realization calls for a leapfrog strategy to focus on the systems characteristics that will enable the entire spectrum of innovative applications of spacelift.

If such a leap is adapted as a national goal, it is prudent to select a pathfinder for the 100X cost reduction effort -- NASA's Future X programs seem the best opportunity. A focused technology study utilizing a thorough systems analysis approach could support program definition to achieve the needed breakthrough goals. Further, recognizing the benefits of coordination of the efforts of DOD, industry and NASA and of leveraging technology dollars, an IHPRPT-like program could be used to create an integrated National roadmap for spacelift technology and systems development -- logical first targets might be coordination of launch facility and operability enhancements, perhaps emphasizing the goals for Future X.

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Policy Assessment

Current Launch Policies

- National Space Transportation Policy (PDD/NSTC-4) - Aug 1994
  - U.S. government as launch provider (ELVs, Shuttle, and RLVs)
    - » Developer and operator of vehicles, systems, and infrastructure
  - Encourage and promote viable commercial launch industry
    - » USG to purchase commercial launches "to the fullest extent feasible"
    - » At-cost access to federal ranges and associated personnel
- National Space Policy (PDD-NSC-49/NSTC-8) - Sep 1996
  - Reiterates National Space Transportation Policy
    - » USG to continue as developer and operator of launch systems

Current Launch Policies

U.S. Government policy governing civil, military, and commercial space launch activity consists of Presidential Directives issued by the executive branch, laws passed by the Congress, and regulations adopted by the Department of Transportation. There are two Presidential Decision Directives (PDDs) outlining the present Administration's policy on space transportation. The first is the National Space Transportation Policy (PDD/NSTC-4), issued in August 1994 which reaffirmed the U.S. Government's role as a developer and operator of launch systems, including the Space Shuttle and a fleet of expendable launch vehicles (ELVs). The policy established assuring reliable and affordable access to space through U.S. space transportation capabilities as a fundamental goal of the U.S. space program.

In particular, the Space Transportation Policy redefined the specific roles played by NASA, the Department of Defense, and the Department of Transportation in the development and operation of launch vehicles. NASA was directed to continue operation of the Space Shuttle and to be the lead agency for development of reusable launch vehicle (RLV) technology. The Department of Defense was assigned the responsibility of continuing to operate the nation's fleet of ELVs and to develop an Evolved Expendable Launch Vehicle (EELV) to reduce the cost of government space launch activities. The Department of Transportation was reassigned the responsibility to "license, facilitate, and promote commercial launch operations." In supporting the U.S. commercial launch industry, the Space Transportation Policy also pledges the government to purchase commercial launches "to the fullest extent feasible" and to provide at-cost access to federal ranges and associated personnel for commercial launches.

In September 1996, the White House released the National Space Policy (PDD-NSC-49/NSTC-8), which reiterated the goal of assuring reliable and affordable access to space established in the National Space Transportation Policy. In addition to space launch guidelines, the National Space Policy also established goals for exploration of outer space, the International Space Station program, and other elements of the U.S. space program.

Current Launch Policies (Cont'd)

- Commercial Space Launch Act (49 USCS 701) - 1984
  - Transportation to oversee U.S. commercial launch activities
    - » "to protect the public health and safety, safety of property, and national security and foreign policy interests of the United States"
    - » "encourage, facilitate, and promote commercial space launches"
  - DOT license required to conduct launch or operate launch site
- Commercial Space Transportation Licensing Regulations, Apr 1988
  - Proposed revisions currently out for public comment, May 1997
  - Launch license requires:
    - » Safety approval - "to protect the public health and safety, . . ."
    - » Policy approval - "national security and foreign policy interests"
    - » Payload determination - payload safety and policy issues
  - Site operator license for state, local, or privately run launch sites
    - » Examine on a case-by-case basis

Current Launch Policies (cont'd)

Commercial launch activity is governed by the Commercial Space Launch Act (49 USCS 701), enacted by Congress in 1984. The only major Act passed by Congress governing space launch activity, the Commercial Space Launch Act of 1984 assigns the Department of Transportation (DOT) the responsibility to oversee U.S. commercial launch activity. According to the Act, regulation of commercial launch activities is necessary to "protect the public health and safety, safety of property, and national security and foreign policy interests of the United States." This is done by licensing commercial launch activity. At the same time, DOT is directed to "encourage, facilitate, and promote commercial space launches."

Acting under the authority of the Commercial Space Launch Act, DOT issued its Commercial Space Transportation Licensing Regulations in April 1988 codifying the licensing process for operation of a launch vehicle or a launch site by U.S. citizens and corporations. The first commercial orbital launch took place in 1989 -- that of a Delta from Cape Canaveral -- and was licensed under these regulations.

Over the next eight years, DOT's process for issuing licenses matured and, in May 1997, DOT published proposed revisions to the licensing regulations to codify these modifications. Under the new rules, the issuance of a launch license is dependent on three things -- safety approval, policy approval, and a payload determination. The safety approval reviews the launch vehicle for safety issues in order to "protect the public health and safety, [and the] safety of property." The policy approval examines issues surrounding the launch of the particular payload for concerns relating to "national security and foreign policy interests." For example, this would include whether it would be in U.S. national security interests to launch a foreign military payload. The payload determination examines both safety and policy issues surrounding the payload itself.

In addition to licensing launch activity, DOT also issues launch site operator's licenses for non-federal launch sites, such as spaceports proposed by private or state-sponsored organizations. To date, two spaceports have received DOT licenses -- Spaceport California, which operates one launch pad situated at California's Vandenberg Air Force Base, the U.S.'s western launch center, and Spaceport Florida, which operates one launch pad at Cape Canaveral Air Station in Florida. DOT examines each application for a launch site operator's license on a case-by-case basis because it has not yet developed standardized regulations.

Future Policy Issues

- Future policies and regulations must reflect:
  - Higher launch rates
  - Aircraft-like reliability
  - Aircraft-like operations
  - Reusability
  - Safe abort
  - Return to launch site
- Major paradigm shift for government
  - Regulation of a commercial industry, not government-developed industry
  - Government may no longer play as large a role in launch activity
    - » Commercial launch activity will no longer take place at federal launch sites with government oversight
    - » Government to operate own systems (military spaceplane, etc.), but likely different from commercial systems
  - Safety will be responsibility of operator, not government ranges
    - » Reduced government role in individual launches

Future Policy Issues

Future space transportation policies and regulations must reflect substantially higher launch rates; more aircraft-like reliability and operations; reusability; safe abort capability; and the ability to return to the launch site, inter alia. Adapting to these changes will require a major paradigm shift in the government's role in space transportation. Up to the present day, most U.S. launch vehicles have been developed and operated by the U.S. government, including those now commercially operated like the Delta, Atlas, and Pegasus. Each of these systems was either derived from a military system or developed according to government requirements and specifications. In the future, however, launch systems will increasingly be developed by the commercial industry and operated out of non-federal launch sites for commercial purposes. At the same time, the government will continue to operate select systems which are different from commercial systems (such as a military spaceplane), but will also likely rely on the commercial industry for the bulk of Government launches into orbit.

As a result, the government may have to regulate a fundamentally commercial industry, not the government-developed industry it is today. In particular, the government may no longer play as large a role in oversight of safety at the launch sites themselves. Instead, maintaining safety could increasingly be the responsibility of the vehicle operator, not the government ranges. Today, DOT relies heavily on government personnel and contractors at the ranges to assure safety. In the future, the role of the government may be to assure safety through regulation and oversight, not on-sight involvement in launch preparations.

Future Policy Issues (Cont'd)

- Licensing to move toward air transportation model
  - Separate licenses issued for aircraft, airlines, and airports
    - » Each aircraft must have FAA airworthiness certificate
    - » Each airline must have FAA operator's license specifying aircraft types allowed to operate
    - » Each airport has operator's license
  - Currently, launch license issued to <u>operate launch system</u>
    - » License covers launch vehicle and operator (vehicle manufacturer and operator are currently the same, in general)
    - » License to operate system based on classes of payloads, envelope of vehicle operations, etc.
    - » Separate license not issued for each launch
  - In future, separate licenses should be issued for launch vehicles and operators, as well as launch site operators

Future Policy Issues (cont'd)

As reusable launch vehicles come into operation and launch rates drastically increase, the licensing of launch activity is likely to move toward the current air transportation model. At present, the FAA issues separate licenses for aircraft, airlines, and airports. Each aircraft must have an FAA airworthiness certificate, each airline must have an operator license for each type of aircraft it operates, and each airport has its own license. By contrast, launch licenses are issued to operate a launch system which includes both the vehicle and the operator, which are generally the same for today's launch vehicles. This means that McDonnell Douglas is issued a license to build and commercially operate the Delta II launch vehicle. The license is issued to operate the vehicle for a certain class of payloads and envelope of operations, i.e. a range of launch azimuths, orbital altitudes, and inclinations. This one license covers a number of commercial launches of the Delta II and a separate license does not need to be issued for each launch. However, McDonnell Douglas has received a new license for each variant of the Delta II (such as Delta 7925 and Delta 7920-10) and has received two licenses for the Delta 7920-10, one in 1993 and one in 1996.

In the future, commercial operators of launch systems that are manufactured by another company -- just as United Airlines operates aircraft built by Boeing -- may need to be issued operator's licenses for vehicles which have flight worthiness certificates. This means that the vehicle itself will need to be certified separately from its operations.

While the launch industry and the regulatory environment are moving in this direction, space transportation systems have a long way to go before they are mature enough to assure the level of reliability and safety found in today's aircraft. Consequently, for the near future, regulation of the launch industry will need to seek a middle ground between today's model and the air transportation industry model.

Future Policy Issues (Cont'd)

- Current policies and licensing do <u>not</u> cover:
  - Reentry and landing of RLVs or reentry vehicles
    - » Authorization to regulate reentry covered in Civilian Space Authorization Act, FY 1998 and 1999, H.R. 1275,
      - Bill passed House, waiting on Senate action
  - Overflight issues
    - » Population centers (safety, shock waves, noise pollution, etc.)
    - » Foreign countries (define boundary between air and space for airplane-like trajectories)
  - Damage to objects already in space caused by launch vehicle, spacecraft, or launch debris
    - » Included in third party liability insurance?
  - Retrieval of items from space

Future Launch Policies (cont'd)

There are several important aspects of future launch activities that are not covered by current launch policies and regulations. The first of these is the reentry and landing of RLVs or other reentry vehicles. The Commercial Space Transportation Act of 1984 does not authorize the Department to Transportation to regulate reentry of any kind. To remedy this situation, the U.S. House of Representatives recently included language in the Civilian Space Authorization Act, FY 1998 and 1999, H.R. 1275, authorizing DOT to regulate reentry as it does each aspect of launch activity. This Act has passed the House, and is waiting on Senate action before becoming law.

Future policies and regulations will also have to consider the overflight of populated areas. Currently, launches from U.S. ranges occur over unpopulated areas, out over the Atlantic Ocean from Florida and out over the Pacific Ocean from California. By contrast, future operations from currently planned launch sites in Alaska, New Mexico, and Nevada will overfly land and, in many cases, populated areas. Although these areas have relatively few people, the development of reusable launch vehicles with routine operations will lead to overflight of much more heavily populated areas as well. Issues that must be examined for overflight of populated areas include vehicle safety and reliability, shock waves, noise pollution, and others. In addition, vehicles routinely re-entering from orbit would overfly foreign countries and therefore would need to be covered under international treaties. Whether they are treated as space objects or aircraft in determining overflight rules must be addressed.

While current launch licenses require insurance to cover damage to people and property on the ground, damage to objects already in space caused by launch and satellite debris is not covered. With the proliferation of launch activity and the number of spacecraft in orbit, space debris will be a commercial issue and policies and regulations will need to be developed.

With the routine deployment and retrieval of items from space, the ownership of abandoned or damaged spacecraft will also be an issue. The "salvage rights" of space objects will need to be defined.

Future Policy Issues (Cont'd)

- In future, there will be less examination of individual payloads
  - Focus more on types of payload classes
  - Need to better define operating envelopes of payload classes
- Foreign ownership of U.S. built launch vehicles
  - Launch vehicles derive from missile delivery systems
  - Systems likely to be used outside U.S. by non-U.S. operators
    - » How to control use to cover non-proliferation obligations

Future Policy Issues (cont'd)

Other future policy issues include the examination of payloads and the foreign ownership of U.S.-built launch vehicles. As space transportation becomes routine and increases in frequency, the examination of individual payloads may become practically impossible. Instead, payload classes will have to be better defined to cover the operating envelopes of types of payloads, including telecommunications and remote sensing spacecraft, manufacturing facilities, and other systems to avoid inspection of individual payloads.

As new commercial launch systems are developed, a significant portion of the money to develop them is expected to come from market investors, some of whom may be of foreign origin. In addition, U.S. manufacturers of RLVs will want to sell or operate these systems outside the United States. Due to their heritage as missile delivery systems, possible foreign ownership of U.S.-built launch vehicles raises several concerns, including the transfer of technology and the use of these systems to launch payloads not controlled or approved by the U.S. Government. To prevent the transfer of such technologies, the U.S. Government founded the Missile Technology Control Regime (MTCR), and the technology and system development of RLVs is expected to also be governed by the regime in order to prevent the technology transfer. This issue is of immediate note because of foreign investment in the development of a new RLV by the Kirkland, Washington-based Kistler Aerospace Corp. Kistler has stated that it requires $400 million to develop its two-stage K-1 RLV, but has disclosed only about $10 million of support by U.S. backers. At the same time, it has courted a number of foreign investors without disclosing how much they have contributed to the K-1 development.

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Summary and Recommendations

Summary

- Study has developed methodologies for defining spacelift characteristics based on near-term and long-term mission requirements
  - Detailed databases developed for both conventional and innovative space applications
- Current spacelift systems will accommodate conventional mission requirements--including Teledesic
  - Majority of traffic and potential revenue in medium-lift class
- Threshold spacelift characteristics determined from database of innovative applications' characteristics
- Existing and planned (ELV & RLV) spacelift systems that provide $\geq$ 3X reduction in cost per flight may enable a significant number of innovative future applications
  - Technology needs generally covered by current programs/ plans
  - Economic viability of applications uncertain

Summary

This study examined a wide range of potential future space applications and identified significant spacelift characteristics and issues relating to future launch vehicles. The study developed databases of future mission requirements and used the data to project launch vehicle requirements and technology needs for both near- and far-term space applications.

The current and in-development family of spacelift systems (Space Shuttle and expendable launch vehicles) can meet the boost needs of planned missions for the 2000-2010 time frame, including spacelift for large LEO constellations such as the proposed Teledesic system. The largest space-transportation market in this time frame is projected to be in the commercial medium- lift category.

Other spacelift system capabilities are required to lower transportation cost and enable a variety of possible future space applications. It should be recognized that there is considerable amount of uncertainty as to the economic viability of specific missions. Threshold characteristics were assessed for the innovative missions, and a comparison was made of the mission requirements to capabilities of existing and planned launch vehicles. Near-term reusable and expendable launch vehicle systems could enable a significant number of the futuristic, innovative missions. For example, the planned expendable commercial vehicles plus the RLV could meet the launch needs of close to 50% of the near-term innovative missions. Also, the technology needs of these near-term planned spacelift systems appear to be adequately addressed by the current individual NASA and DOD technology efforts and NASA's X-vehicle programs.

Summary (Cont'd)

- Large cost reduction (~100X) is the most significant spacelift system characteristic needed to enable the majority of innovative applications, and achievement of this characteristic requires:
  - Very high flight rates (thousands or more per year)
  - Very high reliability
  - Very low operations and infrastructure costs
  - Significant U.S. space transportation policy changes
- Refocus of technology thrust necessary to support 100X cost reduction
  - Long-term technology development requires government leadership and funding
- Flight rates and commercial viability ultimately depend upon technical feasibility, entry costs, and elastic demand for each application
  - Not well defined today
  - Study found no compelling innovative application that would justify large commercial investment in high-flight-rate launch systems

Summary (Cont'd)

A large cost reduction (100X) spacelift system is needed to enable a much wider array of possible innovative space applications. A super low cost (100X) MLV class vehicle plus a low cost (10X) HLV would enable approximately 90% of the innovative space applications. The only missions not enabled would be those requiring a combination of super low cost, heavy lift and rapid turnaround capability.

High system reliability and the ability to achieve a high launch and flight rate per vehicle are key attributes for an economically attractive launch system. For example, to economically justify a commercially developed 100x cost reduction launch vehicle, the total fleet of vehicles must be able to fly several thousand missions per year. In addition, the system must have very high reliability and very low operations and infrastructure costs.

If the goal is to encourage and enable new, innovative space applications, then future technology programs need a long-range focus towards developing the components and subsystems for a 100X cost reduction vehicle. A total systems engineering approach is required that aggressively addresses the attributes necessary to achieve the required airplane-like high flight rates and low-operating costs. Since it is unlikely that such long-term technology programs will be pursued by the commercial sector, heavy government funding and leadership will be needed for the development of the required technologies.

A major unknown in any future projection is the actual demand versus cost relationship of each of the space applications. The elastic demand for these applications is unknown, and an accurate understanding of the potential future demand for these innovative applications is required to provide realistic estimates of future flight rates. This study did not find a single compelling innovative application that would justify the entirely commercial development of a high -flight-rate launch system.

Recommendations

- NASA and the Air Force should conduct analyses and market surveys to establish entry costs and demand elasticity for potential new space applications
  - NASA/Industry - Commercial and Civil applications
  - Air Force - Military Space Plane (MSP) and other DOD applications
- NASA should integrate significant threshold characteristics into requirements baselines for technology and future X-vehicle programs
  - Establish aggressive goals for reliability, operability, and maintenance/reusability
- NASA and Air Force should coordinate RLV requirements and technology development of the MSP
  - Explore option of next generation X-vehicle being a MSP derivative
    - » Required operability characteristics of MSP can significantly enhance commercial RLV
- NASA and Air Force should develop National integrated spacelift technology roadmap

Recommendations

Since similar significant spacelift characteristics are needed for the future systems of NASA, commercial users, and the Air Force, a coordinated development effort by NASA and the Air Force should result in future spacelift systems that will meet the goals of the nation. In order to achieve this coordinated effort, an integrated NASA and Air Force national technology roadmap should be prepared to address the development of launch systems from today's vehicles to the MSP and continuing to the future X-vehicles.

NASA should consider integrating the significant spacelift system threshold characteristics identified in this study into their baseline requirements for future X-vehicle programs. In particular, characteristics that affect flight rate, reliability, operability and low maintenance should be included as goals for the next generation X-vehicles.

NASA and the Air Force should coordinate requirements for the RLV, MSP, and future X-vehicles. The RLV is expected to develop technologies that meet many of the needs of a MSP, such as lower operating costs and improved reusability. However, the MSP reliability and operability requirements are more demanding than those of a first-generation RLV which is designed to the needs of near-term civil and commercial missions. The Air Force development of a system that has the high flight rate and aircraft- like operability requirements of the MSP will also provide the technology required to meet the needs of the more long-range innovative missions that the future X-vehicles should enable. There is a potential for a synergistic flow of technology developments from the RLV to the MSP to future X-vehicles.

NASA and the Air Force should investigate the future demand-versus-cost elasticity for new, innovative applications of space. A better understanding of market elasticity for launch services will enable a more accurate assessment of the potential future launch rates and can help justify the technology investment required to achieve these low-cost launch systems.

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Future Spacelift Requirements Study

Appendix 1
Conventional Space Applications Assessment

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Introduction

Conventional Flight-rate Projections. This appendix contains the database of flight-rate projections for conventional space applications. The projections are for average flight rates for roughly the 2000 to 2010 time frame. The flight-rate projections were derived from a variety of published sources. Market projections are also presented, which are based on present average launch prices for each lift category. Optimistic (maximum) and conservative (expected) values are specified for each estimate. Big LEO systems are included, except for broadband systems such as Teledesic, which are considered separately.

Military Sector

- Sources:
  - National Mission Model (December 3, 1996)
  - SBIRS data
- Flight-rate estimates:
  - Optimistic rate = SVs/5 (2005 - 2007)
  - Conservative rate = SVs/13 (1997 - 2009)
- Comparison of flight-rate estimates:

FSRS	EELV Model	SMC Report
10 - 15	5 - 13	11 - 12

Military Sector

The military sector launch projections were derived from the National Mission Model (December 3, 1996). The mission model covers the time period from 1997 to 2009. For each current and planned military space program, data was tabulated on the scheduled number of launches per year, the target orbit (LEO, MEO, GEO), and the launch vehicle class (S, M, H).

There is usually a high level of uncertainty on future launch projections. This makes it very difficult to calculate a single number for an average yearly flight rate. For this reason, an upper an a lower bound on the yearly flight rate were estimated. The expectation is that the actual flight rate in the future will fall in this range. The lower bound on the flight rate is called the "conservative" rate and the upper bound is the "optimistic" rate. The average yearly flight rate for military programs was calculated in a variety of ways. For some military programs, the conservative and optimistic flight rates were estimated by calculating the flight rate in the 1997-2009 or 2005-2009 time period. This is done by totaling the number of satellites (or space vehicles "SVs") launched during that period and dividing by the number of years in that period.

Using this approach, it is estimated that the military sector will have 10-15 launches per year in the 2000-2010 time period. This flight rate estimate compares reasonably well with similar estimates from two other reports:

1. "Payload Database for the EELV", Version 2.2, 26 June 1996

    (5-13 military launches per year)

2. "Launch Operations Sub-Mission Area Development Plan", FY 96 Version, Dept. of the Air Force, Space and Missile Systems Center/XRT

    (11-12 military launches per year)

After the average yearly launch rate is calculated, an estimate of the market (in dollars) for each military program is made. This is done by multiplying the optimistic and conservative flight rate per year by the estimated cost of the launch vehicle used by that particular military program. This gives conservative and optimistic bounds for the market value of each program.

Military Applications

Program	Orbit	Launch Vehicle	Vehicle Category	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
TSX	LEO-P	Pegasus	S		2			2		1		2		1			8
Misc. Small LEO	LEO-P	Pegasus	S	4	1	2	1					1					9
DMSP	LEO-P	Titan II	S-M	1		1			1	1			1	1		1	7
SBIRS LEO	LEO-P	Delta II	M										2	3	2		7
NPOESS	LEO-P	Delta II	M											2	1		3
Polarcom	LEO-P	Delta II	M													3	3
Milstar	GEO	Titan IV	H			1	1	1	1								4
DSP	GEO	Titan IV	H	1	1	1	1	1		1							6
UFO	GEO	Atlas IIA	M		2	1											3
DSCS	GEO	Atlas IIA	M		1	1	1		1	1							5
AdvMilCom	GEO	Atlas IIA	M									1	1	3	3	2	10
SBIRS GEO	GEO	Atlas IIAS	M-H						1	1	1	1	1				5
GPS	MEO	Delta 7920	M	4	4	3	4	5	4	3	2	2	3	3	3	3	43
SM II	Classified	Atlas IIA	M		1		3				2		1	1			8
SM IV	Classified	Atlas IIA	M			1	1		2		2		1		1		8
SM III	Classified	Titan IV	H	1	2			1		1		1			1		7
SM IV	Classified	Titan IV	H	2	1		2		2	1	1	1	1		2		13

Military Applications (continued)

Program	Orbit	Launch Vehicle	Vehicle Category	Conservative Flight Rate	Optimistic Flight Rate	Conservative Rate Remarks	Optimistic Rate Remarks
TSX	LEO-P	Pegasus	S	0.538	0.600	1997-2009 rate	2005-2009 rate
Misc. Small LEO	LEO-P	Pegasus	S	0.538	1.400	1997-2009 rate	2005-2009 rate
DMSP	LEO-P	Titan II	S-M	0.231	0.600	1997-2009 rate	2005-2009 rate
SBIRS LEO	LEO-P	Delta II	M	0.600	0.615	2005-2009 rate	1997-2009 rate
NPOESS	LEO-P	Delta II	M	0.231	0.600	1997-2009 rate	2005-2009 rate
Polarcom	LEO-P	Delta II	M	0.140	0.690	2005-2009 rate	1997-2009 rate
Milstar	GEO	Titan IV	H	0.308	0.364	1997-2009 rate	1999-2009 rate
DSP	GEO	Titan IV	H	0.462	0.462	1997-2009 rate	1997-2009 rate
UFO	GEO	Atlas IIA	M	0.231	0.250	1997-2009 rate	1998-2009 rate
DSCS	GEO	Atlas IIA	M	0.385	0.417	1997-2009 rate	1998-2009 rate
AdvMilCom	GEO	Atlas IIA	M	0.770	2.000	1997-2009 rate	2005-2009 rate
SBIRS GEO	GEO	Atlas IIAS	M-H	0.385	0.625	1997-2009 rate	2002-2009 rate
GPS	MEO	Delta 7920	M	2.800	3.300	1997-2009 rate	2005-2009 rate
SM II	Classified	Atlas IIA	M	0.620	0.670	1997-2009 rate	2004-2009 rate
SM IV	Classified	Atlas IIA	M	0.620	0.750	1997-2009 rate	2002-2009 rate
SM III	Classified	Titan IV	H	0.444	0.538	2001-2009 rate	1997-2009 rate
SM IV	Classified	Titan IV	H	1.000	1.000	1997-2009 rate	2002-2009 rate

Military Applications (continued)

Program	Conservative Flight Rate	Optimistic Flight Rate	Vehicle Category	Price Per Launch (millions)	Conservative Market (millions)	Optimistic Market (millions)
TSX	0.538	0.600	S	15	8	9
Misc. Small LEO	0.538	1.400	S	15	8	21
DMSP	0.231	0.600	S-M	25	6	15
SBIRS LEO	0.600	0.615	M	60	36	37
NPOESS	0.231	0.600	M	60	14	36
Polarcom	0.110	0.690	M	60	7	41
Milstar	0.308	0.364	H	200	62	73
DSP	0.462	0.462	H	200	92	92
UFO	0.231	0.250	M	60	14	15
DSCS	0.385	0.417	M	60	23	25
AdvMilCom	0.770	2.000	M	60	46	120
SBIRS GEO	0.385	0.625	M-H	110	42	69
GPS	2.800	3.300	M	60	168	198
SM II	0.620	0.670	M	60	37	40
SM IV	0.620	0.750	M	60	37	45
SM III	0.444	0.538	H	200	89	108
SM IV	1.000	1.000	H	200	200	200

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Civil Sector

- Sources:
  - NASA ELV and Upper Stage Program Planning, Aug. 1996 (1996 - 2003)
  - NASA ELV Long Range Planning, Aug. 1996 (2004 - 2010)
  - U.S. Civilian Gov't ELV Payload Compendium, April 1994
- Flight-rate estimates:
  - Conservative rate = SVs / 8 (1996 - 2003)
  - Optimistic rate - SVs / 7 (2004 - 2010)
  - Rate = 0 (if no launches after 2004)
- UNEX, MIDEX, SMEX flight rates assumed to be 1/year (0.85/year LEO-P and 0.15/year LEO)
- Comparison of flight-rate estimates:

FSRS	EELV Model	SMC Report
11 - 20	5 - 16	15 - 17

Civil Sector

The launch projections for the civil sector were derived from three sources:

a. "NASA ELV and Upper Stage Program Planning" (August 1996) which forecasts from 1996 - 2003

b. "NASA ELV Long Range Planning" (August 1996) which forecasts from 2004-2010

c. NASA's estimate of 6-8 Space Shuttle launches per year to support Space Station deployment and re-supply

For each civil space program, data was tabulated on the scheduled number of launches per year, the target orbit (LEO, MEO, GEO), and the launch vehicle class (S, M, H).

There is usually a high level of uncertainty on future launch projections. This makes it very difficult to calculate a single number for an average yearly flight rate. For this reason, an upper an a lower bound on the yearly flight rate were estimated. The expectation is that the actual flight rate in the future will fall in this range. The lower bound on the flight rate is called the "conservative" rate and the upper bound is the "optimistic" rate. The average yearly flight rate for civil space programs was calculated in a variety of ways. For some civil programs, the conservative and optimistic flight rate was estimated by calculating the flight rate in the 1996-2003 or 2004-2010 time periods. This is done by totaling the number of satellites (or space vehicles "SVs") launched during that period and dividing by the number of years in that period. For the SMEX, ESSP, UNEX, and MIDEX programs, both the conservative and optimistic flight rates are assumed to by 1/year with 85% flying polar LEO missions and 15% flying other LEO missions. Finally, when a program has no scheduled launches past 2004, the conservative flight rate for that program is assumed to be zero.

Using this approach, it is estimated that the civil sector will have 11-20 launches per year in the 2000-2010 time period. This flight rate estimate compares reasonably well with similar estimates from two other reports:

1. "Payload Database for the EELV", Version 2.2, 26 June 1996

   (5-16 civil launches per year)

2. "Launch Operations Sub-Mission Area Development Plan", FY 96 Version, Dept. of the Air Force, Space and Missile Systems Center/XRT

   (15-17 civil launches per year)

After the average yearly launch rate is calculated, an estimate of the market (in dollars) for each civil program is made. This is done by multiplying the optimistic and conservative flight rate per year by the estimated cost of the launch vehicle used by that particular civil program. This gives conservative and optimistic bounds for the market value of each program.

Civil Applications

Program	Orbit	Launch Vehicle	Vehicle Category	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
GOES	GEO	Atlas IIA	M		1		1		1										3
TDRS	GEO	Atlas IIA	M				1			1	1								3
Polar	HEO	Delta 7920	M	1															1
FUSE	HEO	Delta 7320	S-M			1													1
AXAF	HEO	STS	H			1													1
SAC/HETE	LEO	Pegasus	S	1															1
SWAS	LEO	Pegasus	S		1														1
SMEX	LEO	Pegasus	S														1	1	2
ESSP	LEO	Pegasus	S												1		1		2
UNEX	LEO	Ultra-Lite	S														1	1	2
MIDEX	LEO	Taurus	S							1									1
Space Station	LEO	STS	H																
UNEX	LEO-P	Ultra-Lite	S				1	1	1	1	1	1	1	1	1	1			10
ESSP	LEO-P	Pegasus	S				1	1	1	1	1	1	1	1		1		1	10
SMEX	LEO-P	Pegasus	S					1	1	1	1	1	1	1	1	1			9
MIDEX	LEO-P	Taurus	S									1	1	1	1	1	1	1	7
TOMS	LEO-P	Pegasus	S	1															1
TIMED	LEO-P	Taurus	S					1											1
ATL-Laser	LEO-P	Taurus	S							1									1
ALT-L2	LEO-P	Taurus	S												1				1
NOAA	LEO-P	Delta 7320	S-M								1								1
NOAA	LEO-P	Titan II	M		1		1		1										3
ORSTED/SUNSAT	LEO-P	Delta 7920	M		1														1
Landsat 7	LEO-P	Delta 7920	M			1													1
EOS-am,pm,chem	LEO-P	Atlas IIAS	M			1		1		1		1		1		1		1	7
GPB	LEO-P	Delta 7920	M					1											1
RADARSAT	LEO-P	Delta 7920	M					1											1
DEEPSPACE	Planetary	Pegasus	S					1	1	1	1								4
Discovery	Planetary	Taurus	S					1	1	1	1	1		1		1		1	8

Civil Applications (continued)

Program	Orbit	Launch Vehicle	Vehicle Category	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Mars Lander 1	Planetary	Delta 7425	S-M				1												1
Mars Lander 2	Planetary	Delta 7320	S-M						1										1
Mars Lander 3	Planetary	Delta 7320	S-M						1										1
DEEPSPACE	Planetary	Delta 7320	S-M			1													1
Mars Orbiter 2	Planetary	Delta 7425	S-M			1													1
MGS	Planetary	Delta 7920	M	1															1
Mars Pathfinder	Planetary	Delta 7920	M	1															1
NEAR	Planetary	Delta 7920	M	1															1
ACE	Planetary	Delta 7920	M		1														1
SIRTF	Planetary	Delta 7920	M								1								1
Solar Probe	Planetary	Delta 7920	M									1							1
Solar Express	Planetary	Delta 7920	M									1							1
CASSINI	Planetary	Titan IV	H		1														1
FAST	Unknown	Pegasus	S	1															1
TRACE	Unknown	Pegasus	S		1														1
SNOE/Orbcomm	Unknown	Ultra-Lite	S		1														1
Terriers/Mublcom	Unknown	Ultra-Lite	S		1														1
WIRE	Unknown	Pegasus	S			1													1
CATSAT	Unknown	Ultra-Lite	S			1													1
EO1/SAC-C	Unknown	Taurus	S			1													1
STARDUST	Unknown	Delta 7425	S-M				1												1
JASON	Unknown	Taurus	S				1					1					1		3
IMAGE	Unknown	Taurus	S				1												1
MAP	Unknown	Taurus	S					1											1
SCISAT	Unknown	Pegasus	S						1										1
EO2	Unknown	Pegasus	S						1										1
Surveyor 1	Unknown	Taurus	S								1								1
Surveyor 2	Unknown	Taurus	S								1								1
SCISAT2	Unknown	Pegasus	S									1							1

Civil Applications (continued)

Program	Orbit	Launch Vehicle	Vehicle Category	Conservative Flight Rate	Optimistic Flight Rate	Conservative Rate Remarks	Optimistic Rate Remarks
GOES	GEO	Atlas IIA	M	0.00	0.38	No launches after 2004	1996 - 2003 rate
TDRS	GEO	Atlas IIA	M	0.00	0.38	No launches after 2004	1996 - 2003 rate
Polar	HEO	Delta 7920	M	0.00	0.13	No launches after 2004	1996 - 2003 rate
FUSE	HEO	Delta 7320	S-M	0.00	0.13	No launches after 2004	1996 - 2003 rate
AXAF	HEO	STS	H	0.00	0.13	No launches after 2004	1996 - 2003 rate
SAC/HETE	LEO	Pegasus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
SWAS	LEO	Pegasus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
SMEX	LEO	Pegasus	S	0.15	0.15	rate based on 1 SMEX/yr	rate based on 1 SMEX/yr
ESSP	LEO	Pegasus	S	0.15	0.15	rate based on 1 ESSP/yr	rate based on 1 ESSP/yr
UNEX	LEO	Ultra-Lite	S	0.15	0.15	rate based on 1 UNEX/yr	rate based on 1 UNEX/yr
MIDEX	LEO	Taurus	S	0.15	0.15	rate based on 1 MIDEX/yr	rate based on 1 MIDEX/yr
Space Station	LEO	STS	H	8.00	8.00	NASA estimate	NASA estimate
UNEX	LEO-P	Ultra-Lite	S	0.85	0.85	rate based on 1 UNEX/yr	rate based on 1 UNEX/yr
ESSP	LEO-P	Pegasus	S	0.85	0.85	rate based on 1 ESSP/yr	rate based on 1 ESSP/yr
SMEX	LEO-P	Pegasus	S	0.85	0.85	rate based on 1 SMEX/yr	rate based on 1 SMEX/yr
MIDEX	LEO-P	Taurus	S	0.85	0.85	rate based on 1 MIDEX/yr	rate based on 1 MIDEX/yr
TOMS	LEO-P	Pegasus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
TIMED	LEO-P	Taurus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
ATL-Laser	LEO-P	Taurus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
ALT-L2	LEO-P	Taurus	S	0.00	0.14	No launches after 2004	2004 - 2010 rate
NOAA	LEO-P	Delta 7320	S-M	0.00	0.13	No launches after 2004	1996 - 2003 rate
NOAA	LEO-P	Titan II	M	0.00	0.38	No launches after 2004	1996 - 2003 rate
ORSTED/SUNSAT	LEO-P	Delta 7920	M	0.00	0.13	No launches after 2004	1996 - 2003 rate
Landsat 7	LEO-P	Delta 7920	M	0.00	0.13	No launches after 2004	1996 - 2003 rate
EOS-am,pm,chem	LEO-P	Atlas IIAS	M	0.50	0.50	1997 - 2010 rate	1997 - 2010 rate
GPB	LEO-P	Delta 7920	M	0.00	0.13	No launches after 2004	1996 - 2003 rate
RADARSAT	LEO-P	Delta 7920	M	0.00	0.13	No launches after 2004	1996 - 2003 rate
DEEPSPACE	Planetary	Pegasus	S	0.00	0.38	No launches after 2004	2000 - 2010 rate
Discovery	Planetary	Taurus	S	0.50	0.72	2005 - 2010 rate	2000 - 2010 rate

Civil Applications (continued)

Program	Orbit	Launch Vehicle	Vehicle Category	Conservative Flight Rate	Optimistic Flight Rate	Conservative Rate Remarks	Optimistic Rate Remarks
Mars Lander 1	Planetary	Delta 7425	S-M	0.00	0.13	No launches after 2004	1996 - 2003 rate
Mars Lander 2	Planetary	Delta 7320	S-M	0.00	0.13	No launches after 2004	1996 - 2003 rate
Mars Lander 3	Planetary	Delta 7320	S-M	0.00	0.13	No launches after 2004	1996 - 2003 rate
DEEPSPACE	Planetary	Delta 7320	S-M	0.00	0.13	No launches after 2004	1996 - 2003 rate
Mars Orbiter 2	Planetary	Delta 7425	S-M	0.00	0.13	No launches after 2004	1996 - 2003 rate
MGS	Planetary	Delta 7920	M	0.00	0.13	No launches after 2004	1996 - 2003 rate
Mars Pathfinder	Planetary	Delta 7920	M	0.00	0.13	No launches after 2004	1996 - 2003 rate
NEAR	Planetary	Delta 7920	M	0.00	0.13	No launches after 2004	1996 - 2003 rate
ACE	Planetary	Delta 7920	M	0.00	0.13	No launches after 2004	1996 - 2003 rate
SIRTF	Planetary	Delta 7920	M	0.00	0.13	No launches after 2004	1996 - 2003 rate
Solar Probe	Planetary	Delta 7920	M	0.00	0.14	No launches after 2004	2004 - 2010 rate
Solar Express	Planetary	Delta 7920	M	0.00	0.14	No launches after 2004	2004 - 2010 rate
CASSINI	Planetary	Titan IV	H	0.00	0.13	No launches after 2004	1996 - 2003 rate
FAST	Unknown	Pegasus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
TRACE	Unknown	Pegasus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
SNOE/Orbcomm	Unknown	Ultra-Lite	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
Terriers/Mublcom	Unknown	Ultra-Lite	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
WIRE	Unknown	Pegasus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
CATSAT	Unknown	Ultra-Lite	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
EO1/SAC-C	Unknown	Taurus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
STARDUST	Unknown	Delta 7425	S-M	0.00	0.13	No launches after 2004	1996 - 2003 rate
JASON	Unknown	Taurus	S	0.00	0.20	No launches after 2004	1996 - 2010 rate
IMAGE	Unknown	Taurus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
MAP	Unknown	Taurus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
SCISAT	Unknown	Pegasus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
EO2	Unknown	Pegasus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
Surveyor 1	Unknown	Taurus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
Surveyor 2	Unknown	Taurus	S	0.00	0.13	No launches after 2004	1996 - 2003 rate
SCISAT2	Unknown	Pegasus	S	0.00	0.14	No launches after 2004	2004 - 2010 rate

Civil Applications (continued)

Program	Conservative Flight Rate	Optimistic Flight Rate	Vehicle Category	Price Per Launch (millions)	Conservative Market (millions)	Optimistic Market (millions)
GOES	0.00	0.38	M	60	0	23
TDRS	0.00	0.38	M	60	0	23
Polar	0.00	0.13	M	60	0	8
FUSE	0.00	0.13	S-M	25	0	3
AXAF	0.00	0.13	H	200	0	25
SAC/HETE	0.00	0.13	S	15	0	2
SWAS	0.00	0.13	S	15	0	2
SMEX	0.15	0.15	S	15	2	2
ESSP	0.15	0.15	S	15	2	2
UNEX	0.15	0.15	S	15	2	2
MIDEX	0.15	0.15	S	15	2	2
Space Station	6.00	8.00	H	300	1800	2400
UNEX	0.85	0.85	S	15	13	13
ESSP	0.85	0.85	S	15	13	13
SMEX	0.85	0.85	S	15	13	13
MIDEX	0.85	0.85	S	15	13	13
TOMS	0.00	0.13	S	15	0	2
TIMED	0.00	0.13	S	15	0	2
ATL-Laser	0.00	0.13	S	15	0	2
ALT-L2	0.00	0.14	S	15	0	2
NOAA	0.00	0.13	S-M	25	0	3
NOAA	0.00	0.38	M	60	0	23
ORSTED/SUNSAT	0.00	0.13	M	60	0	8
Landsat 7	0.00	0.13	M	60	0	8
EOS-am,pm,chem	0.50	0.50	M	60	30	30
GPB	0.00	0.13	M	60	0	8
RADARSAT	0.00	0.13	M	60	0	8
DEEPSPACE	0.00	0.36	S	15	0	5
Discovery	0.50	0.72	S	15	8	11

Civil Applications (continued)

Program	Conservative Flight Rate	Optimistic Flight Rate	Vehicle Category	Price Per Launch (millions)	Conservative Market (millions)	Optimistic Market (millions)
Mars Lander 1	0.00	0.13	S-M	25	0	3
Mars Lander 2	0.00	0.13	S-M	25	0	3
Mars Lander 3	0.00	0.13	S-M	25	0	3
DEEPSPACE	0.00	0.13	S-M	25	0	3
Mars Orbiter 2	0.00	0.13	S-M	25	0	3
MGS	0.00	0.13	M	60	0	8
Mars Pathfinder	0.00	0.13	M	60	0	8
NEAR	0.00	0.13	M	60	0	8
ACE	0.00	0.13	M	60	0	8
SIRTF	0.00	0.13	M	60	0	8
Solar Probe	0.00	0.14	M	60	0	9
Solar Express	0.00	0.14	M	60	0	9
CASSINI	0.00	0.13	H	200	0	25
FAST	0.00	0.13	S	15	0	2
TRACE	0.00	0.13	S	15	0	2
SNOE/Orbcomm	0.00	0.13	S	15	0	2
Terriers/Mublcom	0.00	0.13	S	15	0	2
WIRE	0.00	0.13	S	15	0	2
CATSAT	0.00	0.13	S	15	0	2
EO1/SAC-C	0.00	0.13	S	15	0	2
STARDUST	0.00	0.13	S-M	25	0	3
JASON	0.00	0.20	S	15	0	3
IMAGE	0.00	0.13	S	15	0	2
MAP	0.00	0.13	S	15	0	2
SCISAT	0.00	0.13	S	15	0	2
EO2	0.00	0.13	S	15	0	2
Surveyor 1	0.00	0.13	S	15	0	2
Surveyor 2	0.00	0.13	S	15	0	2
SCISAT2	0.00	0.14	S	15	0	2

LEO Commercial Sector

- Source:
  - Department of Transportation "LEO Commercial Market Projections," April 5, 1996
- Assume SV lifetimes of 5 years for LEO comsats and 10 years for MEO comsats
- Assume SV/flight = 2 - 6 for deployment missions (depending on system)
- Assume SV/flight = 1 for replenishment
- Assume throw weight = SV/flight* Payload weight (adjusted)
- Flight-rate estimates:
  - SV/year = constellation size / lifetime (deployment)
  - SV/year = (1 sat per orbit plane)/lifetime (replenishment)
  - Rate = (SV/year) / (SV/flight)

LEO Commercial Sector

The launch projections for the commercial LEO sector were derived from the Department of Transportation "LEO Commercial Market Projections," April 5, 1996. There are many other proposed commercial LEO satellites than those listed in the Dept. of Transportation report. However, many of these are only conceptual and will not actually be built and deployed in the 2000-2010 time period. The Dept. of Transportation has made an assessment of which proposed systems seem the most viable and likely to be deployed. This study only considers the LEO systems that are deemed viable by the Dept. of Transportation.

Most of the proposed commercial LEO systems are constellations of satellites, ranging in number from less than 10 satellites to over 100. To estimate yearly flight rates for the LEO systems, several assumptions were made:

- LEO comsats have 5 year lifetimes and MEO comsats have 10 year lifetimes
- There are 2-6 satellites per flight for deployment missions. The intent is to deploy an entire orbit plane of a LEO constellation with one launch.
- There is one satellite per flight for replenishment missions.
- There is one replenishment mission for each orbit plane of a constellation during the satellite lifetime.
- Total payload weight per launch is calculated by multiplying the weight of one satellite by
  a. the number of satellites per launch
  b. a "packing factor" to account for satellite/launch vehicle adapters, etc.
  c. an orbit inclination factor which is 1.0 for inclinations of 28 degrees and 1.4 for inclinations of 100 degrees.
  d. an orbit altitude factor which is 1.0 for altitudes of 100 nmi and 1.5 for altitudes of 1000 nmi
  e. a multiple manifest factor to account for extra adapters needed for multiple payloads on a single launch vehicle

The total payload weight is used to classify the launch vehicle as small, medium, or heavy.

The yearly flight rates are calculated in 3 steps:

1. (satellites required per year) = (constellation size) / (satellite lifetime)
2. (average flight rate per year) = (satellites required per year) / (satellites per flight)
3. (flight rate) = (average flight rate per year) x (probability of deployment)

The probability of deployment is 50% for the conservative flight rate estimate and is 100% for the optimistic flight rate estimate. The conservative estimate assumes that half of the proposed LEO systems in the Dept. of Transportation report are actually deployed, and the optimistic estimate assumes that all of the systems are deployed.

LEO Commercial (Continued)

- Comparison of conservative flight-rate estimates: (50% of proposed systems)

LV Class	FSRS	D.O.T. 1	D.O.T.2
S	16	9 - 12	10 - 15
M - H	8	5 - 10	5 - 10

- Optimistic FSRS flight-rate estimates ("everything goes except Teledesic"):

LV Class	FSRS	FSRS* with Teledesic
S	32	40
M - H	17	38

LEO Commercial (continued)

The flight rate estimates in this study for the commercial LEO systems agree reasonably well with the Department of Transportation estimates. The Dept. of Transportation "LEO Commercial Market Projections," 5 April 1996, has flight rate estimates for two different future scenarios. Each scenario assumes that some proposed LEO systems are actually deployed while others are not. The flight rates for both scenarios are compared to the "conservative" flight rate estimates in this study because the conservative estimates assume that only half of the proposed systems will actually be deployed.

Launch Vehicle Weight Class	FSRS	D.O.T. Scenario 1	D.O.T. Scenario 2
Small Class Launches	16	9-12	10-15
Medium-Heavy Class Launches	8	5-10	5-10

After the average yearly launch rate is calculated, an estimate of the market (in dollars) for each LEO system is made. This is done by multiplying the optimistic and conservative flight rate per year by the estimated cost of the launch vehicle used by that LEO system. This gives conservative and optimistic bounds for the market value of each program.

LEO Commercial (Little LEOs)

Program Name		Orbit Inclination (deg)	Orbit Altitude (nmi)	Satellite Weight (lbs)	Satellites Per Flight	Satellite Packing Factor	Orbit Inclination Factor	Orbit Altitude Factor	Multiple Manifest Factor	Equivalent LEO weight (lbs)	Launch Vehicle Category
E-Sat	(Deployment)	100	1000	250	3	1.10	1.40	1.50	1.07	1854	S
	(Replenishment)	100	1000	250	1	1.10	1.40	1.50	1.00	578	S
FAISAT	(Deployment)	68	540	235	6	1.10	1.30	1.25	1.10	2772	S
	(Replenishment)	68	540	235	1	1.10	1.30	1.25	1.00	420	S
GE Americom	(Deployment)	98	432	33	6	1.10	1.40	1.20	1.10	402	S
	(Replenishment)	98	432	33	1	1.10	1.40	1.20	1.00	61	S
GEMNET	(Deployment)	50	525	99	6	1.10	1.30	1.25	1.10	1168	S
	(Replenishment)	50	525	99	1	1.10	1.30	1.25	1.00	177	S
Starsys	(Deployment)	53	700	165	4	1.10	1.30	1.40	1.10	1453	S
	(Replenishment)	53	700	165	1	1.10	1.30	1.40	1.00	330	S
Leo One USA	(Deployment)	50	590	274	6	1.10	1.30	1.25	1.10	3233	S
	(Replenishment)	50	590	274	1	1.10	1.30	1.25	1.00	490	S
Orbcomm	(Deployment)	45, 70	418	95	6	1.10	1.35	1.20	1.10	1117	S
	(Replenishment)	45, 70	418	95	1	1.10	1.35	1.20	1.00	169	S
Vitasat	(Deployment)	88	540	198	2	1.10	1.35	1.25	1.05	772	S
	(Replenishment)	88	540	198	1	1.10	1.35	1.25	1.00	368	S
Elekon	(Deployment)	88	700		3	1.10	1.35	1.40	1.07		S
	(Replenishment)	88	700		1	1.10	1.35	1.40	1.00		S
Gonets	(Deployment)	85	1000	525	6	1.10	1.35	1.50	1.10	7718	S-M
	(Replenishment)	85	1000	525	1	1.10	1.35	1.50	1.00	1169	S
IRIS	(Deployment)	85	520		2	1.10	1.35	1.40	1.05		S
	(Replenishment)	85	520		1	1.10	1.35	1.40	1.00		S
Leo One Panamerica	(Deployment)	80	590	330	6	1.10	1.35	1.40	1.10	4528	S
	(Replenishment)	80	590	330	1	1.10	1.35	1.40	1.00	686	S
SAFIR	(Deployment)	87	540	132	3	1.10	1.35	1.40	1.07	881	S
	(Replenishment)	87	540	132	1	1.10	1.35	1.40	1.00	274	S

LEO Commercial (Little LEOs)

Program Name		Constellation Size	Number of Orbit Planes	Satellite Lifetime (years)	Satellites Per Year	Satellites Per Flight	Average Flight Rate Per Year
E-Sat	(Deployment)	6		5	1.20	3	0.40
	(Replenishment)	1		5	0.20	1	0.20
FAISAT	(Deployment)	26		5	5.20	6	0.87
	(Replenishment)	5		5	1.00	1	1.00
GE Americom	(Deployment)	24	4	5	4.80	6	0.80
	(Replenishment)	4	4	5	0.80	1	0.80
GEMNET	(Deployment)	38		5	7.60	6	1.27
	(Replenishment)	7		5	1.40	1	1.40
Starsys	(Deployment)	24	6	5	4.80	4	1.20
	(Replenishment)	6	6	5	1.20	1	1.20
Leo One USA	(Deployment)	48	8	5	9.60	6	1.60
	(Replenishment)	8	8	5	1.60	1	1.60
Orbcomm	(Deployment)	36	6	5	7.20	6	1.20
	(Replenishment)	6	6	5	1.20	1	1.20
Vitasat	(Deployment)	2	1	5	0.40	2	0.20
	(Replenishment)	1	1	5	0.20	1	0.20
Elekon	(Deployment)	7		5	1.40	3	0.47
	(Replenishment)	1		5	0.20	1	0.20
Gonets	(Deployment)	24		5	4.80	6	0.80
	(Replenishment)	5		5	1.00	1	1.00
IRIS	(Deployment)	2		5	0.40	2	0.20
	(Replenishment)	1		5	0.20	1	0.20
Leo One Panamerica	(Deployment)	18		5	3.60	6	0.60
	(Replenishment)	3		5	0.60	1	0.60
SAFIR	(Deployment)	6		5	1.20	3	0.40
	(Replenishment)	1		5	0.20	1	0.20

LEO Commercial (Little LEOs)

Program Name		Average Flight Rate Per Year	Conservative Probability of Deployment	Optimistic Probability of Deployment	Conservative Flight Rate	Optimistic Flight Rate
E-Sat	(Deployment)	0.40	0.50	1.00	0.20	0.40
	(Replenishment)	0.20	0.50	1.00	0.10	0.20
FAISAT	(Deployment)	0.87	0.50	1.00	0.43	0.87
	(Replenishment)	1.00	0.50	1.00	0.50	1.00
GE Americom	(Deployment)	0.80	0.50	1.00	0.40	0.80
	(Replenishment)	0.80	0.50	1.00	0.40	0.80
GEMNET	(Deployment)	1.27	0.50	1.00	0.63	1.27
	(Replenishment)	1.40	0.50	1.00	0.70	1.40
Starsys	(Deployment)	1.20	0.50	1.00	0.60	1.20
	(Replenishment)	1.20	0.50	1.00	0.60	1.20
Leo One USA	(Deployment)	1.60	0.50	1.00	0.80	1.60
	(Replenishment)	1.60	0.50	1.00	0.80	1.60
Orbcomm	(Deployment)	1.20	0.50	1.00	0.60	1.20
	(Replenishment)	1.20	0.50	1.00	0.60	1.20
Vitasat	(Deployment)	0.20	0.50	1.00	0.10	0.20
	(Replenishment)	0.20	0.50	1.00	0.10	0.20
Elekon	(Deployment)	0.47	0.50	1.00	0.23	0.47
	(Replenishment)	0.20	0.50	1.00	0.10	0.20
Gonets	(Deployment)	0.80	0.50	1.00	0.40	0.80
	(Replenishment)	1.00	0.50	1.00	0.50	1.00
IRIS	(Deployment)	0.20	0.50	1.00	0.10	0.20
	(Replenishment)	0.20	0.50	1.00	0.10	0.20
Leo One Panamerica	(Deployment)	0.60	0.50	1.00	0.30	0.60
	(Replenishment)	0.60	0.50	1.00	0.30	0.60
SAFIR	(Deployment)	0.40	0.50	1.00	0.20	0.40
	(Replenishment)	0.20	0.50	1.00	0.10	0.20

LEO Commercial (Little LEOs)

Program Name		Conservative Flight Rate	Optimistic Flight Rate	Launch Vehicle Category	Price Per Launch (millions)	Conservative Market (millions)	Optimistic Market (millions)
E-Sat	(Deployment)	0.20	0.40	S	15	3	6
	(Replenishment)	0.10	0.20	S	15	2	3
FAISAT	(Deployment)	0.43	0.87	S	15	7	13
	(Replenishment)	0.50	1.00	S	15	8	15
GE Americom	(Deployment)	0.40	0.80	S	15	6	12
	(Replenishment)	0.40	0.80	S	15	6	12
GEMNET	(Deployment)	0.63	1.27	S	15	10	19
	(Replenishment)	0.70	1.40	S	15	11	21
Starsys	(Deployment)	0.60	1.20	S	15	9	18
	(Replenishment)	0.60	1.20	S	15	9	18
Leo One USA	(Deployment)	0.80	1.60	S	15	12	24
	(Replenishment)	0.80	1.60	S	15	12	24
Orbcomm	(Deployment)	0.60	1.20	S	15	9	18
	(Replenishment)	0.60	1.20	S	15	9	18
Vitasat	(Deployment)	0.10	0.20	S	15	2	3
	(Replenishment)	0.10	0.20	S	15	2	3
Elekon	(Deployment)	0.23	0.47	S	15	4	7
	(Replenishment)	0.10	0.20	S	15	2	3
Gonets	(Deployment)	0.40	0.80	S-M	25	10	20
	(Replenishment)	0.50	1.00	S	15	8	15
IRIS	(Deployment)	0.10	0.20	S	15	2	3
	(Replenishment)	0.10	0.20	S	15	2	3
Leo One Panamerica	(Deployment)	0.30	0.60	S	15	5	9
	(Replenishment)	0.30	0.60	S	15	5	9
SAFIR	(Deployment)	0.20	0.40	S	15	3	6
	(Replenishment)	0.10	0.20	S	15	2	3

LEO Commercial (Big LEOs)

Program Name		Orbit Inclination (deg)	Orbit Altitude (nmi)	Satellite Weight (lbs)	Satellites Per Flight	Satellite Packing Factor	Orbit Inclination Factor	Orbit Altitude Factor	Multiple Manifest Factor	Equivalent LEO weight (lbs)	Launch Vehicle Category
Constellation Comm.	(Deployment)	62	1080	1160	6	1.10	1.30	1.50	1.10	16422	M
	(Replenishment)	62	1080	1160	1	1.10	1.30	1.50	1.00	2488	S
Ellipso	(Deployment)	0, 116	4356, 370	1430	5	1.10	1.40	2.00	1.10	24224	M-H
	(Replenishment)	0, 116	4356, 370	1430	1	1.10	1.40	2.00	1.00	4404	S
Globalstar	(Deployment)	52	764	990	6	1.10	1.30	1.40	1.10	13081	M
	(Replenishment)	52	764	990	1	1.10	1.30	1.40	1.00	1982	S
Iridium	(Deployment)	86	421	1500	5	1.10	1.35	1.20	1.10	14702	M
	(Replenishment)	86	421	1500	1	1.10	1.35	1.20	1.00	2673	S
Sativod	(Deployment)	50	800	1540	5	1.10	1.30	1.40	1.10	16957	M
	(Replenishment)	50	800	1540	1	1.10	1.30	1.40	1.00	3083	S
Signal	(Deployment)			680	5	1.10	1.30	1.30	1.10	6953	S-M
	(Replenishment)			680	1	1.10	1.30	1.30	1.00	1264	S

Program Name		Constellation Size	Number of Orbit Planes	Satellite Lifetime (years)	Satellites Per Year	Satellites Per Flight	Average Flight Rate Per Year
Constellation Comm.	(Deployment)	48	7	5	9.20	6	1.53
	(Replenishment)	7	7	5	1.40	1	1.40
Ellipso	(Deployment)	16	3	5	3.20	5	0.64
	(Replenishment)	3	3	5	0.60	1	0.60
Globalstar	(Deployment)	48	8	5	9.60	6	1.60
	(Replenishment)	8	8	5	1.60	1	1.60
Iridium	(Deployment)	66	6	5	13.20	5	2.64
	(Replenishment)	6	6	5	1.20	1	1.20
Sativod	(Deployment)	64		5	12.80	5	2.56
	(Replenishment)	11		5	2.20	1	2.20
Signal	(Deployment)	48		5	9.60	5	1.92
	(Replenishment)	8		5	1.60	1	1.60

LEO Commercial (Big LEOs)

Program Name		Average Flight Rate Per Year	Conservative Probability of Deployment	Optimistic Probability of Deployment	Conservative Flight Rate	Optimistic Flight Rate
Constellation Comm.	(Deployment)	1.53	0.50	1.00	0.77	1.53
	(Replenishment)	1.40	0.50	1.00	0.70	1.40
Ellipso	(Deployment)	0.64	0.50	1.00	0.32	0.64
	(Replenishment)	0.60	0.50	1.00	0.30	0.60
Globalstar	(Deployment)	1.60	0.50	1.00	0.80	1.60
	(Replenishment)	1.60	0.50	1.00	0.80	1.60
Iridium	(Deployment)	2.64	0.50	1.00	1.32	2.64
	(Replenishment)	1.20	0.50	1.00	0.60	1.20
Sativod	(Deployment)	2.56	0.50	1.00	1.28	2.56
	(Replenishment)	2.20	0.50	1.00	1.10	2.20
Signal	(Deployment)	1.92	0.50	1.00	0.96	1.92
	(Replenishment)	1.60	0.50	1.00	0.80	1.60

Program Name		Conservative Flight Rate	Optimistic Flight Rate	Launch Vehicle Category	Price Per Launch (millions)	Conservative Market (millions)	Optimistic Market (millions)
Constellation Comm.	(Deployment)	0.77	1.53	M	60	46	92
	(Replenishment)	0.70	1.40	S	15	11	21
Ellipso	(Deployment)	0.32	0.64	M-H	80	26	51
	(Replenishment)	0.30	0.60	S	15	5	9
Globalstar	(Deployment)	0.80	1.60	M	60	48	96
	(Replenishment)	0.80	1.60	S	15	12	24
Iridium	(Deployment)	1.32	2.64	M	60	79	158
	(Replenishment)	0.60	1.20	S	15	9	18
Sativod	(Deployment)	1.28	2.56	M	60	77	154
	(Replenishment)	1.10	2.20	S	15	17	33
Signal	(Deployment)	0.96	1.92	S-M	25	24	48
	(Replenishment)	0.80	1.60	S	15	12	24

LEO Commercial (MEO comsats)

Program Name		Orbit Inclination (deg)	Orbit Altitude (nmi)	Satellite Weight (lbs)	Satellites Per Flight	Satellite Packing Factor	Orbit Inclination Factor	Orbit Altitude Factor	Multiple Manifest Factor	Equivalent LEO weight (lbs)	Launch Vehicle Category
Odyssey	(Deployment)	50	5590	4800	2	1.10	1.30	2.00	1.10	30202	M-H
	(Replenishment)	50	5590	4800	1	1.10	1.30	2.00	1.00	13728	M
AMSC	(Deployment)	48	5590	5250	2	1.10	1.30	2.00	1.10	33033	M-H
	(Replenishment)	48	5590	5250	1	1.10	1.30	2.00	1.00	15015	M
ICO	(Deployment)	45	5590	5500	2	1.10	1.30	2.00	1.10	34606	M-H
	(Replenishment)	45	5590	5500	1	1.10	1.30	2.00	1.00	15730	M

Program Name		Constellation Size	Number of Orbit Planes	Satellite Lifetime (years)	Satellites Per Year	Satellites Per Flight	Average Flight Rate Per Year
Odyssey	(Deployment)	12	3	10	1.2	2	0.60
	(Replenishment)	3	3	10	0.3	1	0.30
AMSC	(Deployment)	12	2	10	1.2	2	0.60
	(Replenishment)	2	2	10	0.2	1	0.20
ICO	(Deployment)	10	2	10	1	2	0.50
	(Replenishment)	2	2	10	0.2	1	0.20

LEO Commercial (MEO comsats)

Program Name		Average Flight Rate Per Year	Conservative Probability of Deployment	Optimistic Probability of Deployment	Conservative Flight Rate	Optimistic Flight Rate
Odyssey	(Deployment)	0.60	0.50	1.00	0.30	0.60
	(Replenishment)	0.30	0.50	1.00	0.15	0.30
AMSC	(Deployment)	0.60	0.50	1.00	0.30	0.60
	(Replenishment)	0.20	0.50	1.00	0.10	0.20
ICO	(Deployment)	0.50	0.50	1.00	0.25	0.50
	(Replenishment)	0.20	0.50	1.00	0.10	0.20

Program Name		Conservative Flight Rate	Optimistic Flight Rate	Launch Vehicle Category	Price Per Launch (millions)	Conservative Market (millions)	Optimistic Market (millions)
Odyssey	(Deployment)	0.30	0.60	M-H	110	33	66
	(Replenishment)	0.15	0.30	M	60	9	18
AMSC	(Deployment)	0.30	0.60	M-H	110	33	66
	(Replenishment)	0.10	0.20	M	60	6	12
ICO	(Deployment)	0.25	0.50	M-H	110	28	55
	(Replenishment)	0.10	0.20	M	60	6	12

LEO Commercial (Mega LEO)

Program Name	Orbit Inclination (deg)	Orbit Altitude (nmi)	Satellite Weight (lbs)	Satellites Per Flight	Satellite Packing Factor	Orbit Inclination Factor	Orbit Altitude Factor	Multiple Manifest Factor	Equivalent LEO weight (lbs)	Launch Vehicle Category
Teledesic (Deployment)	98	378	1760	8	1.10	1.35	1.20	1.20	30109	M-H
(Replenishment)	98	378	1760	1	1.10	1.35	1.20	1.00	3136	S

Program Name	Constellation Size	Number of Orbit Planes	Satellite Lifetime (years)	Satellites Per Year	Satellites Per Flight	Average Flight Rate Per Year
Teledesic (Deployment)	840	21	5	168.00	8	21.00
(Replenishment)	42	21	5	8.40	1	8.40

Program Name	Average Flight Rate Per Year	Conservative Probability of Deployment	Optimistic Probability of Deployment	Conservative Flight Rate	Optimistic Flight Rate
Teledesic (Deployment)	21.00	0.00	1.00	0.00	21.00
(Replenishment)	8.40	0.00	1.00	0.00	8.40

Program Name	Conservative Flight Rate	Optimistic Flight Rate	Launch Vehicle Category	Price Per Launch (millions)	Conservative Market (millions)	Optimistic Market (millions)
Teledesic (Deployment)	0.00	21.00	M-H	110.00	0	2310
(Replenishment)	0.00	8.40	S	15.00	0	126

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GEO Commercial Sector

- Sources
  - COMSTAC "Commercial Spacecraft Mission Model Update," May 18, 1995
  - COMSTAC data is historical from 1988-1994 and projected from 1995-1997
- Flight Rate Estimates:
  - Optimistic estimate is the 1995-1997 rate (or rate from first year of deployment until 1997)
  - Conservative estimate is the 1988-1997 rate
- Comparison of flight rates (1997-2010)

LV Class	FSRS	COMSTAC 1	COMSTAC 2
M	5-9	3	4
M-H	8-22	14	22
H	4-6	3	5

GEO Commercial

The commercial GEO launch projections were derived from the Commercial Space Transportation Advisory Committee (COMSTAC) "Commercial Spacecraft Mission Model Update," 18 May 1995. The COMSTAC report has historical data on GEO comsats from 1988-1994 as well as projected launches from 1995-1997. The COMSTAC launch vehicle weight classifications of medium (M), medium-heavy (M-H), and heavy (H) were adopted in this study.

There is usually a high level of uncertainty on future launch projections. This makes it very difficult to calculate a single number for an average yearly flight rate. For this reason, an upper and a lower bound on the yearly flight rate were estimated. The expectation is that the actual flight rate in the future will fall in this range. The lower bound on the flight rate is called the "conservative" rate and the upper bound is the "optimistic" rate. The average yearly flight rate for commercial GEO programs was calculated the following of way. The optimistic flight rate estimates for the GEO systems are the 1995-1997 rates from the COMSTAC report (or the rate from the first year of deployment until 1997). The conservative flight rate estimates are the 1988-1997 rates from the COMSTAC report.

Using this approach, the yearly flight rates in the 2000-2010 time period for the commercial GEO sector compare reasonably well with the two future scenarios in the COMSTAC report.

Launch Vehicle Class	FSRS	COMSTAC "Modest Growth Model"	COMSTAC "Higher Growth Model"
Medium	5 - 9	3	4
Medium-Heavy	8 - 22	14	22
Heavy	4 - 6	3	5

After the average yearly launch rate is calculated, an estimate of the market (in dollars) for each GEO system is made. This is done by multiplying the optimistic and conservative flight rate per year by the estimated cost of the launch vehicle used by that particular GEO system. This gives conservative and optimistic bounds for the market value of each program.

GEO Commercial (continued)

Program	Orbit	Launch Vehicle	Vehicle Category	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Total
Comsat-SBS	GEO	Ariane IV	H			1								1
Hughes-DBS	GEO	Ariane IV	H						1					1
Hughes-Galaxy	GEO	Ariane IV	H					1	1					2
IntelSat	GEO	Ariane IV	H		1		2		1	1	1	4	2	12
IntelSat	GEO	Titan III	H			2								2
IntelSat	GEO	Atlas IIAS	H							1	2			3
IntelSat	GEO	Long March 3B	H								1	1	1	3
Japan NStar	GEO	Ariane IV	H								1	1		2
Japan-JCSat1	GEO	Ariane IV	H		1									1
Japan-Superbird	GEO	Ariane IV	H		1	1		2						4
SES Astra	GEO	Ariane IV	H				1		1					2
Solidaridad	GEO	Ariane IV	H						1					1
Telesat-Anik	GEO	Ariane IV	H				2							2
AMSC-MSat	GEO	Atlas IIAS	M-H								1			1
Arabsat	GEO	Ariane IV	M-H										1	1
Argentina-Nahuel	GEO	Long March 3C	M-H									1		1
ASCom	GEO	Unspecified	M-H										1	1
AT&T Telstar	GEO	Atlas IIAS	M-H						1					1
AT&T Telstar	GEO	Ariane IV	M-H							1	1			2
AT&T Telstar	GEO	Unspecified	M-H										1	1
Brazilsat	GEO	Ariane IV	M-H							1	1			2
China-APStar	GEO	Long March 3C	M-H								1			1
China-APStar	GEO	Unspecified	M-H										1	1
China-Asiasat	GEO	Long March 3C	M-H								1			1
China-Asiasat	GEO	Unspecified	M-H										1	1
DBP-TVSat2	GEO	Ariane IV	M-H		1									1
Echo Star	GEO	Long March 3C	M-H								1	1	1	3
Eutelsat	GEO	Ariane IV	M-H			1	1	1		1	1		1	6
Eutelsat	GEO	Atlas IIAS	M-H				1					1		2
GE Primestar	GEO	Atlas IIAS	M-H									1		1
GE Primestar	GEO	Proton	M-H									1		1
GE Satcom	GEO	Ariane IV	M-H									1		1

GEO Commercial (continued)

Program	Orbit	Launch Vehicle	Vehicle Category	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Total
GE Satcom	GEO	Atlas IIAS	M-H									1		1
GE Satcom	GEO	Unspecified	M-H										1	1
Germany-Eur Star	GEO	Unspecified	M-H										1	1
Hughes-DBS	GEO	Ariane IV	M-H								1			1
Hughes-DBS	GEO	Atlas IIAS	M-H							1				1
Hughes-DBS	GEO	Unspecified	M-H										1	1
Hughes-Galaxy	GEO	Atlas IIAS	M-H								1			1
Hughes-Galaxy	GEO	Unspecified	M-H										2	2
India-Insat	GEO	Ariane IV	M-H					1	1					2
Indonesia-Palapa	GEO	Ariane IV	M-H									1		1
Indonesia-Palapa	GEO	Atlas IIAS	M-H									1		1
Inmarsat	GEO	Ariane IV	M-H									1	1	2
Inmarsat	GEO	Atlas IIAS	M-H									2		2
Inmarsat	GEO	Proton	M-H									1		1
Insat	GEO	Ariane IV	M-H								1		1	2
Insat	GEO	Unspecified	M-H										1	1
IntelSat	GEO	Ariane IV	M-H	1	1									2
IntelSat	GEO	Atlas IIAS	M-H					1						1
Italy-Italsat	GEO	Ariane IV	M-H				1					1		2
Japan JSat	GEO	Atlas IIAS	M-H								1		1	2
Japan-JCSat	GEO	Titan III	M-H			1								1
Japan-Superbird	GEO	Unspecified	M-H										1	1
Loral Sat Radio1	GEO	Ariane IV	M-H										1	1
NileSat	GEO	Unspecified	M-H										1	1
Norway-Thor	GEO	Unspecified	M-H										1	1
Optus	GEO	Long March 3C	M-H					2		1				3
Orion	GEO	Atlas IIAS	M-H							1				1
Panamsat	GEO	Ariane IV	M-H							2	2	1		5
Panamsat	GEO	Proton	M-H										1	1
Philippine-Mabsat	GEO	Unspecified	M-H										1	1
SES Astra	GEO	Ariane IV	M-H	1						1	1			3
SES Astra	GEO	Proton	M-H									1	1	2
Solidaridad	GEO	Ariane IV	M-H							1				1

GEO Commercial (continued)

Program	Orbit	Launch Vehicle	Vehicle Category	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Total
Spain-Hispasat	GEO	Ariane IV	M-H					1	1					2
SSC-Tele-X	GEO	Ariane IV	M-H		1									1
Sweden-Sirius	GEO	Unspecified	M-H										1	1
Thaicom	GEO	Unspecified	M-H									1		1
TMI-MSat	GEO	Ariane IV	M-H									1		1
Turksat	GEO	Ariane IV	M-H							2		1		3
Arabsat	GEO	Ariane IV	M					1				1		2
Brazilsat	GEO	Ariane IV	M										1	1
BSB-Marcopolo	GEO	Delta II	M		1	1								2
China-APStar	GEO	Long March 3A	M							1		1		2
China-Asiasat	GEO	Long March 3A	M			1								1
Comsat-SBS	GEO	Ariane IV	M	1										1
DBP-DFS	GEO	Ariane IV	M		1	1								2
DBP-DFS	GEO	Delta II	M					1						1
Eutelsat	GEO	Ariane IV	M	1										1
GE Satcom	GEO	Ariane IV	M			1		1						2
GE Satcom	GEO	Delta II	M				1	1						2
GTE-GStar	GEO	Ariane IV	M	1		1								2
GTE-Spacenet	GEO	Ariane IV	M	1										1
GTE-Spacenet	GEO	Delta II	M				1							1
Hughes-Galaxy	GEO	Ariane IV	M			1								1
Hughes-Galaxy	GEO	Atlas I	M					2						2
Hughes-Galaxy	GEO	Delta II	M							1		1		2
India-Insat	GEO	Ariane IV	M	1										1
India-Insat	GEO	Delta II	M			1								1
Indonesia-IndoStar	GEO	Unspecified	M										1	1
Indonesia-Palapa	GEO	Delta II	M			1		1						2
Inmarsat	GEO	Delta II	M			1	1							2
Inmarsat	GEO	Ariane IV	M				1	1						2
Israel-Amos 1	GEO	Ariane IV	M									1		1
Japan BSat	GEO	Ariane IV	M										1	1
Japan-BS	GEO	Ariane IV	M			1								1

GEO Commercial (continued)

Japan-NHK	GEO	Atlas I	M				1							1
Japan-NHK	GEO	Ariane IV	M							1				1
KoreaSat	GEO	Delta II	M								2			2
Malaysia-Measat	GEO	Ariane IV	M								1			1
Malaysia-Measat	GEO	Unspecified	M									1		1
NATO	GEO	Delta II	M				1		1					2
Panamsat	GEO	Ariane IV	M	1										1
Thaicom	GEO	Ariane IV	M						1	1				2
UK-Skynet	GEO	Ariane IV	M	1		1								2
UK-Skynet	GEO	Titan III	M			1								1
UK-Skynet	GEO	Delta II	M										1	1

GEO Commercial (continued)

Program	Orbit	Launch Vehicle	Vehicle Category	Conservative Flight Rate	Optimistic Flight Rate	Conservative Rate Remarks	Optimistic Rate Remarks
Comsat-SBS	GEO	Ariane IV	H	0.10	0.13	1988 - 1997 rate	1990 - 1997 rate
Hughes-DBS	GEO	Ariane IV	H	0.10	0.20	1988 - 1997 rate	1993 - 1997 rate
Hughes-Galaxy	GEO	Ariane IV	H	0.20	0.33	1988 - 1997 rate	1992 - 1997 rate
IntelSat	GEO	Ariane IV	H	1.20	1.33	1988 - 1997 rate	1989 - 1997 rate
IntelSat	GEO	Titan III	H	0.20	0.25	1988 - 1997 rate	1990 - 1997 rate
IntelSat	GEO	Atlas IIAS	H	0.30	0.75	1988 - 1997 rate	1994 - 1997 rate
IntelSat	GEO	Long March 3B	H	0.30	1.00	1988 - 1997 rate	1995 - 1997 rate
Japan NStar	GEO	Ariane IV	H	0.20	0.66	1988 - 1997 rate	1995 - 1997 rate
Japan-JCSat1	GEO	Ariane IV	H	0.10	0.11	1988 - 1997 rate	1989 - 1997 rate
Japan-Superbird	GEO	Ariane IV	H	0.40	0.44	1988 - 1997 rate	1989 - 1997 rate
SES Astra	GEO	Ariane IV	H	0.20	0.29	1988 - 1997 rate	1991 - 1997 rate
Solidaridad	GEO	Ariane IV	H	0.10	0.20	1988 - 1997 rate	1993 - 1997 rate
Telesat-Anik	GEO	Ariane IV	H	0.20	0.29	1988 - 1997 rate	1991 - 1997 rate
AMSC-MSat	GEO	Atlas IIAS	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Arabsat	GEO	Ariane IV	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Argentina-Nahuel	GEO	Long March 3C	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
ASCom	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
AT&T Telstar	GEO	Atlas IIAS	M-H	0.10	0.20	1988 - 1997 rate	1993 - 1997 rate
AT&T Telstar	GEO	Ariane IV	M-H	0.20	0.50	1988 - 1997 rate	1994 - 1997 rate
AT&T Telstar	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Brazilsat	GEO	Ariane IV	M-H	0.20	0.50	1988 - 1997 rate	1994 - 1997 rate
China-APStar	GEO	Long March 3C	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
China-APStar	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
China-Asiasat	GEO	Long March 3C	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
China-Asiasat	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
DBP-TVSat2	GEO	Ariane IV	M-H	0.10	0.11	1988 - 1997 rate	1989 - 1997 rate
Echo Star	GEO	Long March 3C	M-H	0.30	1.00	1988 - 1997 rate	1995 - 1997 rate
Eutelsat	GEO	Ariane IV	M-H	0.60	0.75	1988 - 1997 rate	1990 - 1997 rate
Eutelsat	GEO	Atlas IIAS	M-H	0.20	0.29	1988 - 1997 rate	1991 - 1997 rate
GE Primestar	GEO	Atlas IIAS	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
GE Primestar	GEO	Proton	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
GE Satcom	GEO	Ariane IV	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate

GEO Commercial (continued)

Program	Orbit	Launch Vehicle	Vehicle Category	Conservative Flight Rate	Optimistic Flight Rate	Conservative Rate Remarks	Optimistic Rate Remarks
GE Satcom	GEO	Atlas IIAS	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
GE Satcom	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Germany-Eur Star	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Hughes-DBS	GEO	Ariane IV	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Hughes-DBS	GEO	Atlas IIAS	M-H	0.10	0.25	1988 - 1997 rate	1994 - 1997 rate
Hughes-DBS	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Hughes-Galaxy	GEO	Atlas IIAS	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Hughes-Galaxy	GEO	Unspecified	M-H	0.20	0.66	1988 - 1997 rate	1995 - 1997 rate
India-Insat	GEO	Ariane IV	M-H	0.00	0.33	1988 - 1997 rate	1992 - 1997 rate
Indonesia-Palapa	GEO	Ariane IV	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Indonesia-Palapa	GEO	Atlas IIAS	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Inmarsat	GEO	Ariane IV	M-H	0.20	0.66	1988 - 1997 rate	1995 - 1997 rate
Inmarsat	GEO	Atlas IIAS	M-H	0.20	0.66	1988 - 1997 rate	1995 - 1997 rate
Inmarsat	GEO	Proton	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Insat	GEO	Ariane IV	M-H	0.20	0.66	1988 - 1997 rate	1995 - 1997 rate
Insat	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
IntelSat	GEO	Ariane IV	M-H	0.20	0.20	1988 - 1997 rate	1988 - 1997 rate
IntelSat	GEO	Atlas IIAS	M-H	0.10	0.17	1988 - 1997 rate	1992 - 1997 rate
Italy-Italsat	GEO	Ariane IV	M-H	0.20	0.29	1988 - 1997 rate	1991 - 1997 rate
Japan-JSat	GEO	Atlas IIAS	M-H	0.20	0.66	1988 - 1997 rate	1995 - 1997 rate
Japan-JCSat	GEO	Titan III	M-H	0.10	0.13	1988 - 1997 rate	1990 - 1997 rate
Japan-Superbird	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Loral Sat Radio1	GEO	Ariane IV	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
NileSat	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Norway-Thor	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Optus	GEO	Long March 3C	M-H	0.00	0.30	1988 - 1997 rate	1995 - 1997 rate
Orion	GEO	Atlas IIAS	M-H	0.10	0.25	1988 - 1997 rate	1994 - 1997 rate
Panamsat	GEO	Ariane IV	M-H	0.50	1.00	1988 - 1997 rate	1993 - 1997 rate
Panamsat	GEO	Proton	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Philippine-Mabsat	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
SES Astra	GEO	Ariane IV	M-H	0.30	0.50	1988 - 1997 rate	1994 - 1997 rate
SES Astra	GEO	Proton	M-H	0.20	0.66	1988 - 1997 rate	1995 - 1997 rate
Solidaridad	GEO	Ariane IV	M-H	0.10	0.25	1988 - 1997 rate	1994 - 1997 rate

GEO Commercial (continued)

Program	Orbit	Launch Vehicle	Vehicle Category	Conservative Flight Rate	Optimistic Flight Rate	Conservative Rate Remarks	Optimistic Rate Remarks
Spain-Hispasat	GEO	Ariane IV	M-H	0.00	0.33	1988 - 1997 rate	1992 - 1997 rate
SSC-Tele-X	GEO	Ariane IV	M-H	0.10	0.11	1988 - 1997 rate	1989 - 1997 rate
Sweden-Sirius	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Thaicom	GEO	Unspecified	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
TMI-MSat	GEO	Ariane IV	M-H	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Turksat	GEO	Ariane IV	M-H	0.30	0.75	1988 - 1997 rate	1994 - 1997 rate
Arabsat	GEO	Ariane IV	M	0.20	0.33	1988 - 1997 rate	1992 - 1997 rate
Brazilsat	GEO	Ariane IV	M	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
BSB-Marcopolo	GEO	Delta II	M	0.20	0.22	1988 - 1997 rate	1989 - 1997 rate
China-APStar	GEO	Long March 3A	M	0.20	0.50	1988 - 1997 rate	1994 - 1997 rate
China-Asiasat	GEO	Long March 3A	M	0.10	0.13	1988 - 1997 rate	1990 - 1997 rate
Comsat-SBS	GEO	Ariane IV	M	0.10	0.10	1988 - 1997 rate	1988 - 1997 rate
DBP-DFS	GEO	Ariane IV	M	0.20	0.22	1988 - 1997 rate	1989 - 1997 rate
DBP-DFS	GEO	Delta II	M	0.10	0.17	1988 - 1997 rate	1992 - 1997 rate
Eutelsat	GEO	Ariane IV	M	0.10	0.10	1988 - 1997 rate	1988 - 1997 rate
GE Satcom	GEO	Ariane IV	M	0.20	0.25	1988 - 1997 rate	1990 - 1997 rate
GE Satcom	GEO	Delta II	M	0.20	0.29	1988 - 1997 rate	1991 - 1997 rate
GTE-GStar	GEO	Ariane IV	M	0.20	0.20	1988 - 1997 rate	1988 - 1997 rate
GTE-Spacenet	GEO	Ariane IV	M	0.10	0.10	1988 - 1997 rate	1988 - 1997 rate
GTE-Spacenet	GEO	Delta II	M	0.10	0.14	1988 - 1997 rate	1991 - 1997 rate
Hughes-Galaxy	GEO	Ariane IV	M	0.10	0.13	1988 - 1997 rate	1990 - 1997 rate
Hughes-Galaxy	GEO	Atlas I	M	0.20	0.33	1988 - 1997 rate	1992 - 1997 rate
Hughes-Galaxy	GEO	Delta II	M	0.20	0.50	1988 - 1997 rate	1994 - 1997 rate
India-Insat	GEO	Ariane IV	M	0.10	0.10	1988 - 1997 rate	1988 - 1997 rate
India-Insat	GEO	Delta II	M	0.10	0.13	1988 - 1997 rate	1990 - 1997 rate
Indonesia-IndoStar	GEO	Unspecified	M	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Indonesia-Palapa	GEO	Delta II	M	0.20	0.25	1988 - 1997 rate	1990 - 1997 rate
Inmarsat	GEO	Delta II	M	0.20	0.25	1988 - 1997 rate	1990 - 1997 rate
Inmarsat	GEO	Ariane IV	M	0.20	0.29	1988 - 1997 rate	1991 - 1997 rate
Israel-Amos 1	GEO	Ariane IV	M	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Japan BSat	GEO	Ariane IV	M	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Japan-BS	GEO	Ariane IV	M	0.10	0.14	1988 - 1997 rate	1991 - 1997 rate

GEO Commercial (continued)

Program	Orbit	Launch Vehicle	Vehicle Category	Conservative Flight Rate	Optimistic Flight Rate	Conservative Rate Remarks	Optimistic Rate Remarks
Japan-NHK	GEO	Atlas I	M	0.10	0.17	1988 - 1997 rate	1992 - 1997 rate
Japan-NHK	GEO	Ariane IV	M	0.10	0.25	1988 - 1997 rate	1994 - 1997 rate
KoreaSat	GEO	Delta II	M	0.20	0.67	1988 - 1997 rate	1995 - 1997 rate
Malaysia-Measat	GEO	Ariane IV	M	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
Malaysia-Measat	GEO	Unspecified	M	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate
NATO	GEO	Delta II	M	0.20	0.29	1988 - 1997 rate	1991 - 1997 rate
Panamsat	GEO	Ariane IV	M	0.10	0.10	1988 - 1997 rate	1988 - 1997 rate
Thaicom	GEO	Ariane IV	M	0.20	0.40	1988 - 1997 rate	1993 - 1997 rate
UK-Skynet	GEO	Ariane IV	M	0.20	0.20	1988 - 1997 rate	1988 - 1997 rate
UK-Skynet	GEO	Titan III	M	0.10	0.14	1988 - 1997 rate	1991 - 1997 rate
UK-Skynet	GEO	Delta II	M	0.10	0.33	1988 - 1997 rate	1995 - 1997 rate

GEO Commercial (continued)

Program	Conservative Flight Rate	Optimistic Flight Rate	Vehicle Category	Price Per Launch (millions)	Conservative Market (millions)	Optimistic Market (millions)
Comsat-SBS	0.10	0.13	H	200	20	25
Hughes-DBS	0.10	0.20	H	200	20	40
Hughes-Galaxy	0.20	0.33	H	200	40	66
IntelSat	1.20	1.33	H	200	240	267
IntelSat	0.20	0.25	H	200	40	50
IntelSat	0.30	0.75	H	200	60	150
IntelSat	0.30	1.00	H	200	60	200
Japan NStar	0.20	0.66	H	200	40	132
Japan-JCSat1	0.10	0.11	H	200	20	22
Japan-Superbird	0.40	0.44	H	200	80	89
SES Astra	0.20	0.29	H	200	40	57
Solidaridad	0.10	0.20	H	200	20	40
Telesat-Anik	0.20	0.29	H	200	40	57
					0	0
AMSC-MSat	0.10	0.33	M-H	110	11	36
Arabsat	0.10	0.33	M-H	110	11	36
Argentina-Nahuel	0.10	0.33	M-H	110	11	36
ASCom	0.10	0.33	M-H	110	11	36
AT&T Telstar	0.10	0.20	M-H	110	11	22
AT&T Telstar	0.20	0.50	M-H	110	22	55
AT&T Telstar	0.10	0.33	M-H	110	11	36
Brazilsat	0.20	0.50	M-H	110	22	55
China-APStar	0.10	0.33	M-H	110	11	36
China-APStar	0.10	0.33	M-H	110	11	36
China-Asiasat	0.10	0.33	M-H	110	11	36
China-Asiasat	0.10	0.33	M-H	110	11	36
DBP-TVSat2	0.10	0.11	M-H	110	11	12
Echo Star	0.30	1.00	M-H	110	33	110
Eutelsat	0.60	0.75	M-H	110	66	83
Eutelsat	0.20	0.28	M-H	110	22	31
GE Primestar	0.10	0.33	M-H	110	11	36
GE Primestar	0.10	0.33	M-H	110	11	36
GE Satcom	0.10	0.33	M-H	110	11	36

GEO Commercial (continued)

Program	Conservative Flight Rate	Optimistic Flight Rate	Vehicle Category	Price Per Launch (millions)	Conservative Market (millions)	Optimistic Market (millions)
GE Satcom	0.10	0.33	M-H	110	11	36
GE Satcom	0.10	0.33	M-H	110	11	36
Germany-Eur Star	0.10	0.33	M-H	110	11	36
Hughes-DBS	0.10	0.33	M-H	110	11	36
Hughes-DBS	0.10	0.25	M-H	110	11	28
Hughes-DBS	0.10	0.33	M-H	110	11	36
Hughes-Galaxy	0.10	0.33	M-H	110	11	36
Hughes-Galaxy	0.20	0.66	M-H	110	22	73
India-Insat	0.00	0.33	M-H	110	0	36
Indonesia-Palapa	0.10	0.33	M-H	110	11	36
Indonesia-Palapa	0.10	0.33	M-H	110	11	36
Inmarsat	0.20	0.66	M-H	110	22	73
Inmarsat	0.20	0.66	M-H	110	22	73
Inmarsat	0.10	0.33	M-H	110	11	36
Insat	0.20	0.66	M-H	110	22	73
Insat	0.10	0.33	M-H	110	11	36
IntelSat	0.20	0.20	M-H	110	22	22
IntelSat	0.10	0.17	M-H	110	11	18
Italy-Italsat	0.20	0.29	M-H	110	22	31
Japan JSat	0.20	0.66	M-H	110	22	73
Japan-JCSat	0.10	0.13	M-H	110	11	14
Japan-Superbird	0.10	0.33	M-H	110	11	36
Loral Sat Radio1	0.10	0.33	M-H	110	11	36
NileSat	0.10	0.33	M-H	110	11	36
Norway-Thor	0.10	0.33	M-H	110	11	36
Optus	0.00	0.30	M-H	110	0	33
Orion	0.10	0.25	M-H	110	11	28
Panamsat	0.50	1.00	M-H	110	55	110
Panamsat	0.10	0.33	M-H	110	11	36
Philippine-Mabsat	0.10	0.33	M-H	110	11	36
SES Astra	0.30	0.50	M-H	110	33	55
SES Astra	0.20	0.66	M-H	110	22	73
Solidaridad	0.10	0.25	M-H	110	11	28

GEO Commercial (continued)

Program	Conservative Flight Rate	Optimistic Flight Rate	Vehicle Category	Price Per Launch (millions)	Conservative Market (millions)	Optimistic Market (millions)
Spain-Hispasat	0.00	0.33	M-H	110	0	36
SSC-Tele-X	0.10	0.11	M-H	110	11	12
Sweden-Sirius	0.10	0.33	M-H	110	11	36
Thaicom	0.10	0.33	M-H	110	11	36
TMI-MSat	0.10	0.33	M-H	110	11	36
Turksat	0.30	0.75	M-H	110	33	83
Arabsat	0.20	0.33	M	60	12	20
Brazilsat	0.10	0.33	M	60	6	20
BSB-Marcopolo	0.20	0.22	M	60	12	13
China-APStar	0.20	0.50	M	60	12	30
China-Asiasat	0.10	0.13	M	60	6	8
Comsat-SBS	0.10	0.10	M	60	6	6
DBP-DFS	0.20	0.22	M	60	12	13
DBP-DFS	0.10	0.17	M	60	6	10
Eutelsat	0.10	0.10	M	60	6	6
GE Satcom	0.20	0.25	M	60	12	15
GE Satcom	0.20	0.29	M	60	12	17
GTE-GStar	0.20	0.20	M	60	12	12
GTE-Spacenet	0.10	0.10	M	60	6	6
GTE-Spacenet	0.10	0.14	M	60	6	9
Hughes-Galaxy	0.10	0.13	M	60	6	8
Hughes-Galaxy	0.20	0.33	M	60	12	20
Hughes-Galaxy	0.20	0.50	M	60	12	30
India-Insat	0.10	0.10	M	60	6	6
India-Insat	0.10	0.13	M	60	6	8
Indonesia-IndoStar	0.10	0.33	M	60	6	20
Indonesia-Palapa	0.20	0.25	M	60	12	15
Inmarsat	0.20	0.25	M	60	12	15
Inmarsat	0.20	0.29	M	60	12	17
Israel-Amos 1	0.10	0.33	M	60	6	20
Japan BSat	0.10	0.33	M	60	6	20
Japan-BS	0.10	0.14	M	60	6	9

GEO Commercial (continued)

Program	Conservative Flight Rate	Optimistic Flight Rate	Vehicle Category	Price Per Launch (millions)	Conservative Market (millions)	Optimistic Market (millions)
Japan-NHK	0.10	0.17	M	60	6	10
Japan-NHK	0.10	0.25	M	60	6	15
KoreaSat	0.20	0.67	M	60	12	40
Malaysia-Measat	0.10	0.33	M	60	6	20
Malaysia-Measat	0.10	0.33	M	60	6	20
NATO	0.20	0.29	M	60	12	17
Panamsat	0.10	0.10	M	60	6	6
Thaicom	0.20	0.40	M	60	12	24
UK-Skynet	0.20	0.20	M	60	12	12
UK-Skynet	0.10	0.14	M	60	6	9
UK-Skynet	0.10	0.33	M	60	6	20

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Future Spacelift Requirements Study

Appendix 2
Innovative Applications Database

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Introduction

This appendix contains the database of 76 innovative space applications developed for the Future Spacelift Requirements Study. The data collected were from multiple sources including the in-house resources of The Aerospace Corporation, industry, NASA, DOD, and other government agencies. The 76 Innovative Applications were grouped into three different mission areas: Civil (10), Commercial (41), and Military (25).

Each application was assigned an Application Number. Some related applications were numbered by assigning a whole number to the primary application (e.g., 31. Space Station Missions) and decimal numbers to related applications (31.1. Space Station Servicing Missions). The details of each application were initially established by recording its Category, Sector, Source of the Concept, Description, and Major System Assumptions.

In order to characterize and define each of these concepts further, The Aerospace Corporation developed a list of 52 questions. In many cases, the available information for these innovative applications consisted of only a short notional description of the concept. In order to quantify space launch requirements for such ideas, a team of Aerospace experts further developed each innovative application into a workable solution, and estimated what it would take to make the idea feasible. The process of technical assessment involved review of existing data as well as further defining the sketchy ideas in group sessions.

All of the innovative applications were collected on an Aerospace developed Web site. The team of Aerospace experts answered the set of questions for each application. The consistency and accuracy of the answers were checked by a second team in an iterative process. When collection was complete, the data were linked to an Excel spreadsheet and automated charting program, as well as to an Access database for automated report generation. Finally, the spacelift attributes associated with the innovative applications database were then used in the technology assessment and the alternative futures of the Future Spacelift Requirements Study.

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Id	Application
1	Global Surveillance, Recon, and Targeting System - deployment mission
1.1	Global Surveillance, Recon, and Targeting System - servicing flight
2	Hyperspectral
3	Light, Affordable, On-demand Surveillance Sats
4	Military Spaceplane
5	Space Control
6	Space Mine
7	Space Surveillance
8	Space Traffic Control
9	Missile Warning
10	Bi-Static Radar
11	Orbit Debris Removal
12.1	Planetary Defense -- Sky Survey
12.2	Planetary Defense -- Sky Guard
12.3	Planetary Defense -- System Development
13	Global Area Strike System (GASS)
14	Force (PGM) Delivery from Space
15	Interceptors
16	Delivery of Electromagnetic Radiation from Space - deployment mission
16.1	Delivery of Electromagnetic Radiation from Space - servicing flight
18	Solar-Powered High Energy Laser System. - deployment mission
18.1	Solar-Powered High Energy Laser System. - servicing flight
19	Space-Based High Energy Laser System - deployment mission
19.1	Space-Based High Energy Laser System - servicing flight
20	Ground-Based High Energy Laser System - deployment mission
20.1	Ground-Based High Energy Laser System - servicing flight
21	KEW Kinetic Energy Weapons
22	Super GPS
23	Communications
24	SPACENET: On-Orbit Support in 2025
25	Communications - Fixed Satellite Services
26	Communications - Broadcast Satellite Services
27	Communications - Mobile Satellite Service - deployment mission
27.1	Communications - Mobile Satellite Service - servicing flight
28	Communications - Positioning Satellite Services
29	Space Manufacturing - deployment mission
29.1	Space Manufacturing - servicing flight
30	Remote Sensing
31	Government Missions - Space Station Missions - deployment mission

Id	Application
31.1	Government Missions - Space Station Missions - servicing flight
32	Government Missions - Human Planetary Exploration
33	Government - Space Science Outwards
34	Transportation - Fast Package Delivery
35	Transportation - Hazardous Waste Disposal
36	Transportation - Space Tourism
37	Transportation - UHigh Speed Civil Transport
38	Transportation - Space Rescue
39	Transportation - Space Servicing and Transfer
40	Entertainment - Digital Movie Satellite
44	Space Utilities - Molniya - deployment mission
44.1	Space Utilities - Molniya - servicing flight
45	Space Utility - GEO - deployment mission
45.1	Space Utility - GEO - servicing flight
46	Space Utility - SunSync - deployment mission
46.1	Space Utility - SunSync - servicing flight
47	Space Utility - Lunar - deployment mission
47.1	Space Utility - Lunar - servicing flight
48	Space Utility - Space-to-Space Power Beaming
49	Space Advertising
50	Space Burial
51	Novelties
52	Space Product Demonstration
53	New Missions - Space Business Park - deployment mission
53.1	New Missions - Space Business Park - servicing flight
53.2	New Missions - Space Medical
53.3	New Missions - Space Settlements (O'Neil Habitats)
53.4	New Missions - Space Settlements (Lunar Outpost)
53.5	New Missions - Space Agriculture
53.6	Entertainment - Orbiting Movie Studio
53.7	Entertainment - Space Athletic Events
53.8	Entertainment - Space Theme Park
56	New Missions - Debris Removal
58	Space Mining - LOX - deployment mission
58.1	Space Mining - LOX - servicing flight
59	Space Mining - Helium-3 (He3) - deployment mission
59.1	Space Mining - Helium-3 (He3) - servicing flight
60	Nanosat Applications

Application # 1

Global Surveillance, Recon, and Targeting System - deployment mission

Category Military

Source Spacecast 2020, Executive Summary p. 41, Space Applications

Date 4/25/97 7:13:34 AM

Reviewers Ho, Ching/Kim, David/Ruth, Edward

Description

The Global Surveillance, Reconnaissance, and Targeting System (GSRT) is a space-based, omnisensorial collection, processing, and dissemination system to provide a real-time information database. This database is used to create a virtual reality image of the area of interest. This virtual reality image can be used at all levels of command to provide situational awareness, technical and intelligence information, and two-way command and control. It is envisioned as a swarm of several hundred small satellites (a couple of hundred pounds) with different groups of SAR, EO, IR, multispectral, and on occasion, hyperspectral, etc.) that will collect omnisensorial data and send data to a central processing facility for data processing and dissemination.

Major System Assumptions

Miniature sensor system, launch capability, built-in-smarts for autonomous operations, minimum ground command and control, etc. Limited processing on-board. ** For initial deployment of full constellation

Comments

Initial input heavily modified after conversation with C. Ho. New input based on a proliferated small LEO satellites with different sensor package, with initial peace time constellation and supplimental satellites in times of crisis. (David J. Kim, 6 Feb 97) Revised by E. Ruth 18 APR 97.

Sector Military (US only)

Orbit LEO

Inclination Wide range of inclinations

Payload to LEO Less than 5,000 lb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Present prices

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge About 300 or more total

Estimated average flight rate Not applicable (surge or one-shot mission)

Confidence in flight rates Medium confidence (+- 50%)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Application # 1

Global Surveillance, Recon, and Targeting System - deployment mission

Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Days
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 1.1

Global Surveillance, Recon, and Targeting System - servicing flight

Category Military

Source Spacecast 2020, Executive Summary p. 41,
Space Applications

Date 4/25/97 7:13:44 AM

Reviewers Ho, Ching/Kim, David/Ruth, Edward

Description

The Global Surveillance, Reconnaissance, and Targeting System (GSRT) is a space-based, omnisensorial collection, processing, and dissemination system to provide a real-time information database. This database is used to create a virtual reality image of the area of interest. This virtual reality image can be used at all levels of command to provide situational awareness, technical and intelligence information, and two-way command and control. It is envisioned as a swarm of several hundred small satellites (a couple of hundred pounds) with different groups of SAR, EO, IR, multispectral, and on occasion, hyperspectral, etc.) that will collect omnisensorial data and send data to a central processing facility for data processing and dissemination.

Major System Assumptions

Miniature sensor system, launch capability, built-in-smarts for autonomous operations, minimum ground command and control, etc. Limited processing on-board. * For replenishment/servicing missions.

Comments

Initial input heavily modified after conversation with C. Ho. New input based on a proliferated small LEO satellites with different sensor package, with initial peace time constellation and supplemental satellites in times of crisis. (David J. Kim, 6 Feb 97) Revised by E. Ruth 18 APR 97.

Sector Military (US only)

Orbit LEO

Inclination Wide range of inclinations

Payload to LEO Less than 5,000 lb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Present prices

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 10 per year (7 to 15)

Confidence in flight rates Medium confidence (+- 50%)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Application # 1.1

Global Surveillance, Recon, and Targeting System - servicing flight

Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Days
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 2

Hyperspectral

Category Military

Source New world Vistas, Executive Summary (p.43)

Date 4/25/97 7:14:50 AM

Reviewers Kellogg, Robert/Ruth, Edward

Description

Small, less expensive satellites with a spatial resolution of 10 m class probably optimizes cost and coverage.

Major System Assumptions

Loosely based on the hyperspectral systems proposed for the Warfighter-1 program being run out of Phillips Lab. Sensor parameters 5-10m resolution 200-500 bands (vis thru LWIR) 40-100cm aperture 10 km swath width sun-synchronous orbits with 2-4 satellites in a constellation. Notes: - Does not need to be a separate satellite. Hyperspectral may be part of "normal" military surveillance sensors or commercial remote sensing. - System described will provide long-term monitoring, not continuous surveillance of targets of interest. In other words the revisit time will be hours not seconds. To provide surveillance would require a much larger constellation and would make even more sense to combine with a "normal" surveillance system.

Comments

52. Launch as needed for replenishment - may or may not be during conflict conditions. Revised by E. Ruth 18 APR 97 Ques. 52. changed to NO.

Sector Military (US only)

Orbit LEO

Inclination Polar or near polar

Payload to LEO Less than 5,000 lb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Present prices

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate One or less per year

Confidence in flight rates Medium confidence (+- 50%)

Launch price elasticity N/A

Schedule importance High: National security or severe launch-window constraints

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement N/A

Application # 2
Hyperspectral

Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap .reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	No
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 3

Light, Affordable, On-demand Surveillance Sats

Category Military

Source New World Vistas, p.26, Attack Volume

Date 4/25/97 7:21:25 AM

Reviewers Lopez, Jesse/Kim, David/Ruth, Edward

Description

The ability to rapidly orbit a tailored constellation of satellites with multimode radar and other sensors, powerful onboard processing, and robust data links support many operational concepts. One year life, substantial all-weather imaging and moving target indication/Ground Moving Target Indication (GMTI) capability at high revisit rates (< 10 min) and with the survivability and assured access inherent in orbital platforms.

Major System Assumptions

Miniature sensor system, launch capability, built-in-smarts for autonomous operations, minimum ground command and control, etc. It is assumed that a basic surveillance constellation with world wide access is available that provides all weather imaging (SAR) and ground moving target indication (GMTI) capability at a nominal revisit rate (30 minutes). Upon an increase in hostile actions or rising tension, a theater area requires more rapid revisits (<10 mins). This system would then provide constellation back filling (additional space platforms) for area of interest. It does not seem practical to build the entire constallation with these satellites and be operational in a matter of days or weeks without a large cost impact. It is assumed a one-year life is required for these satellites.

Comments

Minor modification made for consistency and filled out blank responses. Revised by E. Ruth 18 APR 97.

Sector Military (Foreign or joint programs)

Orbit LEO

Inclination Wide range of inclinations

Payload to LEO Less than 5,000 lb

Turn time (for launcher) N/A

Primary payload\cargo Weapon or sensors

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Factor of 3 reduction

Return payload mass N/A

Standing-alert capability Hours

Launch reliability required Present reliability

Est. flights for one-time surge About 3 total (range 2 to 6)

Estimated average flight rate One or less per year

Confidence in flight rates Medium confidence (+- 50%)

Launch price elasticity Inelastic--lowering price below enabling threshold will not increase flight rate

Schedule importance High: National security or severe launch-window constraints

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Application # 3

Light, Affordable, On-demand Surveillance Sats

Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap .reintegrate substitute payload	Days
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	4X baseline flight rate
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Special operations--less extensive than today
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Quick reaction, 24 hours or less call-up
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	Yes	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	No	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 4

Military Spaceplane

Category Military

Source New World Vistas P. 26, Attack Vol.

Date 4/25/97 7:21:51 AM

Reviewers Gross, Allen/Kim, David/Ruth, Edward

Description

The global-range TAV plane would be housed at existing AF bases within CONUS. It would be used to perform on-demand reconnaissance and strike missions anywhere in the world. It would be capable of overflying any location in the world in < 2 hours and returning to CONUS in < 3 hours from time of take-off. It has airplane-like ground operations and could be maintained within the current aircraft infrastructure. A Mach 18+ boost-glide-skip flight path would enable a global-range capability (Mach 18+ for unrefueled global range capability is much less difficult and costly than the Mach 26 needed to achieve orbit). The plane would provide very rapid reconnaissance when finer detail of a specific area is required to finalize preparations for or initiate action against a specific objective. In the TAV phase of flight, the TAV could deploy weapons that could strike a critical target very precisely. This would give the US an ability to swiftly attack terrorists in their homeland and destroy critical facilities associated with WMD (Weapons of Mass Destruction - manufacturing in particular) with impunity. TAV is the first stage of a two-stage space-launch vehicle. The second stage used to deploy the satellite into operational orbit could be reusable, or it could be a propulsion module, which is different from an upper stage or an orbital transfer vehicle in that the GNC function is performed by the satellite. Propellant tanks and engines are the principal components of a propulsion module.

Major System Assumptions

Assumes a 3 vehicle fleet and flight rate from SRD. Steady flight rate is for peacetime. Surge flightrate is for war conditions. More details in military spaceplane ICT. Initial target location (approximately) from other sources. All-weather day/night sensors for detection and attack may be needed. Self-ferrying or direct return to the launch site(s) needed. * Revision: Based on Operational Spaceplane concept, not initial demo concept.

Comments

Minor modifications and filled in blank responses based on operational military space plane charactersitics as outlined in draft Military Spaceplane SRD. (1997) Revised by E. Ruth 18 APR 97.

Sector Military (US only)

Orbit LEO

Inclination Wide range of inclinations

Payload to LEO 5 Klb to 10 Klb

Turn time (for launcher) Hours

Primary payload\cargo Weapon or sensors

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Factor of 3 reduction

Return payload mass 1000 - 10,000 lb

Standing-alert capability Days

Launch reliability required 100X better than present

Est. flights for one-time surge About 100 total (range 61 to 150)

Estimated average flight rate About 100 per year (61 to 150)

Application # 4

Military Spaceplane

Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	High: National security or severe launch-window constraints
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Transportable, austere launch facilities (e.g., Space Plane)
Return cross-range requirement	Greater than 400 nmi including once-around capability
Safe abort requirement	Same requirements as today (e.g., STS)
Government indemnification requirements for launch services	Greater than today

Time required to swap reintegrate substitute payload	Hours
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	4X baseline flight rate
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Days
Launch range operations for application	Special operations--less extensive than today
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Quick reaction, 24 hours or less call-up
Rendezvous requirement	Yes - uncooperative (passive) target
Rapid cool-down requirements for return payload	Must be considered
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	Yes
On-orbit refueling required	Yes	***On-orbit payload change out required***	No
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	Yes	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	Yes	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	Yes	***Payload fuel handling prior to launch***	No
Crew Requirement	Yes	***Payload fuel handling and safing after landing***	Yes

Application # 5
Space Control

Category Military

Source New World Vistas, Space Applications Volume

Date 4/18/97 1:58:31 PM

Reviewers Gross, Allen/Kim, David/Ruth, Edward

Description

The totality of US spacecraft in orbit 20-30 years from now, military and commercial, together with their ground-based control nodes and launch sites will form a high value element of the national military capability. During the time period of interest, there will also be constellations of spacecraft operated by other nations and international consortia. Adding to the complexity of the situation expected to exist 20-30 years from now, is the likely presence of several, if not many, larger, manned space stations and space power stations. It may be in the national interest of the US to develop and deploy capabilities to disrupt, degrade or even destroy the space assets of adversaries with great precision and discrimination while also having the capability to protect U. S. national security and commercial assets by passive and active means.

Major System Assumptions

Stealth, plausible deniability, hostile and commercial, temporary disruption, ground based and space based. KEW and Directed Energy Weapons (DEW) may be used. Self defense may also be an issue. Deployment will take about 10 years. Multiple attacks may be made as a single flight. DEW may be preferred to reduce debris. For revision: Deployable weapons considered for space control, not including spaceplane like system.

Comments

Previous input was based on military spaceplane like system Based on review of NWV, this is viewed as a space platform with stealth, dormant and clandestine characteristics. Input revised per new concept. Revised by E. Ruth 18 APR 97. Assumption is that this is one system that is deployed over a period of years by a steady launch rate.

Sector	Military (US only)	***Primary payload\cargo***	Weapon or sensors
Orbit	Multiple orbit cases	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Wide range of inclinations	***Enabling launch price***	Factor of 3 reduction
Payload to LEO	5 Klb to 10 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 3 per year (range 2 to 6)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate

Application # 5
Space Control

Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Transportable, austere launch facilities (e.g., Space Plane)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	4X baseline flight rate
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - uncooperative (passive) target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	Yes	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 6

Space Mine

Category Military

Source New World Vistas, Space Applications Volume

Date 4/18/97 1:59:10 PM

Reviewers Gross, Allen/Kim, David/Ruth, Edward

Description

The interest in mines is that they are a form of attack that could operate with cueing sensors comparable to those for direct ascent kinetic energy interceptors. Moreover, they are the type of small, simple payload that a country might just be able to put into space when they first gain an independent space launch capability. If they wished to quickly gain a role as a significant player in space, mines would be a logical vehicle for staking that claim. Force application against other spacecraft can take other forms than beam power projection or physical attack. A number of techniques applicable from rendezvous space weapons have been known for many years though not yet implemented. Following rendezvous and station keeping with the spacecraft in question, paint can be sprayed onto optics, solar arrays, or radiators to disable the spacecraft covertly, assuming that our approach has not been detected. Likewise the spacecraft can be nudged or tipped gently in order to exhaust control fuel. Electronic interference is extremely easy from a few feet away, and takes negligible power. Homing interceptors may not be needed, nor special warheads, if a capability is developed for a space weapon spacecraft capable of on-orbit control, with some form of proximity sensor and the specialized devices to cause the disruptive effects to other spacecraft.

Major System Assumptions

Miniature sensor system, launch capability, built-in-smarts for autonomous operations, minimum ground command and control, etc., more information from Inki Min (study lead, 1996). Numerous concepts are possible. Debris is an issue, expecially for LEO and GEO orbits. Stealth may be important if enemy satellites can maneuver while on routes. Space mine could be planted on orbit in anticipation of possible need. Nuclear weapons in space is assumed as not a possible option.

Comments

Multi Orbit cases include all potential target satellites, including LEO, LEO-Polar, Geo, and Heo. Launch rate would roughly be divided in: 1 LEO, 4 Polar, 3 GEO, and 2 HEO Modifications based on Space Mine concept for temporary disruption to permanent destruction in a clandestine way. Revised by E. Ruth 18 APR 97. This system differs form Space Control in that it would only be deployed during a crisis.

Sector	Military (US only)	***Primary payload\cargo***	Weapon or sensors
Orbit	Multiple orbit cases	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Wide range of inclinations	***Enabling launch price***	Factor of 3 reduction
Payload to LEO	Less than 5,000 lb	***Return payload mass***	N/A
Turn time (for launcher)	Days	***Standing-alert capability***	Days

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Launch reliability required Present reliability

Application # 6

Space Mine

Est. flights for one-time surge	About 30 total (range 10 to 60)
Estimated average flight rate	Not applicable (surge or one-shot mission)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Inelastic--lowering price below enabling threshold will not increase flight rate
Schedule importance	High: National security or severe launch-window constraints
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Transportable, austere launch facilities (e.g., Space Plane)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Days
Injection accuracy requirement (launch system)	Greater accuracy required
Surge requirements (for individual launch vehicle)	4X baseline flight rate
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Special operations--less extensive than today
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Quick reaction, 24 hours or less call-up
Rendezvous requirement	Yes - uncooperative (passive) target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	Yes	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	Yes	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 7

Space Surveillance

Category	Military
Source	New World Vistas, Space Applications Volume
Date	4/18/97 1:59:46 PM
Reviewers	Lopez, Jesse/Kim, David/Ruth, Edward

Description

It appears that in the mid term, two space technologies will be both needed and ready: optical and LWIR focal planes for sensors in space. The former is for very distant, sun-lit objects at GEO, the latter is for the bulk of nearby but cooler objects and for the discrimination of transient satellites. Satellites, computers, and focal planes have now progressed to the point where it should be possible to keep track of much of the catalogue from space without the need for ground-based telescopes. From space, satellites can measure objects that are several visible magnitudes smaller than they can from the ground, which also makes it possible to extend the survey to fainter objects and search for stealthy intruders. There is no corresponding advantage in space-basing for radars. In the long term, the space surveillance system will have to search for objects that are more numerous, maneuvering, stealthy, and potentially hostile. For satellite-based sensors, the greater number of objects is a direct but probably manageable problem. Maneuver cuts two ways: if it is seen, it is a cue, if it is not, it is the occasion for a rapid, wide-area search. Stealth impacts the search rate per satellite, and hence the number of satellites that will be needed. Hostility impacts hardening, maneuver, decoys, and other survivability measures and would appear to force the satellites for space surveillance towards those for missile warning. To the extent that this happens, the two constellations could merge into a single constellation of sensors with a large number of small satellites that could look in all directions and maneuver enough to survive to do so and perform essential assessments.

Major System Assumptions

No identification, cataloging, and characterization, no survivability features (midterm), no C4I. Revision assumed follow on SMTS-like system with IR, visible and RF sensors on a space based platform.

Comments

Revised by E. Ruth 18 APR 97.

Sector	Military (US only)	***Primary payload\cargo***	Deployable satellite/upper stage
Orbit	LEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Inclined (40 to 60 deg)	***Enabling launch price***	Present prices
Payload to LEO	Less than 5,000 lb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 3 per year (range 2 to 6)

Application # 7

Space Surveillance

Confidence in flight rates	High confidence (+- 20%)
Launch price elasticity	N/A
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	*Final-orbit injection required*	Yes
Return-to-launch site requirements	No	*Overflight over populated areas an issue*	No
On-orbit refueling required	No	*On-orbit payload change out required*	No
On-orbit cargo transfer required	No	*On-orbit crew transfer required (space suits)*	No
Launch during conflict conditions	No	*On-orbit crew transfer required (shirt sleeves)*	No
Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	Yes
Alternate landing site(s) required	N/A	*Return-to-launch-site capability after abort*	N/A
Multi-azimuth launch	No	*Payload fuel handling prior to launch*	No
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 8

Space Traffic Control

Category Military

Source New World Vistas, Space Applications Volume

Date 4/18/97 2:09:15 PM

Reviewers Lopez, Jesse/Kim, David/Ruth, Edward

Description

Current traffic to space amounts to somewhat less than one million pounds annually, represented by some 50 spacecraft launches worldwide. The future will be very different, due to the onset of small, proliferated, mainly low altitude satellites. Foremost among these will be commercial communications systems such as Iridium (66 spacecraft) and Teledesic (850 spacecraft), but will also increasingly include military systems such as Brilliant Eyes (~ 30 spacecraft). These will be replaced periodically with more advanced systems, and the old commercial constellations likely be sold to second tier users. Thus, in contrast to today, in 20-30 years there will likely be hundreds to thousands of small- to-medium-sized satellites in orbit. In addition, very large and probably manned systems will exist, such as an International Space Station and one or more Industrial Space Parks. As space operations mature and servicing/upgrading of reusable space systems becomes routine, there will be a need to control approach and departure corridors, at least around the large space facilities and in the more heavily populated orbits, in a way akin to air traffic control today. In essence, a space traffic control system will be needed, controlling traffic in and around high value spacecraft such as the Space Station, and in populated LEO and GEO orbits. A number of security issues will have to be faced if an effective space traffic control is to be adopted.

Major System Assumptions

International space policy issue. It is assumed that an active space surveillance system is needed and may be an outgrowth of the current Spacetrack system and possibly the use of multi-functional space-based surveillance systems. Space traffic control is an international policy issue and will require cooperation of all nations, military, and commercial users. Impact on spacelift requirements should be minimal. Requirements on space based surveillance systems may force design alterations or secondary payloads to be incorporated. Major impact will be on ground based satellite operations. It is not anticipated at this time that a dedicated space clean-up or debris retrieval space vehicle system is required. On those assumptions, there is no direct impact here.

Comments

Revised by E. Ruth 18 APR 97.

Sector Civil (Foreign or joint programs)

Orbit LEO

Inclination Wide range of inclinations

Payload to LEO Less than 5,000 lb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Factor of 3 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Application # 8

Space Traffic Control

Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 3 per year (range 2 to 6)
Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	Inelastic--lowering price below enabling threshold will not increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 9

Missile Warning

Category Military

Source New World Vistas, Space Applications Volume

Date 4/25/97 7:26:40 AM

Reviewers Ho, Ching/Kim, David/Ruth, Edward

Description

The midterm developments are likely to be: more bands, multiple satellites at lower altitudes, large staring arrays, and active ranging sensors. Using multiple satellites at lower altitudes permits them to use the largest effective arrays with detector size to be designed for the targets of interest. Active rangers restore range and hence accurate trajectories without stereo viewing. Space-based radar for all-weather search, detection, and track would then be a natural adjunct to both the other space sensors and the limited AWACs assets. With that suite of sensors it should be possible to perform much of the threat assessment, put trajectories into GPS coordinates, and possibly to direct some intercepts from space. Note that ballistic and cruise missile threats to both Allies and CONUS should emerge in force in about this time frame, so that these should be just the proper suite of sensors and weapons to address them. The long term can be defined simply as a period beyond 30 years, as a time when technology will permit anything we can envision doing today, or as a time when we will have serious and competent adversaries for the control of space. Each definition leads to the conclusion that space is likely to become a place of greater and more lethal competition. In such a competition, non-stationary placement is likely to be an advantage; smaller and more numerous warning satellites are likely to have a distinct advantage. Hardening and decoys will be essential, self-defense capability may also be needed.

Major System Assumptions

No missile identification and characterization, no survivability issues (mid-term) No C4I. Revision based on SBIR follow-on type system, with a large GEO satellite system, similar to Space Based Radar type system.

Comments

Space Based Radar type application with nuclear power source to meet high power demand. Revised by E. Ruth 18 APR 97.

Sector Military (US only)

Orbit GEO/GSO/HEO

Inclination Equatorial or near equatorial

Payload to LEO 10 Klb to 20 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Present prices

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate One or less per year

Application # 9

Missile Warning

Confidence in flight rates	High confidence (+- 20%)
Launch price elasticity	Inelastic--lowering price below enabling threshold will not increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	Yes	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 10

Bi-Static Radar

Category Military

Source New World Vistas, p. 26, Attack volume

Date 4/18/97 2:19:19 PM

Reviewers Duclos, Don/Ruth, Edward

Description

A bistatic radar system would have an illuminator in sanctuary, either in orbit or on a long range aircraft. Receivers would be in multiple platforms over enemy territory, thus enabling passive sensing by these platforms for many functions, including reconnaissance, surveillance, targeting, and weapons launch. In cases where the strategy of potential enemies depends on exploiting radar transmissions, such an aircraft would provide revolutionary capabilities.

Major System Assumptions

POC: W. Shepherd/C. Reid, Aerospace

Comments

Revised by E. Ruth 18 APR 97.

Sector Military (US only)

Orbit GEO/GSO/HEO

Inclination Equatorial or near equatorial

Payload to LEO 10 Klb to 20 Klb

Turn time (for launcher) N/A

Primary payload\cargo Weapon or sensors

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Factor of 3 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge About 10 total (range 7 to 15)

Estimated average flight rate About 3 per year (range 2 to 6)

Confidence in flight rates Medium confidence (+- 50%)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement N/A

Government indemnification requirements for launch services Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload Not a driver--don't care

Application # 10

Bi-Static Radar

Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	*Final-orbit injection required*	Yes
Return-to-launch site requirements	No	*Overflight over populated areas an issue*	No
On-orbit refueling required	No	*On-orbit payload change out required*	No
On-orbit cargo transfer required	No	*On-orbit crew transfer required (space suits)*	No
Launch during conflict conditions	No	*On-orbit crew transfer required (shirt sleeves)*	No
Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	No
Alternate landing site(s) required	N/A	*Return-to-launch-site capability after abort*	N/A
Multi-azimuth launch	No	*Payload fuel handling prior to launch*	Yes
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 11
Orbit Debris Removal

Category Military

Source New World Vistas, DEW, p. xii, p. 20

Date 4/18/97 2:30:53 PM

Reviewers Marshall, Matthew/Ruth, Edward

Description

Use high power laser to burn up orbiting debris that may cause catastrophic damage to friendly satellites. With debris in the size range from one to ten centimeters - larger than 1 cm is very difficult to shield against, and debris smaller than 10 cm is too numerous and too difficult to track with radar to employ an avoidance strategy. The idea of a laser sweep is based on the impulse that a pulsed laser can deliver to a target. If clearing space debris becomes a necessity, high powered pulse ground based lasers may be required. These can only be effective with an accurate pointing system which may require use of LIDAR technology. Though debris at GEO altitudes is less of a problem, it may grow to significance, particularly if very large communications spacecraft are fielded there. Ground-based lasers are not a way to clearing such debris, though a space-based laser may be. However, for both low and high altitudes, passive sweeping using maneuverable spacecraft dragging large balls of Styrofoam or aerogel on a tether may also prove effective. Ultimately, these may have to be augmented by active spacecraft to capture and change the orbits of larger debris and the increasing number of dead satellites.

Major System Assumptions

A multi-pronged strategy for eliminating existing orbital debris would consist of the following areas: (1) Ground based lasers to clear LEO debris in the size range of 1 - 10 cm. (2)"Sweepers" to clear debris in orbits frequented by high value spacecraft. Passive sweepers would either consist of foam filled spheres to capture particles, or plates to modify the delta-V of orbital debris, thereby accelerating the rate of decay. (3) Active spacecraft to clear-out large orbital debris such as spent rocket stages or failed spacecraft. This review addresses only the removal of large orbiting debris using active spacecraft. The focus is on larger objects because a significant amount of debris originates in the breakup of larger particles. Assumptions: Each Debris Removal spacecraft will be placed into a particular inclination and orbit of interest (orbits with multiple debris sources will be preferred). The debris removal spacecraft will rendezvous with debris and will impart sufficient delta-V to deorbit the debris (or place into a safe orbit) either utilizing its on-board propulsion or by emplacing a de-orbit package on the large debris. Due to the delta-V penalty, plane changes will be minimized. However, the Debris removal spacecraft will be designed to be refurbished or refueled, so plane changes to and from some sort of servicing center may be necessary. Question 9: A factor of 10 reduction in launch costs was assumed as an enabler for orbital debris removal spacecraft. Although the removal of orbital debris is important, it is considered a lower priority mission. With a reduction in launch costs, the likelihood of getting an orbital debris removal program funded will be substantially improved.

Comments

Revised by E. Ruth 18 APR 97.

Sector Civil (Foreign or joint programs) ***Primary payload\cargo*** Deployable satellite/upper stage

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Orbit Debris Removal

Orbit	LEO	***Likely deployment period***	Far-term: post 2020
Inclination	Wide range of inclinations	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	10 Klb to 20 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 3 per year (range 2 to 6)
Confidence in flight rates	High confidence (+- 20%)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	None: No launch schedule criticality, launch as available
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - uncooperative (passive) target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No

Application # 11

Orbit Debris Removal

Launch during conflict conditions	N/A	*On-orbit crew transfer required (shirt sleeves)*	No
Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	No
Alternate landing site(s) required	N/A	*Return-to-launch-site capability after abort*	N/A
Multi-azimuth launch	Yes	*Payload fuel handling prior to launch*	Yes
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 12.1

Planetary Defense -- Sky Survey

Category Civil

Source New World Vistas, Space Applications Volume

Date 4/21/97 6:43:47 AM

Reviewers Ruth, Edward

Description

Another potential mission for space surveillance is planet defense, that is cataloging those comets and asteroids that have earth crossing orbits and at some time in the future pose a threat of striking the earth. This poses a stringent requirement in terms of sensing in that some of these objects are distant from the earth during a large part of their orbit. Also because the nature of these bodies is not well understood it is desirable to perform a fly by or impact to determine the composition and to better evaluate the options for deflecting or destroying the object to avoid collision with the earth.

Major System Assumptions

The threat can be broken into two parts: Near Earth Objects (NEOs) and Long Period Comets (LPCs). The main distinction between NEOs and LPCs is that the orbits of the NEOs are close enough to the Earth that they can be detected and tracked over extended periods with existing technology. The LPCs are visitors from the extreme outer solar system who may be on their first visit or their first visit in millennia. Our response to the threat can also be broken into two parts: detection and mitigation (either passive mitigation by evacuation of the impact area or active mitigation by the deflection or destruction of the threatening object).

A sky survey of NEOs and an early warning system for LPCs can mostly be accomplished with ground based telescopes. However, objects whose orbits keep them close to the Sun when viewed from the Earth can best be detected from space based instruments placed closer to the Sun. This latter task will require placing modest sized automated spacecraft into orbits much less than 1 AU at perihelion. No special launch requirements are perceived for these spacecraft and existing launch systems will suffice.

I am assuming that in the 2000 to 2025 time frame we will mainly be collecting information on the potential threat. This collection will include robot flybys and landings on near Earth asteroids and short period comets. A system of space based telescopes may be deployed in a solar orbit much less than one AU to provide coverage of objects that are difficult to observe
from the Earth because of their position relative to the Sun. All of these tasks can be accomplished with existing launch systems.

These survey answers are based on the assumption that the planetary defense requirements for the next 20 -30 years are mainly to gather a greater understanding of the nature of the threat. It would be premature to begin a design of a space based defense system without first obtaining more information on the nature of these bodies. It has been shown that an
active defense, without complete information, can actually increase the threat to Earth. Therefore, planetary defense has only modest launch requirements in the near term. These requirements (provided we are not threatened in that time) can be met with existing launch systems. Design of active mitigation systems requires in situ measurements of the
composition of these bodies (in particular determination if they are solid bodies or merely aggregates of loose material). My belief is that this will eventually require human visitation. However, in the time

period being considered for this survey, robotic explorers will be leading the way. Again existing launch systems will be sufficient.

If a threatening body is detected during the time frame of this survey, a contingency response and active defense may be required. Warning times could range from a few months to a few decades (with the latter being the most probable). Existing launch systems could well prove to be inadequate to this task, especially if the threatening body is a very large LPC with
a very short advanced warning. If the political will is such that we are to prepare for this eventuality then very high energy space transportation systems will be required: far beyond any existing today or planned for the near future.

The near term strategy used as a model for this survey has three parts:

Sky Survey -- catalog of all Near Earth Objects. Mostly accomplished with Earth-based instruments. Modest requirements for some space-based instruments. Possibly radars and optical telescopes.

Sky Guard -- Constant surveillance for new threats from deep space. Requires space based telescopes deployed in a solar orbit much less than one AU to provide coverage of objects that are difficult to observe from the Earth because of their position relative to the Sun.

System Development -- Testing of possible mitigation techniques. Proceeds in parallel with basic science missions to asteroids and comets in gathering increased understanding of these bodies.

This section covers the sky survey.

Comments

Sector Civil (Foreign or joint programs)

Orbit LEO

Inclination Inclined (20 to 40 deg)

Payload to LEO 10 Klb to 20 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price N/A--depends on national need

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge About 3 total (range 2 to 6)

Estimated average flight rate Not applicable (surge or one-shot mission)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity N/A

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

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Planetary Defense -- Sky Survey

Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap . reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 12.2

Planetary Defense -- Sky Guard

Category Civil

Source New World Vistas, Space Applications Volume

Date 4/21/97 6:44:42 AM

Reviewers Ruth, Edward

Description

Another potential mission for space surveillance is planet defense, that is cataloging those comets and asteroids that have earth crossing orbits and at some time in the future pose a threat of striking the earth. This requirement poses a stringent requirement in terms of sensing in that some of these objects are far distant from the earth during a large part of their orbit. Also because the nature of these bodies is not well understood it is desirable to perform a fly by or impact to determine the composition and to better evaluate the options for deflecting or destroying the object to avoid collision with the earth.

Major System Assumptions

The threat can be broken into two parts: Near Earth Objects (NEOs) and Long Period Comets (LPCs). The main distinction between NEOs and LPCs is that the orbits of the NEOs are close enough to the Earth that they can be detected and tracked over extended periods with existing technology. The LPCs are visitors from the extreme outer solar system who may be on their first visit or their first visit in millennia. Our response to the threat can also be broken into two parts: detection and mitigation (either passive mitigation by evacuation of the impact area or active mitigation by the deflection or destruction of the threatening object).

A sky survey of NEOs and an early warning system for LPCs can mostly be accomplished with ground based telescopes. However, objects whose orbits keep them close to the Sun when viewed from the Earth can best be detected from space based instruments placed closer to the Sun. This latter task will require placing modest sized automated spacecraft into orbits much less than 1 AU at perihelion. No special launch requirements are perceived for these spacecraft and existing launch systems will suffice.

I am assuming that in the 2000 to 2025 time frame we will mainly be collecting information on the potential threat. This collection will include robot flybys and landings on near Earth asteroids and short period comets. A system of space based telescopes may be deployed in a solar orbit much less than one AU to provide coverage of objects that are difficult to observe
from the Earth because of their position relative to the Sun. All of these tasks can be accomplished with existing launch systems.

These survey answers are based on the assumption that the planetary defense requirements for the next 20 -30 years are mainly to gather a greater understanding of the nature of the threat. It would be premature to begin a design of a space based defense system without first obtaining more information on the nature of these bodies. It has been shown that an
active defense, without complete information, can actually increase the threat to Earth. Therefore, planetary defense has only modest launch requirements in the near term. These requirements (provided we are not threatened in that time) can be met with existing launch systems. Design of active mitigation systems requires in situ measurements of the
composition of these bodies (in particular determination if they are solid bodies or merely aggregates of loose material). My belief is that this will eventually require human visitation. However, in the time

Application # 12.2

Planetary Defense -- Sky Guard

period being considered for this survey, robotic explorers will be leading the way. Again existing launch systems will be sufficient.

If a threatening body is detected during the time frame of this survey, a contingency response and active defense may be required. Warning times could range from a few months to a few decades (with the latter being the most probable). Existing launch systems could well prove to be inadequate to this task, especially if the threatening body is a very large LPC with a very short advanced warning. If the political will is such that we are to prepare for this eventuality then very high energy space transportation systems will be required: far beyond any existing today or planned for the near future.

The near term strategy used as a model for this survey has three parts:

Sky Survey -- catalog of all Near Earth Objects. Mostly accomplished with Earth-based instruments. Modest requirements for some space-based instruments. Possibly radars and optical telescopes.

Sky Guard -- Constant surveillance for new threats from deep space. Requires space based telescopes deployed in a solar orbit much less than one AU to provide coverage of objects that are difficult to observe from the Earth because of their position relative to the Sun.

System Development -- Testing of possible mitigation techniques. Proceeds in parallel with basic science missions to asteroids and comets in gathering increased understanding of these bodies.

This section covers the sky guard.

Comments

Sector	Civil (Foreign or joint programs)	***Primary payload\cargo***	Deployable satellite/upper stage
Orbit	IP (interplanetary)	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Equatorial or near equatorial	***Enabling launch price***	N/A--depends on national need
Payload to LEO	20 Klb to 40 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	About 3 total (range 2 to 6)
Estimated average flight rate	Not applicable (surge or one-shot mission)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	N/A
Schedule importance	High: National security or severe launch-window constraints
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A

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Planetary Defense -- Sky Guard

Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	Months
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 12.3
Planetary Defense -- System Development

Category Civil
Source New World Vistas, Space Applications Volume
Date 4/21/97 6:46:04 AM

Reviewers Ruth, Edward

Description
Another potential mission for space surveillance is planet defense, that is cataloging those comets and asteroids that have earth crossing orbits and at some time in the future pose a threat of striking the earth. This requirement poses a stringent requirement in terms of sensing in that some of these objects are far distant from the earth during a large part of their orbit. Also because the nature of these bodies is not well understood it is desirable to perform a fly by or impact to determine the composition and to better evaluate the options for deflecting or destroying the object to avoid collision with the earth.

Major System Assumptions
The threat can be broken into two parts: Near Earth Objects (NEOs) and Long Period Comets (LPCs). The main distinction between NEOs and LPCs is that the orbits of the NEOs are close enough to the Earth that they can be detected and tracked over extended periods with existing technology. The LPCs are visitors from the extreme outer solar system who may be on their first visit or their first visit in millennia. Our response to the threat can also be broken into two parts: detection and mitigation (either passive mitigation by evacuation of the impact area or active mitigation by the deflection or destruction of the threatening object).

A sky survey of NEOs and an early warning system for LPCs can mostly be accomplished with ground based telescopes. However, objects whose orbits keep them close to the Sun when viewed from the Earth can best be detected from space based instruments placed closer to the Sun. This latter task will require placing modest sized automated spacecraft into orbits much less than 1 AU at perihelion. No special launch requirements are perceived for these spacecraft and existing launch systems will suffice.

I am assuming that in the 2000 to 2025 time frame we will mainly be collecting information on the potential threat. This collection will include robot flybys and landings on near Earth asteroids and short period comets. A system of space based telescopes may be deployed in a solar orbit much less than one AU to provide coverage of objects that are difficult to observe from the Earth because of their position relative to the Sun. All of these tasks can be accomplished with existing launch systems.

These survey answers are based on the assumption that the planetary defense requirements for the next 20 -30 years are mainly to gather a greater understanding of the nature of the threat. It would be premature to begin a design of a space based defense system without first obtaining more information on the nature of these bodies. It has been shown that an active defense, without complete information, can actually increase the threat to Earth. Therefore, planetary defense has only modest launch requirements in the near term. These requirements (provided we are not threatened in that time) can be met with existing launch systems. Design of active mitigation systems requires in situ measurements of the composition of these bodies (in particular determination if they are solid bodies or merely aggregates of loose material). My belief is that this will eventually require human visitation. However, in the time period being considered for this survey, robotic explorers will be leading the way. Again existing launch systems will be sufficient.

If a threatening body is detected during the time frame of this survey, a contingency response and active defense may be required. Warning times could range from a few months to a few decades (with the latter being the most probable). Existing launch systems could well prove to be inadequate to this task, especially if the threatening body is a very large LPC with
a very short advanced warning. If the political will is such that we are to prepare for this eventuality then very high energy space transportation systems will be required: far beyond any existing today or planned for the near future.

The near term strategy used as a model for this survey has three parts:

Sky Survey -- catalog of all Near Earth Objects. Mostly accomplished with Earth-based instruments. Modest requirements for some space-based instruments. Possibly radars and optical telescopes.

Sky Guard -- Constant surveillance for new threats from deep space. Requires space based telescopes deployed in a solar orbit much less than one AU to provide coverage of objects that are difficult to observe from the Earth because of their position relative to the Sun.

System Development -- Testing of possible mitigation techniques. Proceeds in parallel with basic science missions to asteroids and comets in gathering increased understanding of these bodies.

This section covers mitigation system development.

Comments
Comments on Questions: 11, 35, 36, 42, & 43) Nuclear explosives may be required for mitigation system testing. Launch of nuclear explosives may stress launch system reliabilty and abort capabilities because of safety concerns.

Sector	Civil (Foreign or joint programs)	***Primary payload\cargo***	Deployable satellite/upper stage
Orbit	IP (interplanetary)	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Equatorial or near equatorial	***Enabling launch price***	N/A--depends on national need
Payload to LEO	20 Klb to 40 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	100X better than present
Est. flights for one-time surge	About 10 total (range 7 to 15)
Estimated average flight rate	Not applicable (surge or one-shot mission)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	N/A
Schedule importance	High: National security or severe launch-window constraints
Launch insurance considerations	Government launch (self insured)

Application # 12.3

Planetary Defense -- System Development

Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	More stringent requirements
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing/bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Hours
Launch range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	Months
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - uncooperative (passive) target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	Yes	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	Yes
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 13

Global Area Strike System (GASS)

Category Military

Source (Spacecast 2020, Exec. Summary).

Date 4/25/97 7:25:33 AM

Reviewers Gross, Allen/Kim, David/Ruth, Edward

Description

The Global Area Strike System (GLASS) consists of a high energy laser (HEL) system, a kinetic energy weapon (KEW) system, and a transatmospheric vehicle (TAV). The HEL system consists of ground-based lasers and space-based mirrors which direct energy to the intended target. The KEW system consists of terminally guided projectiles with and without explosive enhancers. The TAV is a flexible platform capable of supporting maintenance and replenishment of the HEL and KEW space assets, and could also be used for rapid deployment of special operations forces.

Major System Assumptions

The mission overlaps with the space mine (ID#6). Launch and in-flight safety are major issues with weapons on board. Multiple payload bay configurations depending on weapon system carried. GASS encompases several different weapon alternatives. For this application, a generic weapon platform is assumed for ground and missile strike (ascent, midcourse and final re-entry), rather than space objects. (D. Kim)

Comments

Revised by E. Ruth 18 APR 97. To be moved to Spaceplane Mission #4.1.

Sector Military (US only)

Orbit LEO

Inclination Wide range of inclinations

Payload to LEO 5 Klb to 10 Klb

Turn time (for launcher) Hours

Primary payload\cargo Weapon or sensors

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Factor of 3 reduction

Return payload mass 1000 - 10,000 lb

Standing-alert capability Minutes

Launch reliability required 3X better than present

Est. flights for one-time surge About 30 total (range 10 to 60)

Estimated average flight rate Not applicable (surge or one-shot mission)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Inelastic--lowering price below enabling threshold will not increase flight rate

Schedule importance High: National security or severe launch-window constraints

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Transportable, austere launch facilities (e.g., Space Plane)

Return cross-range requirement Greater than 400 nmi including once-around capability

Safe abort requirement Same requirements as today (e.g., STS)

Application # 13

Global Area Strike System (GASS)

Government indemnification requirements for launch services	Same as today (range-related and liability caps)
Time required to swap reintegrate substitute payload	Hours
Injection accuracy requirement (launch system)	Greater accuracy required
Surge requirements (for individual launch vehicle)	4X baseline flight rate
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Days
Launch range operations for application	Special operations--less extensive than today
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Quick reaction, 24 hours or less call-up
Rendezvous requirement	No
Rapid cool-down requirements for return payload	Must be considered
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	Yes
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	Yes	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	Yes	***Payload fuel handling prior to launch***	No
Crew Requirement	Yes	***Payload fuel handling and safing after landing***	No

Application # 14

Force (PGM) Delivery from Space

Category Military

Source New World Vistas,

Date 4/25/97 7:25:07 AM

Reviewers Lopez, Jesse/Kim, David/Ruth, Edward

Description

New technologies will allow delivery of very large amounts of precisely aimed and focused electromagnetic energy at microwave and millimeter wavelengths from electromagnetic weapons, as well as optical energy from lasers with much lower cost and greater number of shots than past designs. In addition, they will actually allow small but very effective amounts of mass to be delivered against surface and airborne targets precisely enough as to have locally devastating effects.

Major System Assumptions

It is assumed major technology breakthroughs are achieved such that these space-based DEW systems compare favorably to other force delivery systems or to countermeasures which can be employed by the targets these DEW systems are to negate. It is also assumed that weapons in space do not violate worldwide treaties. If these assumptions are correct, then an HPM space based system may be operational around 2020 and a solid state space-based HEL around 2030. PGM: Precision Guided Missile.

Comments

Redundant with other Applications. E. Ruth 18 APR 97.

Sector Military (US only)

Orbit LEO

Inclination Wide range of inclinations

Payload to LEO Greater than 60 Klb

Turn time (for launcher) Weeks

Primary payload\cargo Weapon or sensors

Likely deployment period Far-term: post 2020

Enabling launch price Present prices

Return payload mass N/A

Standing-alert capability Days

Launch reliability required Present reliability

Est. flights for one-time surge About 10 total (range 7 to 15)

Estimated average flight rate About 3 per year (range 2 to 6)

Confidence in flight rates Medium confidence (+- 50%)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement N/A

Application # 14

Force (PGM) Delivery from Space

Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Special/outsized relative to lift mass in this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	Yes
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	No
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	Yes	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 15

Interceptors

Category Military

Source New World Vistas, DEW

Date 4/25/97 7:27:24 AM

Reviewers Lopez, Jesse /Ruth, Edward

Description

Developments pioneered by the SDIO/BMDO in space based precision guided, small, lightweight hit-to-kill interceptors with large divert radius can be adapted for interdiction of surface or airborne targets. With application of a small deboost rocket, and inclusion of large l/d rods made of depleted uranium, these munitions are able to deorbit autonomously or on command, and guided via GPS to a precision strike at hypersonic velocities essentially anywhere on earth. The extended rods of these munitions would be able to penetrate hundreds of feet into the earth to destroy hardened bunkers or other buried facilities. Used in the divert/homing mode, and fitted with multiple pellets, these weapons would be deadly against high value airborne targets as well, such as AWACS-type aircraft. These weapons could be used sparingly, but with devastating accuracy and effect, and little collateral damage or exposure of friendly forces. This ability to call down and accurately deliver mass from orbit on surface or airborne targets with complete surprise amounts to munitions with ultimate stealth, for which there is little effective passive defense. Cost effectiveness compared to delivery of similar capability via artillery from the air may show favorable ratios when the entire cost of placing and supporting more conventional capabilities is taken into account.

Major System Assumptions

It is assumed weapons in space do not violate worldwide treaties. Treaty restrictions on orbital inclination are assumed to be N/A. It is also assumed that cost-effectiveness trades are favorable to this space-based approach versus other means of global strike capabilities. It is further assumed that a LEO constellation of platforms will provide housekeeping for these munitions, that both space and terrestrial targets are of interest, and that weapon call-up and use can be achieved in <30 minutes.

Comments

Revised by E. Ruth 18 APR 97. Assumed that these payloads can go on either ELV or spaceplane.

Sector	Military (US only)	***Primary payload\cargo***	Deployable satellite/upper stage
Orbit	LEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Polar or near polar	***Enabling launch price***	Factor of 3 reduction
Payload to LEO	5 Klb to 10 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	3X better than present
Est. flights for one-time surge	About 30 total (range 10 to 60)
Estimated average flight rate	About 3 per year (range 2 to 6)
Confidence in flight rates	Medium confidence (+- 50%)

Application # 15

Interceptors

Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Special operations--less extensive than today
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 16

Delivery of Electromagnetic Radiation from Space - deployment mission

Category Military

Source New World Vistas, DEW Volume

Date 4/24/97 4:26:53 PM

Reviewers Marshall, Matthew/Kim, David

Description

This technology would enable very large diameter thin film antennas, or the formation of very large coherent essentially-filled arrays controlled by cheap, small super-processors. When combined with large sources of RF power, on or off-board, such spacecraft could project very narrow beams of extremely high power density long distances to space, airborne, or surface targets. Their availability and use would greatly overpower electronic equipment so as to either incapacitate them for extended periods or destroy their front ends. In addition, they could jam or spoof them, introduce network saturation, disruption, viruses, dis-information, or all of these effects. Consider an antenna of 100 meters (330 ft) diameter. It would have a gain of almost 80 dB at X band, and if a power source of 100 kilowatts were used, the effective radiated power (ERP) of the system would be about 130 dB . This is 10 million megawatts! If the system were deployed in GEO, its footprint on a battlefield would be 6 miles diameter. The power density over this area would be 10 w/sq. m, and the field strength about 1 volt/meter. These power densities and field strengths are about 13 orders or magnitude above the sensitivity of typical communications receivers, and about 6 orders of magnitude greater than that of typical radar receivers and optical or IR sensors. They are far above the damage threshold for these receivers. 1,000 meter antennas are entirely possible, which would have a footprint of about 1 mile from GEO. These systems could have a multiplicity of beams, all electronically steerable and independent. Their use in the field would constitute a "jam-on-demand" capability, if not a "burnout enemy sensors on demand" capability which could be used with surgical precision, in real time, and all the time. The small footprint and sidelobe control would allow them to be used with surgical precision, and with little collateral effect on friendly sensors or forces. Due to threat potential and proliferated constellation, such a system may favor GEO constellation. It goes without saying that such powerful weapons platforms would be able to destroy any incoming interceptor, and thus would be extremely difficult to disable.

Major System Assumptions

Assumption is for a GEO based constellation of approximately 5-6 total platforms to provide reasonable global coverage, with spares. The platforms each consist of a 100 m diameter antenna with a 100 kW transmitter for RF based weapons applications. Note: Although a steady state flight rate is assumed, this is only to build up the assumed constellation. Therefore, after the constellation is completed the flight rate will go to zero. 10-15 year on-orbit lifetime. The platforms should be designed to be servicable on orbit. All of the data in this application is for the initial deployment of the system.

Comments

GEO platform assumed.

Sector Military (US only)

Orbit GEO/GSO/HEO

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Application # 16

Delivery of Electromagnetic Radiation from Space - deployment mission

Inclination	Equatorial or near equatorial	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	Greater than 60 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	10X better than present
Est. flights for one-time surge	About 3 total (range 2 to 6)
Estimated average flight rate	Not applicable (surge or one-shot mission)
Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	N/A
Schedule importance	High: National security or severe launch-window constraints
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Special/outsized relative to lift mass in this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No

Application # 16

Delivery of Electromagnetic Radiation from Space - deployment mission

Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	No
Alternate landing site(s) required	N/A	*Return-to-launch-site capability after abort*	N/A
Multi-azimuth launch	No	*Payload fuel handling prior to launch*	Yes
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 16.1

Delivery of Electromagnetic Radiation from Space - servicing flight

Category Military

Source New World Vistas, DEW Volume

Date 4/24/97 4:27:35 PM

Reviewers Marshall, Matthew/Kim, David

Description

This technology would enable very large diameter thin film antennas, or the formation of very large coherent essentially-filled arrays controlled by cheap, small super-processors. When combined with large sources of RF power, on or off-board, such spacecraft could project very narrow beams of extremely high power density long distances to space, airborne, or surface targets. Their availability and use would greatly overpower electronic equipment so as to either incapacitate them for extended periods or destroy their front ends. In addition, they could jam or spoof them, introduce network saturation, disruption, viruses, dis-information, or all of these effects. Consider an antenna of 100 meters (330 ft) diameter. It would have a gain of almost 80 dB at X band, and if a power source of 100 kilowatts were used, the effective radiated power (ERP) of the system would be about 130 dB . This is 10 million megawatts! If the system were deployed in GEO, its footprint on a battlefield would be 6 miles diameter. The power density over this area would be 10 w/sq. m, and the field strength about 1 volt/meter. These power densities and field strengths are about 13 orders or magnitude above the sensitivity of typical communications receivers, and about 6 orders of magnitude greater than that of typical radar receivers and optical or IR sensors. They are far above the damage threshold for these receivers. 1,000 meter antennas are entirely possible, which would have a footprint of about 1 mile from GEO. These systems could have a multiplicity of beams, all electronically steerable and independent. Their use in the field would constitute a "jam-on-demand" capability, if not a "burnout enemy sensors on demand" capability which could be used with surgical precision, in real time, and all the time. The small footprint and sidelobe control would allow them to be used with surgical precision, and with little collateral effect on friendly sensors or forces. Due to threat potential and proliferated constellation, such a system may favor GEO constellation. It goes without saying that such powerful weapons platforms would be able to destroy any incoming interceptor, and thus would be extremely difficult to disable.

Major System Assumptions

Assumption is for a GEO based constellation of approximately 5-6 total platforms to provide reasonable global coverage, with spares. The platforms each consist of a 100 m diameter antenna with a 100 kW transmitter for RF based weapons applications. Note: Although a steady state flight rate is assumed, this is only to build up the assumed constellation. Therefore, after the constellation is completed the flight rate will go to zero. 10-15 year on-orbit lifetime. The platforms should be designed to be servicable on orbit. This application applies to the servicing flights that support the existing platforms. It is assumed that the sevicing flights are one-way refueling missions.

Comments

For periodic re-fueling/servicing mission, assuming needed technology is already available.

Sector	Military (US only)	***Primary payload\cargo***	Deployable satellite/upper stage
Orbit	GEO/GSO/HEO	***Likely deployment period***	Near-term: 2000 - 2020

Application # 16.1
Delivery of Electromagnetic Radiation from Space - servicing flight

Inclination	Equatorial or near equatorial	***Enabling launch price***	Factor of 3 reduction
Payload to LEO	40 Klb to 60 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	One or less per year
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	N/A
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap .reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	Yes	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	Yes	***On-orbit crew transfer required (shirt sleeves)***	No

Application # 16.1

Delivery of Electromagnetic Radiation from Space - servicing flight

Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	Yes
Alternate landing site(s) required	N/A	*Return-to-launch-site capability after abort*	N/A
Multi-azimuth launch	No	*Payload fuel handling prior to launch*	Yes
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 18
Solar-Powered High Energy Laser System. - deployment mission

Category Military

Source New World Vistas, Spacecast 2020, Exec. Summary

Date 4/24/97 4:28:07 PM

Reviewers Kellogg, Robert/Kim, David

Description

The solar-powered high energy laser system is a space-based, multimegawatt, high-energy solar-powered laser constellation that can operate in several modes. In its weapons mode with the laser at high power, it can attack ground, air, and space targets. In its surveillance mode, it can operate using the laser at low power levels for active illumination imaging, or with the laser inoperative for passive imaging. ****New Description (see comments)***** The Solar Energy Optical Weapon (SEOW) consists of a constellation of space-based mirrors which allow solar radiation to be focused on specific ground, air, or space targets. The lethality of this system is limited, due to optical diffusion, however, it may prove useful for disruption or perhaps weather control. From: Air Force 2025, Appendix B, Section 6.6

Major System Assumptions

Satellite consists primarily of very large (10-100m) mirror that can be steered to focus sunlight on a target. Assume inflatable technology permits launch on current MLV-Class Launch vehicles. Assume constellation of 20 satellites to provide fairly good coverage from inclined LEO orbits. ** This is for initial deployment of complete constellation. This concept has a very low probability of ever being implemented. This concept includes an option that purports to use mirrors in space to focus energy on ground targets. Such a system is not feasible, as the Sun is not a point source and thus cannot be focused into a beam tighter than the Sun's subtended angle at earth, about 0.5 degrees. It thus cannot even match the Sun's intensity on the ground unless the mirror is 180 n. mi. diameter in GEO.

Comments

The differences between items 17) Global Precision Optical Weapon, 18) Solar- Powered High Energy Laser System, and 19) Space-Based High Energy Laser System are small relative to the uncertainty in describing these systems. Item 19) sounds like what is currently called Space-Based Laser (SBL) which is a constellation of 8m aperture lasers in LEO orbit used primarily for boost phase intercept. Item 18) sounds like a solar powered version of the same thing. Item 17) sounds just like SBL except the cost per kill is reduced by technology advancements so it can be used against lower value targets. Only one (or less) of these systems would be flown at a time and the differences between the systems would not change any of my answers to the survey questions so I am going to leave 17) blank and put my answers under 19). I suggest changing the title of 18) to Solar Energy Optical Weapon which is a slightly different system using sunlight instead of laser light.

Sector Military (US only)

Orbit LEO

Inclination Inclined (40 to 60 deg)

Payload to LEO 40 Klb to 60 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Factor of 10 reduction

Return payload mass N/A

Standing-alert capability N/A

Application # 18

Solar-Powered High Energy Laser System. - deployment mission

Launch reliability required	10X better than present
Est. flights for one-time surge	About 30 total (range 10 to 60)
Estimated average flight rate	Not applicable (surge or one-shot mission)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	N/A
Schedule importance	High: National security or severe launch-window constraints
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	Yes	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	No
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes

Application # 18

Solar-Powered High Energy Laser System. - deployment mission

Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 18.1

Solar-Powered High Energy Laser System. - servicing flight

Category Military

Source New World Vistas, Spacecast 2020, Exec. Summary

Date 4/24/97 4:28:37 PM

Reviewers Kellogg, Robert/Kim, David

Description

The solar-powered high energy laser system is a space-based, multimegawatt, high-energy solar-powered laser constellation that can operate in several modes. In its weapons mode with the laser at high power, it can attack ground, air, and space targets. In its surveillance mode, it can operate using the laser at low power levels for active illumination imaging, or with the laser inoperative for passive imaging. ****New Description (see comments)***** The Solar Energy Optical Weapon (SEOW) consists of a constellation of space-based mirrors which allow solar radiation to be focused on specific ground, air, or space targets. The lethality of this system is limited, due to optical diffusion, however, it may prove useful for disruption or perhaps weather control. From: Air Force 2025, Appendix B, Section 6.6

Major System Assumptions

Satellite consists primarily of very large (10-100m) mirror that can be steered to focus sunlight on a target. Assume inflatable technology permits launch on current MLV-Class Launch vehicles. Assume constellation of 20 satellites to provide fairly good coverage from inclined LEO orbits. ** This is for servicing, resupply and refueling type mission after full constellation is placed in the orbit. This concept has a very low probability of ever being implemented. This concept includes an option that purports to use mirrors in space to focus energy on ground targets. Such a system is not feasible, as the Sun is not a point source and thus cannot be focused into a beam tighter than the Sun's subtended angle at earth, about 0.5 degrees. It thus cannot even match the Sun's intensity on the ground unless the mirror is 180 n. mi. diameter in GEO.

Comments

The differences between items 17) Global Precision Optical Weapon, 18) Solar- Powered High Energy Laser System, and 19) Space-Based High Energy Laser System are small relative to the uncertainty in describing these systems. Item 19) sounds like what is currently called Space-Based Laser (SBL) which is a constellation of 8m aperture lasers in LEO orbit used primarily for boost phase intercept. Item 18) sounds like a solar powered version of the same thing. Item 17) sounds just like SBL except the cost per kill is reduced by technology advancements so it can be used against lower value targets. Only one (or less) of these systems would be flown at a time and the differences between the systems would not change any of my answers to the survey questions so I am going to leave 17) blank and put my answers under 19). I suggest changing the title of 18) to Solar Energy Optical Weapon which is a slightly different system using sunlight instead of laser light.

Sector Military (US only)

Orbit LEO

Inclination Inclined (40 to 60 deg)

Payload to LEO 10 Klb to 20 Klb

Primary payload/cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Factor of 3 reduction

Return payload mass N/A

Application # 18.1

Solar-Powered High Energy Laser System. - servicing flight

Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 3 per year (range 2 to 6)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	N/A
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Days
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	Yes	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	Yes	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A

Application # 18.1

Solar-Powered High Energy Laser System. - servicing flight

Multi-azimuth launch	No	*Payload fuel handling prior to launch*	Yes
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 19

Space-Based High Energy Laser System - deployment mission

Category Military

Source New World Vistas, Spacecast 2020, Exec. Summary

Date 4/24/97 4:29:00 PM

Reviewers Kellogg, Robert

Description

The space-based high energy laser (HEL) system is a space-based, multimegawatt, high-energy chemical laser constellation that can operate in several modes. In its weapons mode with the laser at high power, it can attack ground, air, and space targets. In its surveillance mode, it can operate using the laser at low power for active illumination imaging or with the laser inoperative for passive imaging. Worldwide coverage could be provided by a constellation of 15-20 HELs. The system provides optical surveillance by active or passive imaging and has counterspace, counterair, force application, and weather modification uses.

Major System Assumptions

Based on "Ballistic Missile Defense Organization Space-Based Laser for Theater Missile Defense," Cost Analysis Requirements Document (CARD) dated 7/6/95. Key system parameters Laser Type - Hydrogen Flouride (HF) Chemical Laser First Launch Date - FY03 Kill Time at 1290 Km range - <1 second Kill Time at 4000 Km range - 10 seconds Run Time Total - 300 seconds Orbit - 1300 km/ 40 deg inclination Mirror Diameter - 8 m Weight - 68,013 pounds Lifetime - 10 years Deployment Schedule 2003 - 1 2005 - 1 2006 - 4 2007 - 6 2008 - 6 2009 - 2 To build constellation of 20. - These numbers are probably low because they assumed no failures. They predict on-orbit servicing required once per lifetime (10 years). These launches would probably occur after the initial build-up but would probably not exceed the yearly rate experienced during build-up. I have not accounted for these missions anywhere except by answering yes to question 38.

Comments

Sector	Military (US only)	***Primary payload\cargo***	Deployable satellite/upper stage
Orbit	LEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Inclined (40 to 60 deg)	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	Greater than 60 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	10X better than present
Est. flights for one-time surge	About 30 total (range 10 to 60)
Estimated average flight rate	Not applicable (surge or one-shot mission)
Confidence in flight rates	High confidence (+- 20%)
Launch price elasticity	N/A
Schedule importance	High: National security or severe launch-window constraints

Application # 19

Space-Based High Energy Laser System - deployment mission

Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Special/outsized relative to lift mass in this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	N/A
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	No
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 19.1

Space-Based High Energy Laser System - servicing flight

Category	Military
Source	New World Vistas, Spacecast 2020, Exec. Summary
Date	4/24/97 4:29:28 PM
Reviewers	Kellogg, Robert/Kim, David

Description

The space-based high energy laser (HEL) system is a space-based, multimegawatt, high-energy chemical laser constellation that can operate in several modes. In its weapons mode with the laser at high power, it can attack ground, air, and space targets. In its surveillance mode, it can operate using the laser at low power for active illumination imaging or with the laser inoperative for passive imaging. Worldwide coverage could be provided by a constellation of 15-20 HELs. The system provides optical surveillance by active or passive imaging and has counterspace, counterair, force application, and weather modification uses.

Major System Assumptions

Based on "Ballistic Missile Defense Organization Space-Based Laser for Theater Missile Defense," Cost Analysis Requirements Document (CARD) dated 7/6/95. Key system parameters Laser Type - Hydrogen Flouride (HF) Chemical Laser First Launch Date - FY03 Kill Time at 1290 Km range - <1 second Kill Time at 4000 Km range - 10 seconds Run Time Total - 300 seconds Orbit - 1300 km/ 40 deg inclination Mirror Diameter - 8 m Weight - 68,013 pounds Lifetime - 10 years Deployment Schedule 2003 - 1 2005 - 1 2006 - 4 2007 - 6 2008 - 6 2009 - 2 To build constellation of 20. - These numbers are probably low because they assumed no failures. They predict on-orbit servicing required once per lifetime (10 years). These launches would probably occur after the initial build-up but would probably not exceed the yearly rate experienced during build-up. I have not accounted for these missions anywhere except by answering yes to question 38.

Comments

For periodic servicing/re-fueling type mission

Sector	Military (US only)	***Primary payload\cargo***	Deployable satellite/upper stage
Orbit	LEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Inclined (40 to 60 deg)	***Enabling launch price***	Factor of 3 reduction
Payload to LEO	40 Klb to 60 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 3 per year (range 2 to 6)
Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	N/A

Application # 19.1

Space-Based High Energy Laser System - servicing flight

Schedule importance	High: National security or severe launch-window constraints
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing/bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	N/A
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on need, 14 days or less call up
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	Yes	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	Yes	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 20

Ground-Based High Energy Laser System - deployment mission

Category Military

Source New World Vistas, DEW, Sec 2.15

Date 4/24/97 4:29:51 PM

Reviewers Kellogg, Robert/Kim, David

Description

Virtual Presence is envisioned as a system that is both passive and active, with moderate to high power lasers being employed to transmit interactive presence to distant points of the globe at the speed of light. A network of space optics which are accessible from local and remote ground sites can provide real-time "look-through" capability for in-theater missions. The same optical systems in space can pipe low and high-power laser beams from ground sites around the world to enhance theater operations, and can likewise relay surveillance of the battlefield in real time back to distant observers. The principal advantage of ground-based lasers and optical telescopes coupled to a network of space-based relay mirrors is that the heavy, expensive laser hardware remains on the ground where access is straightforward. Not only does this facilitate operations and maintenance, but the laser fuel can be readily replenished, and lasers can be interchanged as may be desirable for different applications. From - New World Vistas, Directed Energy Volume, Section 2.15.

Major System Assumptions

Assume a moderate (20-30 satellite) constellation of large (10-100m) mirrors, in an inclined LEO orbit. Mirrors would utilize inflatable or other advanced technology to minimize launch size and weight. ** For initial deployment of full constellation.

Comments

Sector Military (US only)

Orbit LEO

Inclination Inclined (40 to 60 deg)

Payload to LEO 20 Klb to 40 Klb

Turn time (for launcher) N/A

Primary payload/cargo Deployable satellite/upper stage

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 3 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge About 30 total (range 10 to 60)

Estimated average flight rate Not applicable (surge or one-shot mission)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity N/A

Schedule importance High: National security or severe launch-window constraints

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Application # 20

Ground-Based High Energy Laser System - deployment mission

Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap .reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	N/A
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 20.1

Ground-Based High Energy Laser System - servicing flight

Category Military

Source New World Vistas, DEW, Sec 2.15

Date 4/24/97 4:30:29 PM

Reviewers Kellogg, Robert/Kim, David

Description

Virtual Presence is envisioned as a system that is both passive and active, with moderate to high power lasers being employed to transmit interactive presence to distant points of the globe at the speed of light. A network of space optics which are accessible from local and remote ground sites can provide real-time "look-through" capability for in-theater missions. The same optical systems in space can pipe low and high-power laser beams from ground sites around the world to enhance theater operations, and can likewise relay surveillance of the battlefield in real time back to distant observers. The principal advantage of ground-based lasers and optical telescopes coupled to a network of space-based relay mirrors is that the heavy, expensive laser hardware remains on the ground where access is straightforward. Not only does this facilitate operations and maintenance, but the laser fuel can be readily replenished, and lasers can be interchanged as may be desirable for different applications. From - New World Vistas, Directed Energy Volume, Section 2.15

Major System Assumptions

This application is for the servicing/resupply missions only and assumes approximately 3 flights per year.

Comments

Sector Military (US only)

Orbit LEO

Inclination Inclined (40 to 60 deg)

Payload to LEO 10 Klb to 20 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 3 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 3 per year (range 2 to 6)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity N/A

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Government launch (self insured)

Launch facilities .range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Application # 20.1

Ground-Based High Energy Laser System - servicing flight

Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	*Final-orbit injection required*	Yes
Return-to-launch site requirements	No	*Overflight over populated areas an issue*	No
On-orbit refueling required	Yes	*On-orbit payload change out required*	No
On-orbit cargo transfer required	No	*On-orbit crew transfer required (space suits)*	No
Launch during conflict conditions	Yes	*On-orbit crew transfer required (shirt sleeves)*	No
Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	Yes
Alternate landing site(s) required	N/A	*Return-to-launch-site capability after abort*	N/A
Multi-azimuth launch	No	*Payload fuel handling prior to launch*	Yes
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 21

KEW Kinetic Energy Weapons

Category Military

Source New World Vistas, Spacecast 2020, Exec. Summary

Date 4/18/97 1:22:26 PM

Reviewers Duclos, Don/Kim, David

Description

Kinetic energy weapons employ high speed projectiles to damage or destroy targets through the mechanism of kinetic energy transfer without the use of any type of explosive warhead. A variety of mechanisms can be used to deploy kinetic energy weapons against space systems. Examples might include satellites maneuvered to act as weapons (co-orbital interceptors or space mines,) missiles launched from aircraft or other satellites, and ground based missiles used in direct ascent attacks. A key requirement for these type weapons is the ability to get the weapon in close proximity to the target. Such a weapon would require surveillance and identification capability to acquire and track the targets with sufficient accuracy and timeliness, and some maneuvering capability to perform the engagement end game. Direct ascent missiles are the most likely delivery options for regional type adversaries. Space or aircraft based missile systems would have some advantages over ground based systems (reduced engagement timelines, potential covert employment) but their development would imply considerably increased system complexity and system integration risk. The constraining factor in developing a comprehensive low altitude kinetic energy capability is the required infrastructure and the development of the kill vehicle.

Major System Assumptions

Comments

Sector Military (US only)

Orbit LEO

Inclination Inclined (60 to 80 deg)

Payload to LEO Less than 5,000 lb

Turn time (for launcher) N/A

Primary payload\cargo Weapon or sensors

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Present prices

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 10 per year (7 to 15)

Confidence in flight rates Medium confidence (+- 50%)

Launch price elasticity N/A

Schedule importance High: National security or severe launch-window constraints

Launch insurance considerations Government launch (self insured)

Application # 21

KEW Kinetic Energy Weapons

Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Hours
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	N/A
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 22

Super GPS

Category Civil, Military

Source Spacecast 2020

Date 4/18/97 1:26:00 PM

Reviewers Bywater, Ronald/Kim, David

Description

Major changes in the space segment may not be economically feasible until about 2020. This does not preclude adding complimentary satellites to enhance the role of space for global positioning and time transfer. For example, it is possible to add "special satellites" even into the current constellation which might radiate substantially higher power in support of the P(Y) code and which might illuminate the entire earth's disc or alternatively, use higher gain antennae to illuminate just the combat area, etc. There is room for analysis on other orbital options. With time, the determination of satellite orbits will improve, atomic clock technology (maybe using masers) will improve, compact accurate INS will become available, better "GPS - INS" integration and receiver tracking of both range and range-rate (Doppler) will result. Such expected improvements when integrated in UE, together with more accurate data on the troposphere9, lead the panel to conclude that in the 2025 period the horizontal accuracy of the PPS can be brought down to 30 centimeters and time transfer to 1 nanosecond.

Major System Assumptions

Size and power similar to GPS. Some Tech. improvements. Orbit - MEO and some HEO for theater. USAF control with some commercial users. On-orbit spares. No on-orbit servicing. Integral propulsion system on Spacecraft.

Comments

This is for strictly military application and for possible military upgrade program.

Sector	Military (US only)	***Primary payload\cargo***	Deployable satellite/upper stage
Orbit	MEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Inclined (40 to 60 deg)	***Enabling launch price***	Present prices
Payload to LEO	Less than 5,000 lb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 3 per year (range 2 to 6)
Confidence in flight rates	High confidence (+- 20%)
Launch price elasticity	N/A
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)

Application # 22

Super GPS

Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 23
Communications

Category Military

Source New World Vistas

Date 4/18/97 1:32:07 PM

Reviewers Kim, David

Description

Earth will be a "wired world" whereby anyone, anywhere, including soldiers, sailors and marines, and airmen, can carry crackerjack box size devices and communicate with any location in the world via multimedia and in any trackless, featureless environment know their spherical position within meters (actually centimeters) in any weather, day or night. The comprehensive situational awareness will be viewed by the on-scene commander, the one with the ultimate responsibility, and will have an indelible effect on how wars/conflicts are waged. Time will no longer be measured in years, months, days, hours, and minutes, but nanoseconds. Information will be tagged with GPS time accuracy that will serve as its primary and basic attribute. In fact, all communications will have GPS position, time and velocity vector superimposed upon every transmission to enable all in the net to know the others exact position and their relative position. Communication satellites in the year 2015 must incorporate emerging technologies to ensure bandwidth is available to provide the warfighters the information that they will require. Massive onboard signal processing should be a major factor in the design of communications satellites to improve the signal to noise ratio, effectively increase the power output and ameliorate the power aperture problem for the mobile, tactical users with small antennas. This quantum leap in processing capability will enable communications 30 to 40 dB, and possibly greater, below the noise level. This spread spectrum, frequency agility mode of operation was employed in the past, with the attendant trade-off in bandwidth, to achieve an antijam margin of protection, and low probability of detection. Probability of intercept communications can now permit users to operate on top of each other without interference, preserving precious frequency spectrum. This feature takes on ever increasing importance as the competition for frequency spectrum becomes excruciating and spectrum becomes a lucrative source of revenue and takes on greater significance during this period when military used frequencies are the most vulnerable. Small, lightweight, rugged, affordable, broadband, high gain, electronically steerable antennas that are able to access multiple satellites, in different frequency bands, in different parts of the sky simultaneously must be designed and fielded for the mobile, tactical users.

Major System Assumptions

Military Communication systems of multiple orbit applications.

Comments

Sector	Military (US only)	***Primary payload\cargo***	Deployable satellite/upper stage
Orbit	Multiple orbit cases	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Wide range of inclinations	***Enabling launch price***	Present prices
Payload to LEO	20 Klb to 40 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	Hours

Application # 23

Communications

Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 3 per year (range 2 to 6)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Inelastic--lowering price below enabling threshold will not increase flight rate
Schedule importance	High: National security or severe launch-window constraints
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Days
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical military control (as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on need, 14 days or less call up
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	Yes	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 23

Communications

Application # 24
SPACENET: On-Orbit Support in 2025

Category Military

Source Spacecast 2020

Date 4/18/97 1:43:36 PM

Reviewers Lopez, Jesse

Description

In 2025, on-orbit support will be vital to employing space assets as an instrument of national power. Four areas of on-orbit support need to be developed over the next three decades to ensure that the US maintains space dominance. First, supporting forces in the field will be the primary mission of the military space program. Theater commanders require reliable, timely support from space to maximize their war-fighting potential. This includes communications, navigation, weather, missile launch warning, interdiction, and data transfer. Second, satellite command, control, and communications (C3) systems must be responsive enough to position satellites in correct orbits to support the theater commander. While satellite autonomy is the goal, the reality for the foreseeable future is likely to be a system of C3 to control satellites over the horizon from a ground control station, automatic, redundant switching to ensure a particular satellite receives the correct commands, and flexible, secure, and mobile ground stations. The third component is satellite design. This will lower costs, improve flexibility, and enhance survivability. Key design considerations include satellite size, longevity, power and propulsion requirements, survivability, computer processing capability, and cost. While quantum leaps in information technology will occur, adapting them to the environment of space may take a little longer. Finally, space assets need to be made survivable in a hostile space environment and be immediately replaceable if destroyed. Such protection should include a system of both passive and active defense measures to counter both man-made and environmental threats. These might include antisatellite (ASAT) systems and those to protect satellites from space debris and meteorites. Solving these four problems through SPACENET will make it the ultimate in force enhancement and projection in order to ensure US dominance in the twenty-first century. This concept is to ensure that on-orbit support is developed over the next three decades to ensure that the U.S. maintains space dominance. Four areas of importance are: (1) to provide reliable, timely support from space to theater commanders to maximize their war-fighting potential; (2) the satellite C3 systems must be responsive enough to position satellites in correct orbits to support the theater commander; (3) the design of satellites must lower costs, improve flexibility, and enhance survivability; (4) space assets need to be survivable in a hostile environment and be immediately replaceable if destroyed. It is expected that Spacenet address these 4 problem areas. Spacenet should be addressed as a requirement and policy-driven approach that will impact space system elements and their concepts of operations within the context of an over-arching space system-of-systems architect. Each mission system element, because of spacenet requirements, will levy additional demands on future spacelift requirements. The spacenet requirements may also create new mission element acquisitions.

Major System Assumptions

The potential missions outlined in this application are implemented by other applications. This application does not represent a specific mission and should not be included in the database.

Comments

Application # 24

SPACENET: On-Orbit Support in 2025

Sector

Orbit

Inclination

Payload to LEO

Turn time (for launcher)

Primary payload\cargo

Likely deployment period

Enabling launch price

Return payload mass

Standing-alert capability

Launch reliability required

Est. flights for one-time surge

Estimated average flight rate

Confidence in flight rates

Launch price elasticity

Schedule importance

Launch insurance considerations

Launch facilities range requirements

Return cross-range requirement

Safe abort requirement

Government indemnification requirements for launch services

Time required to swap reintegrate substitute payload

Injection accuracy requirement (launch system)

Surge requirements (for individual launch vehicle)

Environmental standards for applications

Payload fairing\bay-size requirements

On-orbit mission duration (for launch vehicle)

Launch range operations for application

Acceptable transition time to final orbit

Max g-load and vibration requirement

Call-up time for space-transportation service

Rendezvous requirement

Rapid cool-down requirements for return payload

Crew/passenger ejection during ascent/descent

Nuclear materials on board

Return-to-launch site requirements

On-orbit refueling required

Final-orbit injection required

Overflight over populated areas an issue

On-orbit payload change out required

Application # 24

SPACENET: On-Orbit Support in 2025

On-orbit cargo transfer required

Launch during conflict conditions

Payload fuel handling flight abort

Alternate landing site(s) required

Multi-azimuth launch

Crew Requirement

On-orbit crew transfer required (space suits)

On-orbit crew transfer required (shirt sleeves)

Encapsulated or containerized payload

Return-to-launch-site capability after abort

Payload fuel handling prior to launch

Payload fuel handling and safing after landing

Application # 25

Communications - Fixed Satellite Services

Category Commercial

Source CSTS, 3.1.3, Fixed Satellite Services

Date 4/18/97 1:51:03 PM

Reviewers Kim, David

Description

Fixed satellite service (FSS) is the transmission of analog and digital data over long distances from fixed sites. For the purpose of this report, it is further defined to mean basic services by the telephone and television industry using geostationary satellites (satellites in geostationary orbit communicating with fixed ground stations). The users of these services are telephone, television, and business doing business in multiple cities. 3,000 to 7,000 lb to GEO orbit with annual launch rate of 20 to 31 satellites.

Major System Assumptions

The high annual launch rate assumes that there are several commercial users launching payloads.

Comments

Sector Commercial (US and Foreign)

Orbit GEO/GSO/HEO

Inclination Equatorial or near equatorial

Payload to LEO 20 Klb to 40 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Present prices

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 30 per year (16 to 60)

Confidence in flight rates Medium confidence (+- 50%)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Commercial insurance through usual channels

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement N/A

Government indemnification requirements for launch services Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload Days

Application # 25

Communications - Fixed Satellite Services

Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 26

Communications - Broadcast Satellite Services

Category Commercial

Source CSTS, 3.1.4, Broadcast Satellite Services

Date 4/18/97 1:56:31 PM

Reviewers Kim, David

Description

Extrapolation of existing BSS satellites, including direct broadcast TV and network feed, with weight capability of 3,000 to 7,000 lb to GEO, 2 to 3 satellites per year. A new market area is broadcast of TV and audio channels directly to homes, remote or business directly from satellites, via direct broadcast services (DBS). Direct broadcast is extremely attractive for areas such as the Pacific Rim, where infrastructure has not been fully established and is difficult to establish. DBS was reintroduced in the United States in 1994. DBS providers are intending to provide high-definition TV service. Another new market is direct broadcast digital radio from satellites. This offers the advantage over conventional radio by consistency of programming over large global areas or on a global basis. Estimates of several hundred channels of programming may be possible.

Major System Assumptions

Based on the current demand for similar systems, a higher launch rate of 10 per year is assumed over the original estimate of 2 to 3 per year.

Comments

Extrapolation of current BSS systems

Sector Commercial (US and Foreign)

Orbit GEO/GSO/HEO

Inclination Equatorial or near equatorial

Payload to LEO 20 Klb to 40 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Present prices

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 10 per year (7 to 15)

Confidence in flight rates High confidence (+- 20%)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance High: National security or severe launch-window constraints

Launch insurance considerations Commercial insurance through usual channels

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement N/A

Application # 26

Communications - Broadcast Satellite Services

Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Days
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 27

Communications - Mobile Satellite Service - deployment mission

Category Commercial

Source CSTS, 3.1.5, Mobile Satellite Service

Date 4/18/97 2:03:16 PM

Reviewers Kim, David

Description

Combination of Big LEO, Small LEO, and Mega LEOs, with total weight of 16.5 Klb to 150 Klb per year to LEO of < 1,000 nmi with inclination range of 55 deg to 98.6 deg. Satellite weights range from 300 lb to 3,000 lb. The areas of mobile communications are the most volatile of all the communications segments. The mobile services are intended to provide wireless communication to any point on the globe and there are several competing concepts (over 20 !) being proposed or developed.

Major System Assumptions

Teledesic-like system for future - a constellation of 1000 LEO satellites in 2010 time frame. ** This is for initial deployment of full constellation.

Comments

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Deployable satellite/upper stage
Orbit	LEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Polar or near polar	***Enabling launch price***	Factor of 3 reduction
Payload to LEO	Less than 5,000 lb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	About 300 or more total
Estimated average flight rate	Not applicable (surge or one-shot mission)
Confidence in flight rates	High confidence (+- 20%)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Low: Some risk of loss of service, but w/o significant revenue penalty
Launch insurance considerations	Self insured (commercial)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Application # 27

Communications - Mobile Satellite Service - deployment mission

Time required to swap reintegrate substitute payload	Days
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Special operations--less extensive than today
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 27.1

Communications - Mobile Satellite Service - servicing flight

Category Commercial

Source CSTS, 3.1.5, Mobile Satellite Service

Date 4/18/97 2:05:46 PM

Reviewers Kim, David

Description

Combination of Big LEO, Small LEO, and Ultra LEOs, with total weight of 16.5 Klb to 150 Klb per year to LEO of < 1,000 nmi with inclination range of 55 deg to 98.6 deg. Satellite weights range from 300 lb to 3,000 lb. The areas of mobile communications are the most volatile of all the communications segments. The mobile services are intended to provide wireless communication to any point on the globe and there are several competing concepts (over 20 !) being proposed or developed.

Major System Assumptions

Teledesic-like system for future - a constellation of 1000 LEO satellites in 2010 time frame. This application is for replenishment of the Mega LEO concept.

Comments

Sector Commercial (US and Foreign)

Orbit LEO

Inclination Polar or near polar

Payload to LEO Less than 5,000 lb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Factor of 3 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 30 per year (16 to 60)

Confidence in flight rates Medium confidence (+- 50%)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance Low: Some risk of loss of service, but w/o significant revenue penalty

Launch insurance considerations Self insured (commercial)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement N/A

Government indemnification requirements for launch services Same as today (range-related and liability caps)

Application # 27.1
Communications - Mobile Satellite Service - servicing flight

Time required to swap reintegrate substitute payload	Days
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Special operations--less extensive than today
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 28

Communications - Positioning Satellite Services

Category Commercial, Civil

Source CSTS, 3.1.6, Positioning Satellite Services

Date 4/18/97 2:33:32 PM

Reviewers Kim, David J

Description

Extension of current GPS like system, with growth capability of 2x GPS weight class. The global positioning system (GPS) was originally designed to allow its users to locate any position near the Earth, vertically and horizontally, to within 16m accuracy. This is accomplished by using the Navstar (Navigation System using Timing and Ranging) satellite network, consisting of a 24-satellite constellation with eight satellites positioned in three different planes parked in sun-synchronous 12-hr, 20,200 km orbits. Continual progress is being made that refines that location accuracy to levels down in the single meters. This system is in the process of transitioning over from a sole U.S. government DOD user to include in large part the commercial industry. Users range from foot soldiers in Desert Storm and aircraft pilots on the military side to mapping and excavating with heavy equipment on the commercial side. This market evaluation was focused on the impacts to this system that reduced launched cost would have. These impacts might possibly increase the number of launches per year and stimulate additional market growth from the user community that would increase demand for a larger network.

Major System Assumptions

This system is specifically for the commercial sector based on future upgrade beyond GPS IIF.

Comments

Sector Civil (US only)

Orbit GEO/GSO/HEO

Inclination Equatorial or near equatorial

Payload to LEO 5 Klb to 10 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Present prices

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge About 10 total (range 7 to 15)

Estimated average flight rate Not applicable (surge or one-shot mission)

Confidence in flight rates High confidence (+- 20%)

Launch price elasticity Inelastic--lowering price below enabling threshold will not increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Self insured (commercial)

Launch facilities .range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Application # 28

Communications - Positioning Satellite Services

Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap .reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 29

Space Manufacturing - deployment mission

Category Commercial

Source CSTS, 3.2.2, Space Manufacturing

Date 4/18/97 2:45:59 PM

Reviewers Wolfe, Malcolm/ Johnson, Ray/Kim, David

Description

In the years 2000 through 2010, commercially owned and operated space manufacturing and processing facilities are orbiting in sun-synchronous low Earth orbits (LEO). These facilities provide high-powered, ultrahigh-vacuum, microgravity environments to enable the automated production of unique materials used in ground-based biotechnological, pharmaceutical, electronic, and catalytic processing industries. It would be useful at this point to summarize a sample of the potential advantages and products that may be produced in a microgravity environment.

a. Immune response understanding leading to viral infection antibodies or vaccines.
b. Synthetic production of collagen for use in constructing replacement human organs (e.g, corneas).
c. Manipulated differentiation of plant cells to produce desired chemicals (e.g., Taxol).
d. Production of targetable pharmaceuticals (cancer cures).
e. Protein crystal formation for structure identification (structured biology).
f. Protein assembly.
g. Growth of large pure electronic, photonic and detector crystal materials (computer chips, quantum devices, infrared materials).
h. Ultrapure epitaxial thin film production in very high vacuum (e.g., Wake Shield Facility)
i. Production of perfect solid geometric structures.
j. Manufacture of pure zeolite crystal material for filtration applications (pollution control).
k. Manufacture of polymers with unique characteristics.
l. Electrophoresis for separation of microscopic components within fluids. The orbital assets are routinely serviced by regularly scheduled launch vehicles with maneuverable upper stages that provide autonomous rendezvous and docking for orbital delivery of unprocessed samples and constituent supplies. Need Rendezvous and docking, with return capability of 3,000 lb of product, one launch every 30 days (TBD).

Major System Assumptions

This application applies to initial build up and deployment phase.

Comments

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Rack-mounted equipment
Orbit	LEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Inclined (20 to 40 deg)	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	Greater than 60 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Application # 29

Space Manufacturing - deployment mission

Launch reliability required	10X better than present
Est. flights for one-time surge	About 10 total (range 7 to 15)
Estimated average flight rate	Not applicable (surge or one-shot mission)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	Same requirements as today (e.g., STS)
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Bulk cargo--tailor to fit available dimensions
On-orbit mission duration (for launch vehicle)	Days
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	Yes
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	Yes
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 29.1

Space Manufacturing - servicing flight

Category Commercial

Source CSTS, 3.2.2, Space Manufacturing

Date 4/18/97 2:50:58 PM

Reviewers Wolfe, Malcolm/ Johnson, Ray

Description

In the years 2000 through 2010, commercially owned and operated space manufacturing and processing facilities are orbiting in sun-synchronous low Earth orbits (LEO). These facilities provide high-powered, ultrahigh-vacuum, microgravity environments to enable the automated production of unique materials used in ground-based biotechnological, pharmaceutical, electronic, and catalytic processing industries. It would be useful at this point to summarize a sample of the potential advantages and products that may be produced in a microgravity environment.

a. Immune response understanding leading to viral infection antibodies or vaccines.
b. Synthetic production of collagen for use in constructing replacement human organs (e.g, corneas).
c. Manipulated differentiation of plant cells to produce desired chemicals (e.g., Taxol).
d. Production of targetable pharmaceuticals (cancer cures).
e. Protein crystal formation for structure identification (structured biology).
f. Protein assembly.
g. Growth of large pure electronic, photonic and detector crystal materials (computer chips, quantum devices, infrared materials).
h. Ultrapure epitaxial thin film production in very high vacuum (e.g., Wake Shield Facility)
i. Production of perfect solid geometric structures.
j. Manufacture of pure zeolite crystal material for filtration applications (pollution control).
k. Manufacture of polymers with unique characteristics.
l. Electrophoresis for separation of microscopic components within fluids. The orbital assets are routinely serviced by regularly scheduled launch vehicles with maneuverable upper stages that provide autonomous rendezvous and docking for orbital delivery of unprocessed samples and constituent supplies. Need Rendezvous and docking, with return capability of 3,000 lb of product, one launch every 30 days (TBD).

Major System Assumptions

This application covers the recurring flights to an existing Space Manufacturing facility.

Comments

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Rack-mounted equipment
Orbit	LEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Inclined (20 to 40 deg)	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	10 Klb to 20 Klb	***Return payload mass***	1000 - 10,000 lb
Turn time (for launcher)	Weeks	***Standing-alert capability***	N/A

Application # 29.1

Space Manufacturing - servicing flight

Launch reliability required	10X better than present
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 10 per year (7 to 15)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	Same requirements as today (e.g., STS)
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap .reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Bulk cargo--tailor to fit available dimensions
On-orbit mission duration (for launch vehicle)	Days
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	Yes
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 30

Remote Sensing

Category Commercial, Civil

Source CSTS, 3.3.2 Remote Sensing

Date 4/25/97 12:54:51 P

Reviewers Kim, David

Description

Space remote sensing is a high-growth international market that is poised for rapid expansion in commercial applications over the next 5 to 7 years. Several U.S. companies are planning to deploy their own remote- sensing satellites and market their own space imagery. The civil sector has responded to government's vision. Throughout the world today, the private sectors and government agencies of many nations have begun to rely on satellite imagery. The remote-sensing market has emerged from its embryonic state and is experiencing double-digit growth. It is a "high tech" industry with the potential to generate several billion dollars in sales annually within 10 years. Many commercial companies are poised to enter the market with better products than are currently being produced from government satellites.LEO platforms with 6 different types for total launch rate of 10 to 18 per year from 2000 to 2010 time frame.

Major System Assumptions

For this application, we will only assume LEO Polar cases.

Comments

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Deployable satellite/upper stage
Orbit	LEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Polar or near polar	***Enabling launch price***	Present prices
Payload to LEO	Less than 5,000 lb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 10 per year (7 to 15)
Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities .range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A

Application # 30

Remote Sensing

Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap .reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 31

Government Missions - Space Station Missions - deployment mission

Category Civil, NASA

Source CSTS, 3.4.4 Increased Space Station Missions

Date 4/25/97 1:40:38 PM

Reviewers Ruth, Edward/Kim, David/Smith, Pat

Description

The Space Station program, now a joint US/Russia/International venture, has tremendous potential as a growth transportation market. The additional resources of the combined Mir II and Alpha Station will speed the testing and development of new manufacturing and research processes. It is projected that reduced transportation costs will allow more frequent visits to the station as well as usher in the viability of free-flying platforms which will offload the matured processes and experiments from the station. The main, if not only, users for the space stations will be governments and their agencies, each contributing its own share of investment. Although we expect the station to have a wide range of use, they would mostly fall under the areas of technology development, testing and demonstration. LEO missions of up to 25 Klb to 220 nmi circular at 51.6 deg. orbit for ISSA support, for 7 to 12 missions/yr.

Major System Assumptions

** This is for initial deployment of ISSA-like system for future.

Comments

Comments on Questions: 1) Civil missions are also possible. 15) Bulk cargo may also be important. Assume that human transportation is separate launch system. 21) The station is too big to maneuver. 35) Nuclear material not needed for power. Small amounts of nuclear material may be needed for experiments.

Sector Civil (Foreign or joint programs)

Orbit LEO

Inclination Inclined (40 to 60 deg)

Payload to LEO 20 Klb to 40 Klb

Turn time (for launcher) N/A

Primary payload\cargo Rack-mounted equipment

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 10 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required 10X better than present

Est. flights for one-time surge About 30 total (range 10 to 60)

Estimated average flight rate Not applicable (surge or one-shot mission)

Confidence in flight rates Medium confidence (+- 50%)

Launch price elasticity Inelastic--lowering price below enabling threshold will not increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Application # 31

Government Missions - Space Station Missions - deployment mission

Return cross-range requirement	N/A
Safe abort requirement	Same requirements as today (e.g., STS)
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Weeks
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Days
Launch range operations for application	Special operations--more extensive than today
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	Not a consideration
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	Yes	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	Yes
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	Yes
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	No
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 31.1

Government Missions - Space Station Missions - servicing flight

Category Civil, NASA

Source CSTS, 3.4.4 Increased Space Station Missions

Date 4/25/97 1:41:12 PM

Reviewers Ruth, Edward/Kim, David/Smith, P.L.

Description

The Space Station program, now a joint US/Russia/International venture, has tremendous potential as a growth transportation market. The additional resources of the combined Mir II and Alpha Station will speed the testing and development of new manufacturing and research processes. It is projected that reduced transportation costs will allow more frequent visits to the station as well as usher in the viability of free-flying platforms which will offload the matured processes and experiments from the station. The main, if not only, users for the spacestations will be governments and their agencies, each contributing its own share of investment. Although we expect the station to have a wide range of use, they would mostly fall under the areas of technology development, testing and demonstration. LEO missions of up to 25 Klb to 220 nmi circular at 51.6 deg. orbit for ISSA support, for 7 to 12 missions/yr.

Major System Assumptions

** For periodic resupply, refuel and servicing missions, including cargo return, but not human crews (assumed to be separate launch for passengers/crews).

Comments

Comments on Questions: 1) Civil missions are also possible. 15) Bulk cargo may also be important. Assume that human transportation is separate launch system. 21) The station is too big to maneuver 35) Nuclear material not needed for power. Small amounts of nuclear material may be needed for experiments.

Sector	Civil (Foreign or joint programs)	***Primary payload\cargo***	Rack-mounted equipment
Orbit	LEO	***Likely deployment period***	Far-term: post 2020
Inclination	Inclined (40 to 60 deg)	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	20 Klb to 40 Klb	***Return payload mass***	1000 - 10,000 lb
Turn time (for launcher)	Weeks	***Standing-alert capability***	N/A

Launch reliability required	10X better than present
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 10 per year (7 to 15)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Government launch (self insured)

Application # 31.1

Government Missions - Space Station Missions - servicing flight

Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	Less than 400 nmi (typical of STS)
Safe abort requirement	Same requirements as today (e.g., STS)
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Weeks
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Days
Launch range operations for application	Special operations--more extensive than today
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	No
On-orbit refueling required	Yes	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	Yes
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	Yes
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 32
Government Missions - Human Planetary Exploration

Category Civil, NASA
Source CSTS, 3.4.6 Human Planetary Exploration

Date 4/25/97 1:42:02 PM

Reviewers Ruth, Edward/ Smith, P.L.

Description

Recently, NASA and the U.S. government have led several studies to help pave the way for the next steps in space exploration by man and manmade machines. Almost all exploration scenario studies concentrated on missions to the Moon and Mars exclusively, with manned involvement at various levels of activities. Whether they will occur in the near- or far- term future, many believe exploration missions are man's destiny. Lunar: A crew of 4 and 5 tons of cargo, or 33 tons of cargo alone to lunar surface for TBD days of stay, and TBD kgs of cargo return. Mars: A crew of TBD and TBD tons of cargo or TBD tons of cargo alone to the surface of Mars for TBD days of stay, and TBD kgs of cargo return. Launch rate of 4 /year to growth of TBD/yr.

Major System Assumptions

What I have assumed is that the mission will consist of a ship or ships assembled in LEO and launched to Mars or wherever. We are only interested in the Earth to LEO segment. The payload manifest will be mixed. Some payloads will involve human passengers and some will only involve bulk cargo like propellant, food, etc. I have tried to answer the survey questions in such a way so as to cover the range of payloads expected. There are a number of Mars mission studies available. They range from the reasonable to the ludicrous. Two extremes are von Braun's Mars Project and Zubrin's Mars Direct. The von Braun scheme required 950 launches to LEO to deliver 37 200 tonnes; to Zubrin needed only 4 launches to deliver 480 tonnes. The model I have adopted is more reasonable with about 40 launches to deliver 1400 tonnes.

Comments

Comments on questions: 2) This is a hard one to answer. Mars missons may well be far term (>2020). However, it is a good bet that after the Space Station is in operation, people will start looking for the next step and a Mars mission is a logical choice. 15) The assumption is that the majority of payload will be propellant. Humans and other gear will also have to be launched. 26,27,28) I am answering these based on the fact there will be crew onboard for some missions. 35) It may be possible to get by without nuclear power: but, I doubt it.

Sector	Civil (Foreign or joint programs)	***Primary payload\cargo***	Man - untrained, as passenger
Orbit	IP (interplanetary)	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	N/A	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	Greater than 60 Klb	***Return payload mass***	Over 10,000 lb
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required 10X better than present
Est. flights for one-time surge About 30 total (range 10 to 60)

Application # 32

Government Missions - Human Planetary Exploration

Estimated average flight rate	Not applicable (surge or one-shot mission)
Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	N/A
Schedule importance	High: National security or severe launch-window constraints
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	Less than 400 nmi (typical of STS)
Safe abort requirement	Same requirements as today (e.g., STS)
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Weeks
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Bulk cargo--tailor to fit available dimensions
On-orbit mission duration (for launch vehicle)	Days
Launch range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	Not a consideration
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	Yes	***Final-orbit injection required***	No
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	Yes
On-orbit refueling required	Yes	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	Yes
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	Yes
Payload fuel handling flight abort	Yes	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	Yes

Application # 33

Government - Space Science Outwards

Category Civil, NASA

Source CSTS, 3.4.9 Space Science Outwards

Date 4/21/97 10:38:52 A

Reviewers Ruth, Edward/Smith, P. L.

Description

Multiple payload classes to support Flagship, Discovery and Explorer classes of missions. - Flagship: TBD lb to LEO, GEO and planetary orbits - Discovery: TBD lb to LEO, GEO and planetary orbits - Explorer: Up to 1,000 lb to Leo and near earth orbits - Others: 500 lb into 100nmi, 250 lb into 600 nmi, Delta, Atlas and T-4 class payloads - Up to 25 missions/year for payloads ranging from 500 lb to 250 lb.

Major System Assumptions

Even if smaller class missions are more likely, launch system specifications should be driven by Flagship mission requirements.

Comments

3) Payload mass is the maximum expected for Flagship mission. 6) The case that is given in the scenario description of 25 science missions a year rate is unrealistic, even with only small class payloads. Only a slight increase over today's launch rate of 1 to 2 a year should be expected. So 2 to 6 a year is about right. If costs fall dramatically (doubtful in near term) or they take the asteroid threat seriously, then who knows? 35, 36) We need to plan for nuclear material even if it is never used.

Sector Civil (Foreign or joint programs)

Orbit IP (interplanetary)

Inclination Equatorial or near equatorial

Payload to LEO 10 Klb to 20 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Factor of 3 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 10 per year (7 to 15)

Confidence in flight rates Medium confidence (+- 50%)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance High: National security or severe launch-window constraints

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement N/A

Application # 33
Government - Space Science Outwards

Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap .reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Hours
Launch range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	Yes	*Final-orbit injection required*	Yes
Return-to-launch site requirements	No	*Overflight over populated areas an issue*	Yes
On-orbit refueling required	No	*On-orbit payload change out required*	No
On-orbit cargo transfer required	No	*On-orbit crew transfer required (space suits)*	No
Launch during conflict conditions	N/A	*On-orbit crew transfer required (shirt sleeves)*	No
Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	Yes
Alternate landing site(s) required	N/A	*Return-to-launch-site capability after abort*	N/A
Multi-azimuth launch	No	*Payload fuel handling prior to launch*	No
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 34

Transportation - Fast Package Delivery

Category Commercial

Source CSTS, 3.5.3 Fast Package Delivery

Date 4/21/97 10:40:54 A

Reviewers Kim, David/Smith, P.L.

Description

Fast package delivery via space transportation is a logical extrapolation of current overnight delivery business. The commodities and markets to support fast package delivery service include items such as: human organs, fresh food delicacies, biologic specimens for research, as well as conventional legal and financial documents. Capable of delivering 3,000 lb in intercontinental range, for total delivery of 30 to 500 tons per year. Range of 10,000 nmi, operate two flights daily into and out of conventional airports.

Major System Assumptions

Use of existing infrastructure such as conventional airports. Piloted vehicle assumed for operations in and out of conventional airport like facilities.

Comments

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Bulk - unpressurized
Orbit	SUB (for suborbital)	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	N/A	***Enabling launch price***	Factor of 100 reduction
Payload to LEO	Less than 5,000 lb	***Return payload mass***	1000 - 10,000 lb
Turn time (for launcher)	Hours	***Standing-alert capability***	Hours

Launch reliability required	100X better than present
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 300 or more per year
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	High: National security or severe launch-window constraints
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical airport facilities (e.g., package delivery)
Return cross-range requirement	Greater than 400 nmi including once-around capability
Safe abort requirement	Same requirements as today (e.g., STS)
Government indemnification requirements for launch services	Unknown--could be showstopper

Application # 34

Transportation - Fast Package Delivery

Time required to swap reintegrate substitute payload	Hours
Injection accuracy requirement (launch system)	Not applicable (or less than today's typical performa
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairinglbay-size requirements	Bulk cargo--tailor to fit available dimensions
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Special operations--less extensive than today
Acceptable transition time to final orbit	N/A
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	No
Rapid cool-down requirements for return payload	Must be considered
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	Yes
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	Yes	***Payload fuel handling prior to launch***	No
Crew Requirement	Yes	***Payload fuel handling and safing after landing***	No

Application # 35

Transportation - Hazardous Waste Disposal

Category Civil, Commercial

Source CSTS, 3.5.5. Hazardous Waste Disposal

Date 4/21/97 11:06:07 A

Reviewers Wolfe, Malcolm/ Johnson, Ray/Smith, P.L.

Description

Resolve the nuclear waste disposal problem for the future of nuclear power. Current cost of disposal and world wide production rate of nuclear waste is rapidly becoming a global problem. There are various options for in-space storage, such as earth orbit, solar orbit, solar impact and lunar depository, but for this study, lunar depository is selected as baseline. The capability of placing 8 tons of payload, consisting of nuclear waste and canisters, onto the lunar surface, launch every 9 days.

Major System Assumptions

Intact safety abort is a must, but highly dependent on public sentiment and political winds

Comments

Sector Civil (Foreign or joint programs)

Orbit IP (interplanetary)

Inclination N/A

Payload to LEO 10 Klb to 20 Klb

Turn time (for launcher) N/A

Primary payload\cargo Bulk - unpressurized

Likely deployment period Unknown (too uncertain to say)

Enabling launch price Factor of 100 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Equivalent to commercial AC flight reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 10 per year (7 to 15)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance High: National security or severe launch-window constraints

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement More stringent requirements

Government indemnification requirements for launch services Unknown--could be showstopper

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Time required to swap reintegrate substitute payload Not a driver--don't care

Application # 35

Transportation - Hazardous Waste Disposal

Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Bulk cargo--tailor to fit available dimensions
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Special operations--more extensive than today
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	Yes	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	Yes
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	Yes

Application # 36

Transportation - Space Tourism

Category Commercial

Source CSTS, 3.5.6 Space Tourism

Date 4/21/97 11:28:34 A

Reviewers Kim, David J./Smith, P. L.

Description

Recreational space travel for the average person, for a day to a week long duration. Obviously, several days of stay may require separate space hotel arrangement.

a. Joy ride: A high speed vehicle for an exhilarating, relatively short (hours) ride suborbitally or up to a few orbits in duration.
b. Orbital visit: Tourists visit a fairly simple orbital facility (i.e. ISSA or Mir) for duration of several days. Amenities are few and the transportation elements would probably be small (a few passengers).
c. Space Hotel: Large numbers of tourists would stay at a multi-featured orbital facility. Both 0 g and positive g zones would be available for living, playing, and sightseeing.
d. Lunar Flyby: An Apollo 8 type mission where passengers experience 0 g, the starry blackness of space, and view of the Moon and distant Earth.
e. Lunar Resort and beyond: Space resorts and more ambitious ventures.

Major System Assumptions

For this activity, concentrate on a and c for excursion range. Jay Penn paper for C., titled "Space Tourism Optimized Reusable Spaceplane Design", Dec. 1996, Revised by P. L. Smith 17 April 97

Comments

Sector Commercial (US and Foreign)

Orbit LEO

Inclination Inclined (20 to 40 deg)

Payload to LEO 20 Klb to 40 Klb

Turn time (for launcher) Hours

Primary payload\cargo Man - untrained, as passenger

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 100 reduction

Return payload mass Over 10,000 lb

Standing-alert capability N/A

Launch reliability required Equivalent to commercial AC flight reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 100 per year (61 to 150)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Commercial insurance through usual channels

Launch facilities range requirements Typical airport facilities (e.g., package delivery)

Application # 36

Transportation - Space Tourism

Return cross-range requirement	Less than 400 nmi (typical of STS)
Safe abort requirement	More stringent requirements
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap .reintegrate substitute payload	Hours
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Special/outsized relative to lift mass in this category
On-orbit mission duration (for launch vehicle)	Hours
Launch range operations for application	Special operations--more extensive than today
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Less than today's required
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	Must be considered
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	Yes
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	Yes
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	Yes	***Payload fuel handling and safing after landing***	No

Application # 37

Transportation - UHigh Speed Civil Transport

Category Commercial

Source CSTS, 3.5.7. Ultra High Speed Civil Transport (UHSCT)

Date 4/21/97 11:37:28 A

Reviewers Ruth, Edward/Smith, P. L.

Description

Much reduced travel time between trans-oceanic ranges (5,000 to 7,000 nmi range) at mach 9 to 25 range.

Major System Assumptions

Too many technical constraints and not attractive ROI to be feasible. This kind of mission may be enabled if a TSTO type vehicle is developed for other applications, and the first stage can be used for Passenger service: or, if Fast Package becomes wildly successful, this will be an evolutionary growth of such application.

Comments

It is hard to believe that there is really a market for this. To expect passengers to pay a premium to have themselves subjected to high-g loads and the dangers of rocket flight so as to arrive at their destinations a few hours earlier than a supersonic transport seems ludicrous. Any time saved would be lost while the average person recovered from the rigors of the trip. It is also hard to imagine that there are a lot of material goods that have to be moved this quickly.

Sector Commercial (US and Foreign)

Orbit SUB (for suborbital)

Inclination Wide range of inclinations

Payload to LEO 20 Klb to 40 Klb

Turn time (for launcher) Hours

Primary payload\cargo Man - untrained, as passenger

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 100 reduction

Return payload mass N/A

Standing-alert capability Hours

Launch reliability required Equivalent to commercial AC flight reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 300 or more per year

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Commercial insurance through usual channels

Launch facilities range requirements Typical airport facilities (e.g., package delivery)

Return cross-range requirement Greater than 400 nmi including once-around capability

Safe abort requirement More stringent requirements

Application # 37

Transportation - UHigh Speed Civil Transport

Government indemnification requirements for launch services	Unknown--could be showstopper

Time required to swap reintegrate substitute payload	Hours
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Special/outsized relative to lift mass in this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Special operations--less extensive than today
Acceptable transition time to final orbit	N/A
Max g-load and vibration requirement	Less than today's required
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	No
Rapid cool-down requirements for return payload	Must be considered
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	Yes
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	Yes	***Payload fuel handling prior to launch***	No
Crew Requirement	Yes	***Payload fuel handling and safing after landing***	No

Application # 38

Transportation - Space Rescue

Category Civil

Source CSTS, 3.5.2. Space Rescue

Date 4/21/97 11:42:20 A

Reviewers Kim, David/Smith, P. L.

Description

Timely rescue of humans and/or valuable space assets in support of International Space Station Alpha (ISSA) and other promising space ventures such as Space Business Park, and others. First and immediate need will be emergency crew return vehicle for ISSA.

Major System Assumptions

This is a "must-have" to support any type of manned space presence, not driven by market economics.

Comments

Based on X-38 kind of Crew Return Vehicle

Sector Civil (Foreign or joint programs)

Orbit LEO

Inclination Wide range of inclinations

Payload to LEO Less than 5,000 lb

Turn time (for launcher) Hours

Primary payload\cargo Man - trained astronaut

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Present prices

Return payload mass 1000 - 10,000 lb

Standing-alert capability Hours

Launch reliability required Present reliability

Est. flights for one-time surge About 3 total (range 2 to 6)

Estimated average flight rate One or less per year

Confidence in flight rates Medium confidence (+- 50%)

Launch price elasticity Inelastic--lowering price below enabling threshold will not increase flight rate

Schedule importance High: National security or severe launch-window constraints

Launch insurance considerations N/A

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement Less than 400 nmi (typical of STS)

Safe abort requirement Same requirements as today (e.g., STS)

Government indemnification requirements for launch services Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload Hours

Injection accuracy requirement (launch system) Typical of today's launch vehicles

Surge requirements (for individual launch vehicle) 2X baseline flight rate

Application # 38

Transportation - Space Rescue

Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Special/outsized relative to lift mass in this category
On-orbit mission duration (for launch vehicle)	Days
Launch range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Quick reaction, 24 hours or less call-up
Rendezvous requirement	Yes - uncooperative (passive) target
Rapid cool-down requirements for return payload	Must be considered
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	Yes
Launch during conflict conditions	Yes	***On-orbit crew transfer required (shirt sleeves)***	Yes
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	Yes	***Payload fuel handling and safing after landing***	No

Application # 39

Transportation - Space Servicing and Transfer

Category Commercial

Source CSTS, 3.5.4. Space Servicing and Transfer

Date 4/21/97 11:46:21 A

Reviewers Wolfe, Malcolm/ Johnson, Ray/Smith, P. L.

Description

Provide on-orbit servicing, fueling, repair and change out capability for commercial spacecraft in orbit.

Major System Assumptions

Assume this system can service payloads in LEO or deploy a space tug to service payloads in other orbits.

Comments

This is assumed to be unmanned servicing/repair mission with telerobotics. It is also assumed that it may bring high-value satellites back to the earth for repair/servicing. 4/21/97

Sector	Commercial (US and Foreign)	*Primary payload\cargo*	Deployable satellite/upper stage
Orbit	LEO	*Likely deployment period*	Near-term: 2000 - 2020
Inclination	Wide range of inclinations	*Enabling launch price*	Factor of 3 reduction
Payload to LEO	20 Klb to 40 Klb	*Return payload mass*	1000 - 10,000 lb
Turn time (for launcher)	Weeks	*Standing-alert capability*	Days

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Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 10 per year (7 to 15)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	Less than 400 nmi (typical of STS)
Safe abort requirement	Same requirements as today (e.g., STS)
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Hours
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A

Application # 39

Transportation - Space Servicing and Transfer

Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Weeks
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	*Final-orbit injection required*	Yes
Return-to-launch site requirements	Yes	*Overflight over populated areas an issue*	No
On-orbit refueling required	Yes	*On-orbit payload change out required*	Yes
On-orbit cargo transfer required	Yes	*On-orbit crew transfer required (space suits)*	No
Launch during conflict conditions	No	*On-orbit crew transfer required (shirt sleeves)*	No
Payload fuel handling flight abort	Yes	*Encapsulated or containerized payload*	Yes
Alternate landing site(s) required	Yes	*Return-to-launch-site capability after abort*	Yes
Multi-azimuth launch	Yes	*Payload fuel handling prior to launch*	No
Crew Requirement	No	*Payload fuel handling and safing after landing*	Yes

Application # 40

Entertainment - Digital Movie Satellite

Category Commercial

Source CSTS, 3.6.1.1 Digital Movie Satellite.

Date 4/21/97 11:49:48 A

Reviewers Johnson, Ray F./Smith, P. L.

Description

Digital movie satellites are envisioned to fill an entertainment niche not unlike that of current pay-per-view satellite systems for home viewing. The big difference is that the digital movie satellite would downlink an entire movie to the viewer's set at one time. This would enable the viewer to specify any of a large number of films to be screened on demand. In effect, it would combine the attributes of video rental and pay-per-view. Replacement or augmentation of current movie distribution systems could take advantage of lower satellite transportation costs while providing for on-demand access to a large digitally stored movie database. This would allow for increased worldwide distribution without the need to make and distribute actual prints of films, and also avoid the added costs from the wired infrastructure needed for competing services such as cable systems.

Major System Assumptions

Assume the spacelift requirements are similar to present direct broadcast TV satellites. The CSTS Study gave this a very low probability of being implemented because of technical problems in delivering the potentially large number of downlinked compressed signals, and because there are ground-based fiber-optic cable solutions being demonstrated that could offer a simpler, lower cost solution. For this reason, I consider the likely deployment period as far-term. REVISION on 4/18/97 assumptions stated above was based on CSTS report in 1994. During last year, as many as 12 different concepts for Broadband (Ka) communication system have been proposed by the commercial industry to address "Bandwidth on demand" and "Internet-on-the-sky" type service. Currently, the cable and space communication services are no longer competitive, rather, complementary to each other. Digital Movie Satellite is viewed as a special application of such Broadband communication satellite system.

Comments

Sector Commercial (US and Foreign)

Orbit GEO/GSO/HEO

Inclination Equatorial or near equatorial

Payload to LEO 20 Klb to 40 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Near-term: 2000 - 2020

Enabling launch price Present prices

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 3 per year (range 2 to 6)

Application # 40

Entertainment - Digital Movie Satellite

Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	Same requirements as today (e.g., STS)
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Weeks
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Hours
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	No	***Return-to-launch-site capability after abort***	No
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 44

Space Utilities - Molniya - deployment mission

Category Commercial

Source CSTS, 3.8.2. Molniya Space Power Utilities

Date 4/25/97 1:51:37 PM

Reviewers Bywater, R/Kim, D/Smith, P. L.

Description

Two different nonsynchronous orbit solar power satellite options were examined. Selection of the orbit is crucial to space-based power satellites performance and system cost. A high altitude requires large antennas and a low orbital period yields short dwell times. Molniya SPS meets peak power demands from northern hemisphere with higher population density and northern latitude areas with higher seasonal peak power demand. Molniya missions: 25 to 50 tons of payload to a Molniya orbit at 63 deg. inclination. Launching 2 missions/week during build up phase.

Major System Assumptions

Some space assembly and servicing may be required, multiple flights to assemble one S/C in orbit. On-orbit robotics. EELV used (heavy lift). Containerized P/L required for LEO storage. Equivalent P/L to LEO is total S/C. Assembly crews provided via separate contract/service. Manned assmbly in LEO - then transfer to HEO via XIPS and deploy arrays in HEO. >300 flts/yr @ $100 mil/LV. $1 bil total ea. S/C - i.e. $100 mil/flt (or module). Space fueling/servicing required. ** For Initial Deployment per discussion with R. Bywater 4/22/97. Total system weight (LEO Equiv. lb) = 30.8E6 lb, requiring 320 launches for 1 GW system.

Comments

Depends on what OTV looks like and whether on-orbit propulsion is a separate module such that other power modules have no fuel at launch. These entries based primarily on solar which is why no nuclear onboard is assumed. Not clear why assumptions as received refer to 2 missions per week during build up phase. That is too low. Except for focus on niche markets, it isn't clear why this system is judged "somewhat" viable compared to the GEO system given that the satellites are similar in size and cost and the large initial costs are apparently dominant in the GEO assessment. Also, the assembly procedure for this concept is noted to be less costly than GEO. However it seems the same approach could be used in both cases given the apparent similarity of the satellites.

Sector Commercial (US and Foreign)

Orbit GEO/GSO/HEO

Inclination Inclined (60 to 80 deg)

Payload to LEO Greater than 60 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 100 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required 100X better than present

Est. flights for one-time surge About 300 or more total

Estimated average flight rate Not applicable (surge or one-shot mission)

Application # 44
Space Utilities - Molniya - deployment mission

Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Months
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	*Final-orbit injection required*	Yes
Return-to-launch site requirements	No	*Overflight over populated areas an issue*	No
On-orbit refueling required	Yes	*On-orbit payload change out required*	No
On-orbit cargo transfer required	No	*On-orbit crew transfer required (space suits)*	Yes
Launch during conflict conditions	N/A	*On-orbit crew transfer required (shirt sleeves)*	No
Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	Yes
Alternate landing site(s) required	N/A	*Return-to-launch-site capability after abort*	N/A
Multi-azimuth launch	No	*Payload fuel handling prior to launch*	No
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 44.1

Space Utilities - Molniya - servicing flight

Category Commercial

Source CSTS, 3.8.2. Molniya Space Power Utilities

Date 4/25/97 1:52:16 PM

Reviewers Bywater, Ronald/Kim, David/Smith, P. L.

Description

Two different nonsynchronous orbit solar power satellite options were examined. Selection of the orbit is crucial to space-based power satellites performance and system cost. A high altitude requires large antennas and a low orbital period yields short dwell times. Molniya SPS meets peak power demands from northern hemisphere with higher population density and northern latitude areas with higher seasonal peak power demand. Molniya missions: 25 to 50 tons of payload to a Molniya orbit at 63 deg. inclination. Launching 2 missions/week during build up phase.

Major System Assumptions

Some space assembly and servicing may be required, multiple flights to assemble one S/C in orbit. On-orbit robotics. EELV used (heavy lift). Containerized P/L required for LEO storage. Equivalent P/L to LEO is total S/C. Assembly crews provided via separate contract/service. Manned assmbly in LEO - then transfer to HEO via XIPS and deploy arrays in HEO. >300 flts/yr @ $100 mil/LV. $1 bil total ea. S/C - i.e. $100 mil/flt (or module). Space fueling/servicing required. ** For Initial Deployment per discussion with R. Bywater 4/22/97. Total system weight (LEO Equiv. lb) = 30.8E6 lb, requiring 320 launches for 1 GW system.

Comments

Depends on what OTV looks like and whether on-orbit propulsion is a separate module such that other power modules have no fuel at launch. These entries based primarily on solar which is why no nuclear onboard is assumed. Not clear why assumptions as received refer to 2 missions per week during build up phase. That is too low. Except for focus on niche markets, it isn't clear why this system is judged "somewhat" viable compared to the GEO system given that the satellites are similar in size and cost and the large initial costs are apparently dominant in the GEO assessment. Also, the assembly procedure for this concept is noted to be less costly than GEO. However it seems the same approach could be used in both cases given the apparent similarity of the satellites.

Sector Commercial (US and Foreign)

Orbit GEO/GSO/HEO

Inclination Inclined (60 to 80 deg)

Payload to LEO 20 Klb to 40 Klb

Turn time (for launcher) N/A

Primary payload\cargo Bulk - pressurized

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 3 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 3 per year (range 2 to 6)

Application # 44.1

Space Utilities - Molniya - servicing flight

Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Inelastic--lowering price below enabling threshold will not increase flight rate
Schedule importance	Low: Some risk of loss of service, but w/o significant revenue penalty
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Months
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	Yes	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	Yes
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 45

Space Utility - GEO - deployment mission

Category Commercial

Source CSTS, 3.8.2.2.1 GEO Solar Power Satellite

Date 4/25/97 1:53:19 PM

Reviewers Bywater, Ronald/Kim, D/Smith, P. L.

Description

Large power satellites in GEO were extensively studied in the late 1970s by various organizations, and in several large contractual studies from DOE to Boeing Aerospace and Rockwell International. These satellites were designed to provide high power levels (tens to hundreds of gigawatts) to terrestrial receivers by converting incident solar energy into microwave power for transmission to large antenna sites on the Earth. The power was then transferred into the terrestrial power grid. These satellites were primarily designed to serve the base-power needs for terrestrial users. A subsequent preliminary study was performed by General Dynamics Corporation into the utility of using lunar resources to provide components of the GEO SPSs. A low level of enthusiast-fueled effort in analysis and development of GEO SPSs has continued since that time.

Major System Assumptions

Satellite mass/unit power = (approx.)10 ktons/GW. LEO assembly. GEO spare modules and robotic replacement. GEO maintenance -- robotics-OTV. ** For initial deployment per R. Bywater, 4/22/97 Total LEO Equiv. weight = 19e6 lb, requiring 190 launches for 1 GW system.

Comments

Launch costs are not a dominant factor. Vehicle Concepts Dept. review (circa '95) cited cost ($100bil+) and safety/environmental concerns as show stoppers, e.g., AIAA '95 workshop. 190 launches required - entered as 100 launches with low priority (+/= 100 %) range, rather than 300 launches.

Sector Commercial (US and Foreign)

Orbit GEO/GSO/HEO

Inclination Equatorial or near equatorial

Payload to LEO Greater than 60 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 100 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required 100X better than present

Est. flights for one-time surge About 100 total (range 61 to 150)

Estimated average flight rate Not applicable (surge or one-shot mission)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Inelastic--lowering price below enabling threshold will not increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Commercial insurance through usual channels

Application # 45

Space Utility - GEO - deployment mission

Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Months
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	Yes	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	Yes
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 45.1

Space Utility - GEO - servicing flight

Category Commercial

Source CSTS, 3.8.2.2.1 GEO Solar Power Satellite

Date 4/25/97 1:54:19 PM

Reviewers Bywater, R/Kim, D. J/Smith, P. L

Description

Large power satellites in GEO were extensively studied in the late 1970s by various organizations, and in several large contractual studies from DOE to Boeing Aerospace and Rockwell International. These satellites were designed to provide high power levels (tens to hundreds of gigawatts) to terrestrial receivers by converting incident solar energy into microwave power for transmission to large antenna sites on the Earth. The power was then transferred into the terrestrial power grid. These satellites were primarily designed to serve the base-power needs for terrestrial users. A subsequent preliminary study was performed by General Dynamics Corporation into the utility of using lunar resources to provide components of the GEO SPSs. A low level of enthusiast-fueled effort in analysis and development of GEO SPSs has continued since that time.

Major System Assumptions

Satellite mass/unit power = (approx.)10 ktons/GW. LEO assembly. GEO spare modules and robotic replacement. GEO maintenance -- robotics-OTV. ** For initial deployment per R. Bywater, 4/22/97 Total LEO Equiv. weight = 19e6 lb, requiring 190 launches for 1 GW system.

Comments

Launch costs are not a dominant factor. Vehicle Concepts Dept. review (circa '95) cited cost ($100bil+) and safety/environmental concerns as show stoppers, e.g., AIAA '95 workshop. 190 launches required - entered as 100 launches with low priority (+/= 100 %) range, rather than 300 launches.

Sector Commercial (US and Foreign)

Orbit GEO/GSO/HEO

Inclination Equatorial or near equatorial

Payload to LEO 20 Klb to 40 Klb

Turn time (for launcher) N/A

Primary payload\cargo Rack-mounted equipment

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 3 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 10 per year (7 to 15)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Inelastic--lowering price below enabling threshold will not increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Commercial insurance through usual channels

Application # 45.1

Space Utility - GEO - servicing flight

Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Weeks
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Months
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	Yes	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 46

Space Utility - SunSync - deployment mission

Category Commercial

Source CSTS, 3.8.2.2.3 Sun Synchronous Power Satellite

Date 4/23/97 7:37:05 AM

Reviewers Bywater, Ronald/Kim, David/Smith, P. L.

Description

The major market for power is to the major metropolitan areas within the continental United States. Within this market, a premium is paid through existing systems for power provided during peak demand periods. This premium price is paid since generating systems are most efficient if run at constant level. During peak power conditions, new assets or stored power must be brought on line and run solely for this peak power demand.

Major System Assumptions

Initial Deployment - per R. Bywater, 0.8 GW system weighs 6.3e6 lb total, requiring 64 launches total

Comments

Somewhat independent of launch costs. Appears economically not viable. However, launch costs would have to drop to approx. $100/lb if other factors such as initially large investment are overcome. Requires large supporting infrastructure to be developed. e.g. OTV, assembly and maintenance crew services. Robotics (?)

Sector Commercial (US and Foreign)

Orbit LEO

Inclination Polar or near polar

Payload to LEO Greater than 60 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 100 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge About 100 total (range 61 to 150)

Estimated average flight rate Not applicable (surge or one-shot mission)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Inelastic--lowering price below enabling threshold will not increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Commercial insurance through usual channels

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement N/A

Government indemnification requirements for launch services Same as today (range-related and liability caps)

Application # 46

Space Utility - SunSync - deployment mission

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Months
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	Yes	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	Yes
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 46.1

Space Utility - SunSync - servicing flight

Category Commercial

Source CSTS, 3.8.2.2.3 Sun Synchronous Power Satellite

Date 4/25/97 1:55:42 PM

Reviewers Bywater, Ronald/Kim, David/Smith, P. L.

Description

The major market for power is to the major metropolitan areas within the continental United States. Within this market, a premium is paid through existing systems for power provided during peak demand periods. This premium price is paid since generating systems are most efficient if run at constant level. During peak power conditions, new assets or stored power must be brought on line and run solely for this peak power demand.

Major System Assumptions

Comments

Somewhat independent of launch costs. Appears economically not viable. However, launch costs would have to drop to approx. $100/lb if other factors such as initially large investment are overcome. Requires large supporting infrastructure to be developed. e.g. OTV, assembly and maintenance crew services. Robotics (?)

Sector Commercial (US and Foreign)

Orbit LEO

Inclination Polar or near polar

Payload to LEO 10 Klb to 20 Klb

Turn time (for launcher) N/A

Primary payload\cargo Bulk - pressurized

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 100 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required 100X better than present

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 10 per year (7 to 15)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Inelastic--lowering price below enabling threshold will not increase flight rate

Schedule importance Low: Some risk of loss of service, but w/o significant revenue penalty

Launch insurance considerations Commercial insurance through usual channels

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement N/A

Government indemnification requirements for launch services Unknown--could be showstopper

Application # 46.1

Space Utility - SunSync - servicing flight

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Months
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	Yes	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 47

Space Utility - Lunar - deployment mission

Category Commercial

Source CSTS, 3.8.2.2.4 Lunar Based Power Station

Date 4/25/97 1:59:06 PM

Reviewers Bywater,Ronald/Kim, David

Description

After the major contractual studies of the GEO satellite power systems were performed in the late 1970s it was identified that much of the cost was for transporting equipment and components upwards in the Earth's gravitational well. Since that time several studies have generated an interest in producing solar power satellite components and system on the lunar surface or mining the Moon to provide construction material for SPSs. The specific venture examined here is to produce and install large solar power generation and transmission systems on the lunar surface and transmit power back to the Earth for terrestrial use.

Major System Assumptions

Comments

Sector Commercial (US and Foreign)

Orbit Other

Inclination N/A

Payload to LEO Greater than 60 Klb

Turn time (for launcher) N/A

Primary payload\cargo Bulk - unpressurized

Likely deployment period Unknown (too uncertain to say)

Enabling launch price Factor of 3 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	About 100 total (range 61 to 150)
Estimated average flight rate	Not applicable (surge or one-shot mission)
Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	Inelastic--lowering price below enabling threshold will not increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Unknown--could be showstopper

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Application # 47

Space Utility - Lunar - deployment mission

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Bulk cargo--tailor to fit available dimensions
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	Yes
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 47.1

Space Utility - Lunar - servicing flight

Category Commercial

Source CSTS, 3.8.2.2.4 Lunar Based Power Station

Date 4/21/97 2:14:21 PM

Reviewers Bywater,Ronald/Kim, David

Description

After the major contractual studies of the GEO satellite power systems were performed in the late 1970s it was identified that much of the cost was for transporting equipment and components upwards in the Earth's gravitational well. Since that time several studies have generated an interest in producing solar power satellite components and system on the lunar surface or mining the Moon to provide construction material for SPSs. The specific venture examined here is to produce and install large solar power generation and transmission systems on the lunar surface and transmit power back to the Earth for terrestrial use.

Major System Assumptions

Comments

Assumed to be non-manned flight for servicing/scheduled maintenance by tele-robotics.

Sector Commercial (US and Foreign)

Orbit Other

Inclination N/A

Payload to LEO Greater than 60 Klb

Turn time (for launcher) N/A

Primary payload\cargo Bulk - pressurized

Likely deployment period Unknown (too uncertain to say)

Enabling launch price Factor of 100 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 10 per year (7 to 15)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Inelastic--lowering price below enabling threshold will not increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Commercial insurance through usual channels

Launch facilities .range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement N/A

Government indemnification requirements for launch services Unknown--could be showstopper

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Application # 47.1

Space Utility - Lunar - servicing flight

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Bulk cargo--tailor to fit available dimensions
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Months
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	Yes
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 48

Space Utility - Space-to-Space Power Beaming

Category Commercial

Source CSTS 3.8.2.2.5. Space-to-Space Power Beaming

Date 4/25/97 2:00:34 PM

Reviewers Bywater, Ronald/Kim, D. J.

Description

Space-to-space power beaming for the purpose of providing power to orbiting satellites is another possible market area of interest. This area has been identified as a potential near-term application of in-space beaming and as potential market area. The main attraction or advantage to space-to-space power beaming is to be able to simplify satellites by off-loading the power-generation systems and thereby also extending the life of the satellite indefinitely. Options for doing this include microwave or laser power transmission options. The primary concept for such a venture is to place a central "power station" in orbit equipped with large power-generating systems (usually solar arrays). From this centralized power station beamed power is transmitted to other orbital assests to provide them power. The advantages of this are claimed to be lighter, cheaper co-orbiting satellites and lower cost overall to the system architecture.

Major System Assumptions

Assume each power station will be able to power several GSO satellites. Not considering feasibility, it is assumed that the power satellite will provide high power via solar arrays, and transmit power to recipient satellites by laser or microwave, and the receiving medium is lighter and smaller than comparable solar arrays/batteries. Considered low probability mission.

Comments

Sector Commercial (US and Foreign)

Orbit GEO/GSO/HEO

Inclination Equatorial or near equatorial

Payload to LEO Greater than 60 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 3 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 10 per year (7 to 15)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Inelastic--lowering price below enabling threshold will not increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Commercial insurance through usual channels

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Application # 48

Space Utility - Space-to-Space Power Beaming

Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap .reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Special/outsized relative to lift mass in this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Months
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 49
Space Advertising

Category	Commercial
Source	CSTS, 3.10.3 Space Advertising
Date	4/21/97 2:19:29 PM
Reviewers	Bywater, Ronald/Kim, D. J.

Description

The use of launch vehicles as an advertising medium is a newly evolving market with the potential to make substantial financial contributions. Several major commercial advertising firms have already contracted to place advertisements for their clients on both U.S. and international vehicles. In the past, launch vehicle manufacturers have used the advertising space to promote their subcontractors and suppliers, as well as the payload manufacturer or end user. These events have generally not involved any monetary compensation, but have been used to promote overall programs in hope of increased future sales. Although it is extremely unlikely that advertisements could fund an entire mission, they may provide significant supplementary revenue. Advertisements may be purchased on their own, but they are generally integrated into overall promotional campaigns. As such, they have the potential to generate additional revenues on the order of $3 million to $5 million or more per mission. This may approach the funding necessary for a small launch vehicle mission, and the revenue from the additional payloads would be pure profit. NEW REVISION: This concept includes Space Billboard of several miles long, made of lightweight deployable structure, to be visible by naked eyes in the earth. It may be lighted at night time for simple messages or simple logo. (Example: Tether was visible from the earth).

Major System Assumptions

Space policy issue (domestic and international) Launch complex access (international more likely than US) Primary limitation - launch schedule variability - must accommodate event timing of advertising campaign.

Comments

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Deployable satellite/upper stage
Orbit	LEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Wide range of inclinations	***Enabling launch price***	Factor of 3 reduction
Payload to LEO	Less than 5,000 lb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 10 per year (7 to 15)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate

Application # 49

Space Advertising

Schedule importance	Low: Some risk of loss of service, but w/o significant revenue penalty
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Not applicable (or less than today's typical performa
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	N/A
Max g-load and vibration requirement	Much more than today's acceptable (e.g., rail gun lau
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 50

Space Burial

Category Commercial

Source CSTS, 3.10.5 Space Burial

Date 4/19/97 3:32:16 PM

Reviewers Bywater, Ronald/Kim, David

Description

In 1985 the Transportation Department granted mission approval for preliminary plans for Space Services, Inc. (SSI) to carry cremated human remains into space in 1986 or early 1987. SSI, whose president was former astronaut Donald K. "Deke" Slayton, developed the Conestoga booster as a commercial space venture. The launches were to be contracted for by the Celestis Group of Melbourne, Florida, a consortium of morticians and former KSC contractor engineers. LEO mission, with TBD lb. 1 to 2 missions/year from 2000 to 2030.

Major System Assumptions

Based on study a large market exists. Assumes no competitive response from terrestrial based services which may employ the same extended mass reduction technique which reduces each unit from 3-4 lb. to 0.25 ounces. Celestes proposes as many as 10 missions/year of Pegasus class.

Comments

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Bulk - unpressurized
Orbit	MEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	N/A	***Enabling launch price***	Present prices
Payload to LEO	Less than 5,000 lb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 10 per year (7 to 15)
Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	None: No launch schedule criticality, launch as available
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical airport facilities (e.g., package delivery)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Application # 50

Space Burial

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Not applicable (or less than today's typical performa
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	N/A
Max g-load and vibration requirement	Much more than today's acceptable (e.g., rail gun lau
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 51

Novelties

Category Commercial

Source CSTS, 3.10.2 Novelties

Date 4/19/97 3:35:13 PM

Reviewers Kim, David

Description

The novelties area covers the sale of used/spare space assets, objects captured from space, and items flown specifically to be resold as "space trinkets." Although this is an ongoing market, it has been severely limited by the availability of suitable items. Due to the scarceness of these items, their sale has been generally confined to highly specialized auctions. Considering the demand for such items and the prices at which they are sold, it may appear that there is a significant opportunity being missed. However, it must be remembered that it is the scarcity itself that forms the value of these items since their intrinsic value is generally negligible. For instance, moon rocks would have little or no value if it wasn't for their origin.

Major System Assumptions

Comments

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Bulk - unpressurized
Orbit	LEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Inclined (20 to 40 deg)	***Enabling launch price***	Factor of 100 reduction
Payload to LEO	10 Klb to 20 Klb	***Return payload mass***	1000 - 10,000 lb
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 10 per year (7 to 15)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Inelastic--lowering price below enabling threshold will not increase flight rate
Schedule importance	None: No launch schedule criticality, launch as available
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	N/A

Application # 51
Novelties

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Not applicable (or less than today's typical performa
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	No	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 52

Space Product Demonstration

Category Commercial

Source CSTS, 3.10.4 Space Product Demonstration.

Date 4/19/97 3:39:34 PM

Reviewers Kim, David

Description

The ability to demonstrate commercial products on orbit has existed since the early 1980s with the initiation of several commercial launch vehicle companies. The demonstration of products on orbit, like advertising, would be integrated into a company's promotional campaign. In general, demonstrating products on orbit serves little, if any, technical purpose. The companies considering such a demonstration, however, felt the use of their products on orbit provided them technical credibility and further added a feeling of "toughness" and "reliability." This change in public perception is the value-added contribution of an on orbit product demonstration from their point of view. Additionally, if any of these demonstrated products can be returned to earth, it appears that there would be a substantial market for the sale of such items.

Major System Assumptions

Comments

Possibility of docking with space station and transfer cargo to/from Space station

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Bulk - unpressurized
Orbit	LEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Inclined (20 to 40 deg)	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	Less than 5,000 lb	***Return payload mass***	1000 - 10,000 lb
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 3 per year (range 2 to 6)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	None: No launch schedule criticality, launch as available
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	Less than 400 nmi (typical of STS)
Safe abort requirement	Same requirements as today (e.g., STS)

Application # 52
Space Product Demonstration

Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap .reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	*Final-orbit injection required*	No
Return-to-launch site requirements	Yes	*Overflight over populated areas an issue*	No
On-orbit refueling required	No	*On-orbit payload change out required*	No
On-orbit cargo transfer required	No	*On-orbit crew transfer required (space suits)*	No
Launch during conflict conditions	No	*On-orbit crew transfer required (shirt sleeves)*	No
Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	Yes
Alternate landing site(s) required	Yes	*Return-to-launch-site capability after abort*	Yes
Multi-azimuth launch	No	*Payload fuel handling prior to launch*	No
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 53

New Missions - Space Business Park - deployment mission

Category Commercial

Source CSTS, 3.7.7. Space Business Park

Date 4/19/97 3:44:01 PM

Reviewers Bywater, Ronald/Johnson, Ray/Kim, David

Description

Conceptualized to represent a multi-use commercially oriented facility in Earth orbit, this market area was identified from the preliminary results of several market areas that did not generate enough revenues by themselves to justify a separate space facility. Numerous business opportunities have been identified that have the potential for using an in-space facility as part of their routine business operations, including space manufacturing, and industrial research. Some of the unique resources from space include: vacuum, microgravity, wide range of temperatures, unattenuated solar spectrum, radiation, and no ecology based environmental restrictions. As an aggregate of this market area's demand, it was assessed that a multi-use, commercially oriented space facility could be a viable commercial venture at launch costs of greater then $500/lb to orbit. LEO and GEO platforms with 6 different types for total launch rate of 10 to 18 per year from 2000 to 2010 time frame

Major System Assumptions

This application is for the nonrecurring build-up of the space facility. It is assumed that the facility weighs approximately 1,000,000 lb. Only the LEO case is considered.

Comments

This segment focuses on assembly of business park, so no consideration given to operating crew. Any crews will be assembly crews spending Shuttle-type periods on orbit. Those assembly crews are considered part of a separate contract/service required as infrastructure to support general space construction typical of the time frame during which this project is undertaken.

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Bulk - unpressurized
Orbit	LEO	***Likely deployment period***	Far-term: post 2020
Inclination	Inclined (20 to 40 deg)	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	Greater than 60 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	Present reliability
Est. flights for one-time surge	About 10 total (range 7 to 15)
Estimated average flight rate	Not applicable (surge or one-shot mission)
Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Commercial insurance through usual channels

Application # 53

New Missions - Space Business Park - deployment mission

Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Weeks
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Bulk cargo--tailor to fit available dimensions
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - uncooperative (passive) target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	*Final-orbit injection required*	No
Return-to-launch site requirements	No	*Overflight over populated areas an issue*	No
On-orbit refueling required	Yes	*On-orbit payload change out required*	No
On-orbit cargo transfer required	Yes	*On-orbit crew transfer required (space suits)*	Yes
Launch during conflict conditions	N/A	*On-orbit crew transfer required (shirt sleeves)*	No
Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	Yes
Alternate landing site(s) required	N/A	*Return-to-launch-site capability after abort*	N/A
Multi-azimuth launch	No	*Payload fuel handling prior to launch*	No
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 53.1

New Missions - Space Business Park - servicing flight

Category Commercial

Source CSTS, 3.7.7. Space Business Park

Date 4/19/97 3:48:06 PM

Reviewers Bywater, Ronald/Johnson, Ray/Kim, David

Description

Conceptualized to represent a multi-use commercially oriented facility in Earth orbit, this market area was identified from the preliminary results of several market areas that did not generate enough revenues by themselves to justify a separate space facility. Numerous business opportunities have been identified that have the potential for using an in-space facility as part of their routine business operations, including space manufacturing, and industrial research. Some of the unique resources from space include: vacuum, microgravity, wide range of temperatures, unattenuated solar spectrum, radiation, and no ecology based environmental restrictions. As an aggregate of this market area's demand, it was assessed that a multi-use, commercially oriented space facility could be a viable commercial venture at launch costs of greater then $500/lb to orbit. LEO and GEO platforms with 6 different types for total launch rate of 10 to 18 per year from 2000 to 2010 time frame

Major System Assumptions

This application is for the routine servicing of an existing Space Business Park. It is assumed that the spacelift vehicle will transport both crews and cargo to the business park.

Comments

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Bulk - unpressurized
Orbit	LEO	***Likely deployment period***	Far-term: post 2020
Inclination	Inclined (20 to 40 deg)	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	20 Klb to 40 Klb	***Return payload mass***	1000 - 10,000 lb
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	10X better than present
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 10 per year (7 to 15)
Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities .range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	Less than 400 nmi (typical of STS)

Application # 53.1

New Missions - Space Business Park - servicing flight

Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Bulk cargo--tailor to fit available dimensions
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	No	*Final-orbit injection required*	No
Return-to-launch site requirements	Yes	*Overflight over populated areas an issue*	No
On-orbit refueling required	Yes	*On-orbit payload change out required*	Yes
On-orbit cargo transfer required	Yes	*On-orbit crew transfer required (space suits)*	Yes
Launch during conflict conditions	N/A	*On-orbit crew transfer required (shirt sleeves)*	Yes
Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	Yes
Alternate landing site(s) required	Yes	*Return-to-launch-site capability after abort*	N/A
Multi-azimuth launch	No	*Payload fuel handling prior to launch*	No
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 53.2

New Missions - Space Medical

Category	Commercial
Source	CSTS, 3.7.3 & 3.7.4. Space Medical Facilities/Space Hospital
Date	4/25/97 2:02:08 PM
Reviewers	Kim, David

Description

Use space environment to treat life-threatening or debilitating diseases. Some of major diseases/sicknesses that may be benefited by space treatments are: Orthopedics, burns and physical therapy. Space hospital is for long term care on orbit to treat life-threatening or debilitating diseases, to reduce the suffering with chronic illnesses, or to improve the quality of life of the permanently disabled. Based upon market contacts, several promising medical treatments that used the space environment (primarily microgravity) were identified. However, there is a large level of uncertainty in the use of these treatments, based upon a lack of clinical or experimental data on them. Furthermore, to ship a patient to space and provide the treatment on orbit at rates equivalent to terrestrial costs would require launch costs, of $100/lb or less.

Major System Assumptions

Economic viability is questionable at this time due to limited data available and potential benefits. Space Medical Facility is assumed to be a module of Space Business Park.

Comments

Assume there is a space hospital facility already deployed, and this application just considers delivery and return of patients.

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Man - untrained, as passenger
Orbit	LEO	***Likely deployment period***	Far-term: post 2020
Inclination	Inclined (20 to 40 deg)	***Enabling launch price***	Factor of 100 reduction
Payload to LEO	20 Klb to 40 Klb	***Return payload mass***	1000 - 10,000 lb
Turn time (for launcher)	Weeks	***Standing-alert capability***	Hours

Launch reliability required	100X better than present
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 100 per year (61 to 150)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	High: National security or severe launch-window constraints
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical airport facilities (e.g., package delivery)
Return cross-range requirement	Greater than 400 nmi including once-around capability

Application # 53.2

New Missions - Space Medical

Safe abort requirement	More stringent requirements
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Special/outsized relative to lift mass in this category
On-orbit mission duration (for launch vehicle)	Hours
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Less than today's required
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	Must be considered
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	Yes	***Final-orbit injection required***	Yes
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	Yes	***On-orbit crew transfer required (shirt sleeves)***	Yes
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 53.3

New Missions - Space Settlements (O'Neil Habitats)

Category Commercial

Source CSTS, 3.7.5. Space Settlements

Date 4/25/97 7:31:04 AM

Reviewers Kim, David/Ruth, Edward

Description

Long term manned settlements in space, based on moon, planets or LEO. Representing the popular idea of large human habitations in space, this market had the weakness that the participants of the large habitats needed some occupation and the settlement needed some cash flow to justify market investment and support. Such cash flows could only be found if other large-scale space business activities, such as solar power satellite (SPS) construction in GEO, were underway. Based upon the market area potentials for these other areas, the assessed market for space settlements was determined to occur with transportation systems cost well under $100/lb to orbit.

Major System Assumptions

O'Neil type large space habitat in L5 orbit assumes daily flights required for both initial construction and day-to-day operation. No major economical benefits in near future.

Comments

Assumed primary payload is bulk material but will also carry human passengers. Assumed initial deployment and routine operations will have similar flight rates. Question 4) Cis-lunar flight. Revised by E. Ruth 19 APR 97.

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Bulk - unpressurized
Orbit	Other	***Likely deployment period***	Unknown (too uncertain to say)
Inclination	Equatorial or near equatorial	***Enabling launch price***	Factor of 100 reduction
Payload to LEO	40 Klb to 60 Klb	***Return payload mass***	Over 10,000 lb
Turn time (for launcher)	Hours	***Standing-alert capability***	N/A

Launch reliability required	Equivalent to commercial AC flight reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 300 or more per year
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Low: Some risk of loss of service, but w/o significant revenue penalty
Launch insurance considerations	Self insured (commercial)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	Less than 400 nmi (typical of STS)
Safe abort requirement	More stringent requirements

Application # 53.3

New Missions - Space Settlements (O'Neil Habitats)

Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Hours
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Days
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Months
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	Must be considered
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	No
On-orbit refueling required	Yes	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	Yes
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 53.4

New Missions - Space Settlements (Lunar Outpost)

Category Commercial

Source CSTS, 3.7.5. Space Settlements

Date 4/25/97 7:30:46 AM

Reviewers Kim, David/Ruth, Edward

Description

Long term manned settlements in space, based on moon, planets or LEO. Representing the popular idea of large human habitations in space, this market had the weakness that the participants of the large habitats needed some occupation and the settlement needed some cash flow to justify market investment and support. Such cash flows could only be found if other large-scale space business activities, such as solar power satellite (SPS) construction in GEO, were underway. Based upon the market area potentials for these other areas, the assessed market for space settlements was determined to occur with transportation systems cost well under $100/lb to orbit.

Major System Assumptions

This is for deployment of small science outpost on Moon. Assumes monthly flights required for both initial construction and day-to-day operation.

Comments

Space settlement or permanent habitat is considered not economically viable by the CSTS conclusion. However, there may be some scientific value to a permanent settlement. This application only considered the initial build-up of Lunar Base. Periodic resupply and crew delivery mission, as well as crew/cargo return would have somewhat different launch requirements. Question 4) Cis-lunar flight. Revised by E. Ruth 19 APR 97.

Sector Civil (Foreign or joint programs)

Orbit Other

Inclination Equatorial or near equatorial

Payload to LEO 40 Klb to 60 Klb

Turn time (for launcher) Days

Primary payload\cargo Bulk - unpressurized

Likely deployment period Unknown (too uncertain to say)

Enabling launch price Factor of 10 reduction

Return payload mass Over 10,000 lb

Standing-alert capability N/A

Launch reliability required 10X better than present

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 10 per year (7 to 15)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Application # 53.4

New Missions - Space Settlements (Lunar Outpost)

Return cross-range requirement	Less than 400 nmi (typical of STS)
Safe abort requirement	More stringent requirements
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Days
Launch range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	Yes
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 53.5

New Missions - Space Agriculture

Category Commercial

Source CSTS, 3.7.1.2 Space Agriculture.

Date 4/19/97 4:02:32 PM

Reviewers Kim, David

Description

Initially, this market area was conceptualized as a large in-space facility providing high-density and high-intensity agricultural production. As with the space settlements market, this venture would require other very large in-space business activities to occur before justifying this market area. Based upon the market area potentials for these other areas, the assessed market for space agriculture was determined to occur with transportation systems costs well under $100/lb to orbit

Major System Assumptions

No economic viability unless other large scale space application is developed (i.e., Space Habitat, Space Business Park, etc.).

Comments

Sector Civil (Foreign or joint programs)

Orbit LEO

Inclination Inclined (20 to 40 deg)

Payload to LEO 40 Klb to 60 Klb

Turn time (for launcher) N/A

Primary payload\cargo Bulk - unpressurized

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 100 reduction

Return payload mass Over 10,000 lb

Standing-alert capability N/A

Launch reliability required Present reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 10 per year (7 to 15)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance Low: Some risk of loss of service, but w/o significant revenue penalty

Launch insurance considerations Commercial insurance through usual channels

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement Less than 400 nmi (typical of STS)

Safe abort requirement N/A

Government indemnification requirements for launch services Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload Not a driver--don't care

Application # 53.5

New Missions - Space Agriculture

Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	*Final-orbit injection required*	Yes
Return-to-launch site requirements	Yes	*Overflight over populated areas an issue*	No
On-orbit refueling required	No	*On-orbit payload change out required*	Yes
On-orbit cargo transfer required	Yes	*On-orbit crew transfer required (space suits)*	No
Launch during conflict conditions	No	*On-orbit crew transfer required (shirt sleeves)*	Yes
Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	Yes
Alternate landing site(s) required	Yes	*Return-to-launch-site capability after abort*	Yes
Multi-azimuth launch	No	*Payload fuel handling prior to launch*	No
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Application # 53.6

Entertainment - Orbiting Movie Studio

Category Commercial

Source CSTS, 3.6.3 Orbiting Movie Studio

Date 4/19/97 4:27:43 PM

Reviewers Johnson, Ray F./Kim, David

Description

Explore a concept of using an in-space facility for feature film or TV show production. Unique aspect of space environment such as microgravity, planets, moon, and stars can be exploited by the film industry. It requires low transportation cost, based upon current industry production costs, but generates a potential 650K lb/year transportation market at $100/lb LEO transportation price. Deliver cargo and passengers to a LEO business park. Annual estimated mass of 650 Klb based on launching 12.5 Klb on a weekly basis. Orbiting facility has an initial launch mass of 80 Klb to a LEO orbit, operational by 2005-6 time frame. Need a passenger transporter, for a group of 12 to 20 people with camera equipemnt to and from the facility. Goal of < $ 400/lb, weekly launch rate.

Major System Assumptions

This facility is assumed to be attached to an existing space facility, which provides common housekeeping functions, such as power generation, thermal control, and attitude control. For the purposes of this evaluation, the spacelift requirements are based on operating the studio and the recurring transfer of crews and equipment to and from the studio. I am assuming an implementation time frame of beyond 2020, which is well beyond the CSTS assumption of 2008 to 2010.

Comments

Sector Commercial (US and Foreign)

Orbit LEO

Inclination Inclined (20 to 40 deg)

Payload to LEO 10 Klb to 20 Klb

Turn time (for launcher) Weeks

Primary payload\cargo Man - untrained, as passenger

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 100 reduction

Return payload mass Over 10,000 lb

Standing-alert capability N/A

Launch reliability required Equivalent to commercial AC flight reliability

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 30 per year (16 to 60)

Confidence in flight rates Medium confidence (+- 50%)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Commercial insurance through usual channels

Launch facilities _range requirements Typical airport facilities (e.g., package delivery)

Application # 53.6

Entertainment - Orbiting Movie Studio

Return cross-range requirement	Less than 400 nmi (typical of STS)
Safe abort requirement	More stringent requirements
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Days
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Bulk cargo--tailor to fit available dimensions
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	Must be considered
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	No
On-orbit refueling required	Yes	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	Yes
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 53.7

Entertainment - Space Athletic Events

Category Commercial

Source CSTS, 3.6.4 Space Athletic Events

Date 4/19/97 4:32:21 PM

Reviewers Johnson, Ray F./Kim, David

Description

Use of the space environment as the venues for a major broadcast sporting event. This concept is for athletic events performed in an on-orbit facility, and broadcasts (beamed) to terrestrial audiences. The analysis and contacts on this market area indicated positive results, if it was included in a multi- use facility-- with revenue-generating options identified for single and multiple events with launch costs reduced at least an order of magnitude from today's price. Deliver cargo and passengers, approximately 20Klb to a LEO business park. The initial orbiting facility is approximately size of an STS External Tank to a LEO orbit, for 2005 - 6 time frame. At a cost goal of < $100/lb, it will accommodate 426 to 850 Klb/year, at < $ 500/lb, the system must accommodate 16 to 66 Klb/yr. Weekly flight rate possible.

Major System Assumptions

Assume the facility is part of a business park and the spacelift characteristics outlined in the survey are for recurring delivery of cargo and passengers.

Comments

Sector	Commercial (US and Foreign)	***Primary payload/cargo***	Man - untrained, as passenger
Orbit	LEO	***Likely deployment period***	Far-term: post 2020
Inclination	Inclined (20 to 40 deg)	***Enabling launch price***	Factor of 100 reduction
Payload to LEO	10 Klb to 20 Klb	***Return payload mass***	Over 10,000 lb
Turn time (for launcher)	Weeks	***Standing-alert capability***	N/A

Launch reliability required	Equivalent to commercial AC flight reliability
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 30 per year (16 to 60)
Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	Less than 400 nmi (typical of STS)
Safe abort requirement	More stringent requirements

Application # 53.7

Entertainment - Space Athletic Events

Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing/bay-size requirements	Special/outsized relative to lift mass in this category
On-orbit mission duration (for launch vehicle)	Hours
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	Must be considered
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	Yes
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	Yes
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 53.8

Entertainment - Space Theme Park

Category Commercial

Source CSTS, 3.6.6. Space Theme Park

Date 4/25/97 2:03:41 PM

Reviewers Johnson, Ray F./Kim, D. J.

Description

A mass market using an in-space facility to provide entertainment. The concept of using the space environment as a unique platform for space theme attractions continues as an area of interest within a multi-use commercial facility associated with space tourism. Moreover, contacts within the industry have indicated there is the potential for near- term demand for high-quality real-time data for interactive "space rides" using virtual reality systems. A 15 Klb/year transportation market was identified at current launch costs, including piggyback and small sat systems. The larger space-based theme park/resort market requires substantially lower launch costs, under $400/lb. Deliver cargo and passengers to a LEO business park. Initial delivery of orbiting station: TBD lb, to LEO build up: Operational: Passenger service from 15 - 25 passengers to 75+ passengers later on. At current launch cost, the system must deliver 6 - 42 Klb/yr, at $ 500/lb, 360 to 830 Klb/yr, at < $100/lb, 700 to 7200 Lb/yr. Initially, 9 missions/yr for build up phase to 52 missions/yr initially to 135/yr at $ 100/lb launch cost.

Major System Assumptions

The CSTS study considered two concepts for a space theme park. The first is a ground-based "virtual" space theme park that uses LEO satellites to provide a video link to an Earth-based entertainment center. The second concept is an in-space theme park that is used by space tourist. For the purposes of this survey, the responses to the questions relate to the first concept since it is the more practical concept and has a higher probability of being implemented.

Comments

Sector	Commercial (US and Foreign)	***Primary payload\cargo***	Deployable satellite/upper stage
Orbit	LEO	***Likely deployment period***	Near-term: 2000 - 2020
Inclination	Inclined (20 to 40 deg)	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	10 Klb to 20 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	10X better than present
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 3 per year (range 2 to 6)
Confidence in flight rates	Low confidence (just a guess)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Low: Some risk of loss of service, but w/o significant revenue penalty

Application # 53.8

Entertainment - Space Theme Park

Launch insurance considerations	Commercial insurance through usual channels
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	N/A
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	No	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 56

New Missions - Debris Removal

Category Commercial

Source CSTS, 3.7.2. Debris Removal

Date 4/25/97 2:04:11 PM

Reviewers David J. Kim

Description

Orbital debris is becoming more and more of a significant problem in space operations. As future space operations increase, this problem may be expected to grow. This market area examined the market potential of mitigating the impact of orbital debris, including the market viability of dedicated debris removal systems. However, the market assessment showed that for LEO operations, this market may most effectively be addressed by regulation and additional shielding on LEO systems. No significant space transportation demand was identified for this market area.

Major System Assumptions

This concept is different from concept #11 (NWV), in that this proposes actual debris collection system, rather than a de-orbiting debris (11). CSTS study proposed 3 satellites, one each for LEO, GEO and high polar orbit. This concept originated from Johnson Space Center, NASA. Q.4 should be interpreted as multiple orbits, LEO, GEO, and Inclined.

Comments

This concept covers 3 different orbits, LEO, GEO and Inclined. Limited data field does not permit multiple entries.

Sector Civil (Foreign or joint programs)

Orbit Other

Inclination Wide range of inclinations

Payload to LEO Greater than 60 Klb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 10 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required 10X better than present

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 3 per year (range 2 to 6)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Inelastic--lowering price below enabling threshold will not increase flight rate

Schedule importance None: No launch schedule criticality, launch as available

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement N/A

Application # 56

New Missions - Debris Removal

Government indemnification requirements for launch services	N/A

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	N/A
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - uncooperative (passive) target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	No	***On-orbit crew transfer required (space suits)***	No
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	N/A	***Return-to-launch-site capability after abort***	N/A
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	No

Application # 58

Space Mining - LOX - deployment mission

Category Commercial

Source CSTS, 3.9.2 Lunar Liquid Oxygen (LOX).

Date 4/25/97 2:04:32 PM

Reviewers Wolfe, Malcolm/Ruth, Edward/Kim, David

Description

LOX produced on the lunar surface has the potential of replacing LOX transported from Earth for lunar orbit operations and for return of astronauts and equipment from the lunar surface. It also has the potential of being used in deep space or planetary missions.

Major System Assumptions

Assume a 300,000 lb facility on the moon.

Comments

Question 4) cis-lunar flight. Revised by E. Ruth 18 APR 97 d. J. Kim 21 April - changed flight rate and rendezvous requirements.

Sector Civil (Foreign or joint programs)

Orbit Other

Inclination Equatorial or near equatorial

Payload to LEO Greater than 60 Klb

Turn time (for launcher) N/A

Primary payload\cargo Bulk - pressurized

Likely deployment period Far-term: post 2020

Enabling launch price Factor of 100 reduction

Return payload mass N/A

Standing-alert capability N/A

Launch reliability required 100X better than present

Est. flights for one-time surge About 100 total (range 61 to 150)

Estimated average flight rate Not applicable (surge or one-shot mission)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Government launch (self insured)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement N/A

Government indemnification requirements for launch services Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload Not a driver--don't care

Injection accuracy requirement (launch system) Typical of today's launch vehicles

Application # 58

Space Mining - LOX - deployment mission

Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	More stringent (e.g. because of higher launch rates)
Payload fairing\bay-size requirements	Bulk cargo--tailor to fit available dimensions
On-orbit mission duration (for launch vehicle)	Days
Launch range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	*Final-orbit injection required*	Yes
Return-to-launch site requirements	No	*Overflight over populated areas an issue*	No
On-orbit refueling required	No	*On-orbit payload change out required*	No
On-orbit cargo transfer required	Yes	*On-orbit crew transfer required (space suits)*	Yes
Launch during conflict conditions	N/A	*On-orbit crew transfer required (shirt sleeves)*	No
Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	Yes
Alternate landing site(s) required	N/A	*Return-to-launch-site capability after abort*	N/A
Multi-azimuth launch	No	*Payload fuel handling prior to launch*	No
Crew Requirement	No	*Payload fuel handling and safing after landing*	Yes

Application # 58.1

Space Mining - LOX - servicing flight

Category Commercial

Source CSTS, 3.9.2 Lunar Liquid Oxygen (LOX).

Date 4/25/97 2:05:54 PM

Reviewers Wolfe, Malcolm/Johnson, Ray/Ruth, Edward/Kim, D. J.

Description

LOX produced on the lunar surface has the potential of replacing LOX transported from Earth for lunar orbit operations and for return of astronauts and equipment from the lunar surface. It also has the potential of being used in deep space or planetary missions.

Major System Assumptions

This application is for the servicing of an existing lunar facility.

Comments

Question 4) Cis-lunar flight. Revised by E. Ruth 19 APR 97 d. Kim 21 April 97 - launch cost and crew return to be consistent with described mission.

Sector	Civil (Foreign or joint programs)	***Primary payload\cargo***	Bulk - unpressurized
Orbit	Other	***Likely deployment period***	Far-term: post 2020
Inclination	Equatorial or near equatorial	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	20 Klb to 40 Klb	***Return payload mass***	1000 - 10,000 lb
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	10X better than present
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 10 per year (7 to 15)
Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Government launch (self insured)
Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	Less than 400 nmi (typical of STS)
Safe abort requirement	Same requirements as today (e.g., STS)
Government indemnification requirements for launch services	Greater than today

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles

Application # 58.1

Space Mining - LOX - servicing flight

Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Bulk cargo--tailor to fit available dimensions
On-orbit mission duration (for launch vehicle)	Weeks
Launch range operations for application	Special operations--more extensive than today
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Periodic, scheduled service (daily, weekly, monthly)
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	Must be considered
Crew/passenger ejection during ascent/descent	Required

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	Yes
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	Yes
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	Yes	***Payload fuel handling and safing after landing***	Yes

Application # 59
Space Mining - Helium-3 (He3) - deployment mission

Category Commercial

Source CSTS, 3.9.3 Helium-3 (He3)

Date 4/25/97 2:06:03 PM

Reviewers Wolfe, Malcolm/ Johnson, Ray/Ruth, Edward

Description

Demand for lunar He3 is predicated upon the commercial generation of electrical power from fusion power plants that use deuterium/helium-3 or helium-3/helium-3 fusion reactions. There is only enough He3 in weapons stockpiles for research and initial development of these types of fusion. Predictions for the achievements of commercial fusion of this type ranges from 2015 at the earliest to 2030 in more conservative productions. A cost-to-orbit of $300/lb to LEO must be obtained before lunar helium becomes a viable space launch market item. This cost is based on achieving He3-generated electricity rates that are competitive with current rates. He3 is an attractive fuel for nuclear fusion reactors. There are two reasons for this attractiveness: (1) the deuterium/helium-3 reaction does not produce any fast neutrons and (2) the helium-3/helium-3 reaction produces no radioactivity at all (fig. 3.9.3.1-1). Because of the very large amount of energy that can be generated by even small amounts of He3, it appears economically viable to mine it from the lunar surface. Figure 3.9.3.1-2 outlines and He3 mining strategy developed by the University of Wisconsin that produces 33 kg of He3 per year. Figure 3.9.3.1-3 indicates the required equipment and crew needed for a mining operation.

Major System Assumptions

The mission requirements are for the building of the facility. They do not include the recurring servicing of the facility which is addressed in question 59.1. The CSTS Study does not include an estimate of the required mass for the facility. It is assumed to weigh approximately 300,000 lb.

Comments

Question 4) Cis-lunar flight Revised by E. Ruth 19 APR 97.

Sector	Civil (Foreign or joint programs)	***Primary payload\cargo***	Bulk - pressurized
Orbit	Other	***Likely deployment period***	Far-term: post 2020
Inclination	Equatorial or near equatorial	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	Greater than 60 Klb	***Return payload mass***	N/A
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	10X better than present
Est. flights for one-time surge	About 10 total (range 7 to 15)
Estimated average flight rate	Not applicable (surge or one-shot mission)
Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty

Application # 59

Space Mining - Helium-3 (He3) - deployment mission

Launch insurance considerations	Government launch (self insured)
Launch facilities .range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	N/A
Safe abort requirement	Same requirements as today (e.g., STS)
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Bulk cargo--tailor to fit available dimensions
On-orbit mission duration (for launch vehicle)	Weeks
Launch .range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	Days
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - uncooperative (passive) target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	Yes
Return-to-launch site requirements	No	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	Yes
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	No	***Return-to-launch-site capability after abort***	No
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	Yes

Application # 59.1
Space Mining - Helium-3 (He3) - servicing flight

Category Commercial

Source CSTS, 3.9.3 Helium-3 (He3)

Date 4/25/97 2:06:29 PM

Reviewers Wolfe, Malcolm/ Johnson, Ray/Ruth, Edward

Description

Demand for lunar He3 is predicated upon the commercial generation of electrical power from fusion power plants that use deuterium/helium-3 or helium-3/helium-3 fusion reactions. There is only enough He3 in weapons stockpiles for research and initial development of these types of fusion. Predictions for the achievements of commercial fusion of this type ranges from 2015 at the earliest to 2030 in more conservative productions. A cost-to-orbit of $300/lb to LEO must be obtained before lunar helium becomes a viable space launch market item. This cost is based on achieving He3-generated electricity rates that are competitive with current rates. He3 is an attractive fuel for nuclear fusion reactors. There are two reasons for this attractiveness: (1) the deuterium/helium-3 reaction does not produce any fast neutrons and (2) the helium-3/helium-3 reaction produces no radioactivity at all (fig. 3.9.3.1-1). Because of the very large amount of energy that can be generated by even small amounts of He3, it appears economically viable to mine it from the lunar surface. Figure 3.9.3.1-2 outlines and He3 mining strategy developed by the University of Wisconsin that produces 33 kg of He3 per year. Figure 3.9.3.1-3 indicates the required equipment and crew needed for a mining operation.

Major System Assumptions

This application supports an existing Lunar Facility.

Comments

Question 4) Cis-lunar flight Revised E. Ruth 19 APR 97 d. Kim 21 Apr 97 (revised for return payload to launch site).

Sector	Civil (Foreign or joint programs)	***Primary payload\cargo***	Bulk - pressurized
Orbit	Other	***Likely deployment period***	Far-term: post 2020
Inclination	Equatorial or near equatorial	***Enabling launch price***	Factor of 10 reduction
Payload to LEO	40 Klb to 60 Klb	***Return payload mass***	1000 - 10,000 lb
Turn time (for launcher)	N/A	***Standing-alert capability***	N/A

Launch reliability required	10X better than present
Est. flights for one-time surge	Not applicable (steady-state average flight rate)
Estimated average flight rate	About 10 per year (7 to 15)
Confidence in flight rates	Medium confidence (+- 50%)
Launch price elasticity	Elastic--lowering price will greatly increase flight rate
Schedule importance	Medium: Loss of service or revenue penalty
Launch insurance considerations	Government launch (self insured)

Application # 59.1

Space Mining - Helium-3 (He3) - servicing flight

Launch facilities range requirements	Typical of today's full-service range facilities (e.g., ETR, WTR)
Return cross-range requirement	Less than 400 nmi (typical of STS)
Safe abort requirement	Same requirements as today (e.g., STS)
Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Not a driver--don't care
Injection accuracy requirement (launch system)	Typical of today's launch vehicles
Surge requirements (for individual launch vehicle)	N/A
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Weeks
Launch range operations for application	Typical civil (NASA) control (as today)
Acceptable transition time to final orbit	Hours
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	Yes - cooperative target
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	***Final-orbit injection required***	No
Return-to-launch site requirements	Yes	***Overflight over populated areas an issue***	No
On-orbit refueling required	No	***On-orbit payload change out required***	No
On-orbit cargo transfer required	Yes	***On-orbit crew transfer required (space suits)***	Yes
Launch during conflict conditions	N/A	***On-orbit crew transfer required (shirt sleeves)***	No
Payload fuel handling flight abort	No	***Encapsulated or containerized payload***	Yes
Alternate landing site(s) required	Yes	***Return-to-launch-site capability after abort***	No
Multi-azimuth launch	No	***Payload fuel handling prior to launch***	No
Crew Requirement	No	***Payload fuel handling and safing after landing***	Yes

Application # 60

Nanosat Applications

Category Dual

Source Final Frontier, June 1997 & Aerospace America xx 96

Date 4/23/97 7:50:03 AM

Reviewers Kim, David

Description

Nanosat technology may revolutionize the space application by miniaturizing the satellite size to a "toaster" size or "coffee can" size, weighing no more than 10 to 20 lb. NASA,ARPA, various labs and commercial companies are investigating miniaturization technology and related space applications to reduce the size of space probe (Cassini class) to a several micro satellites with specific payloads. Several dozen nanosatellites will be able to replace one large satellite, while reducing risk and allowing multiple payloads and multiple coverage. Some of the key technologies will be demonstrated in the early 21st century.

Major System Assumptions

This is a class of satellite that may change the way we think of satellites in the future. This class of satellite may apply to all, if not most, of already mentioned innovative space applications. This entry assumes if this technology was to be available in the future, what its impact would be to the space transportation segment, rather than a specific application description.

Comments

***

Sector Commercial (US and Foreign)

Orbit Multiple orbit cases

Inclination Wide range of inclinations

Payload to LEO Less than 5,000 lb

Turn time (for launcher) N/A

Primary payload\cargo Deployable satellite/upper stage

Likely deployment period Far-term: post 2020

Enabling launch price Present prices

Return payload mass N/A

Standing-alert capability N/A

***

Launch reliability required 10X better than present

Est. flights for one-time surge Not applicable (steady-state average flight rate)

Estimated average flight rate About 30 per year (16 to 60)

Confidence in flight rates Low confidence (just a guess)

Launch price elasticity Elastic--lowering price will greatly increase flight rate

Schedule importance Medium: Loss of service or revenue penalty

Launch insurance considerations Self insured (commercial)

Launch facilities range requirements Typical of today's full-service range facilities (e.g., ETR, WTR)

Return cross-range requirement N/A

Safe abort requirement N/A

Application # 60

Nanosat Applications

Government indemnification requirements for launch services	Same as today (range-related and liability caps)

Time required to swap reintegrate substitute payload	Weeks
Injection accuracy requirement (launch system)	Greater accuracy required
Surge requirements (for individual launch vehicle)	2X baseline flight rate
Environmental standards for applications	Same as standards for today's space missions
Payload fairing\bay-size requirements	Typical of LV class for this category
On-orbit mission duration (for launch vehicle)	Minutes (expendable)
Launch range operations for application	Commercial control (about the same as today)
Acceptable transition time to final orbit	Months
Max g-load and vibration requirement	Today's nominal are acceptable
Call-up time for space-transportation service	Launch on schedule, 3 months or longer lead time
Rendezvous requirement	No
Rapid cool-down requirements for return payload	N/A
Crew/passenger ejection during ascent/descent	N/A

Nuclear materials on board	No	*Final-orbit injection required*	Yes
Return-to-launch site requirements	No	*Overflight over populated areas an issue*	No
On-orbit refueling required	No	*On-orbit payload change out required*	No
On-orbit cargo transfer required	No	*On-orbit crew transfer required (space suits)*	No
Launch during conflict conditions	N/A	*On-orbit crew transfer required (shirt sleeves)*	No
Payload fuel handling flight abort	No	*Encapsulated or containerized payload*	Yes
Alternate landing site(s) required	N/A	*Return-to-launch-site capability after abort*	N/A
Multi-azimuth launch	No	*Payload fuel handling prior to launch*	No
Crew Requirement	No	*Payload fuel handling and safing after landing*	No

Bibliography

1. *Spacecast 2020.* USAF Air University. 10 Sept. 1993. http://www.au.af.mil/Spacecast/Spacecast.html
2. *New World Vistas.* Scientific Advisory Board. 15 December, 1995. http://www.plk.af.mil/ORG_CHART/XP/XPB/nwvistas.html
3. *Air Force 2025.* USAF Air University. December, 1994. http://www.au.af.mil/au/2025/
4. *Commercial Space Transportation Study (CSTS).* July 1994. http://www.islandone.org/Policy/CSTS-BruceDunn-9407.html
5. *Final Frontier.* June 1997.

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Future Spacelift Requirements Study

Appendix 3
Additional Threshold Characteristics for Innovative Applications

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Introduction

This appendix contains plots of threshold characteristics for innovative applications that were not presented in the main report. These plots summarize the information in the innovative applications database (Appendix 2) according to each launch requirement category. The data is presented in two ways: one set comprising the entire database; and the other set comprising only those applications that have Space Transportation Economic Index (STEI) value of less than 3.

List of Characteristics

- Sector
- Orbit
- Inclination
- Est. flights for one-time surge
- Confidence in flight rates
- Launch price elasticity
- Launch insurance considerations
- Return payload mass
- Standing-alert capability
- Turn time (for launcher)
- Schedule importance
- Launch facilities range requirements
- Likely deployment period
- Payload to LEO
- Estimated average flight rate
- Enabling launch price
- Launch reliability required

List of Characteristics (Cont'd)

- Primary payloadlcargo
- Acceptable transition time to final orbit
- Injection accuracy requirement (basic launch system)
- Rendezvous requirement
- Max g-load and vibration requirement
- Surge requirements (for individual launch vehicle)
- Environmental standards for applications
- On-orbit mission duration (for launch vehicle)
- Time required to swap reintegrate substitute payload
- Crew/passenger ejection during ascent/descent
- Payload fairinglbay-size requirements
- Call-up time for space-transportation service
- Rapid cool-down requirements for return payload
- Launch range operations for application
- Safe abort requirement
- Return cross-range requirement
- Government indemnification requirements for launch services
- Multi-azimuth launch

List of Characteristics (Cont'd)

- Crew Requirement
- Final-orbit injection required
- Return-to-launch site requirements
- Alternate landing site(s) required
- Nuclear materials on board
- Overflight over populated areas an issue
- On-orbit refueling required
- On-orbit payload change out required
- On-orbit cargo transfer required
- On-orbit crew transfer required (space suits)
- On-orbit crew transfer required (shirt sleeves)
- Return-to-launch-site capability after abort
- Encapsulated or containerized payload
- Payload fuel handling prior to launch
- Payload fuel handling inflightlabort
- Payload fuel handling and safing after landing
- Launch during conflict conditions

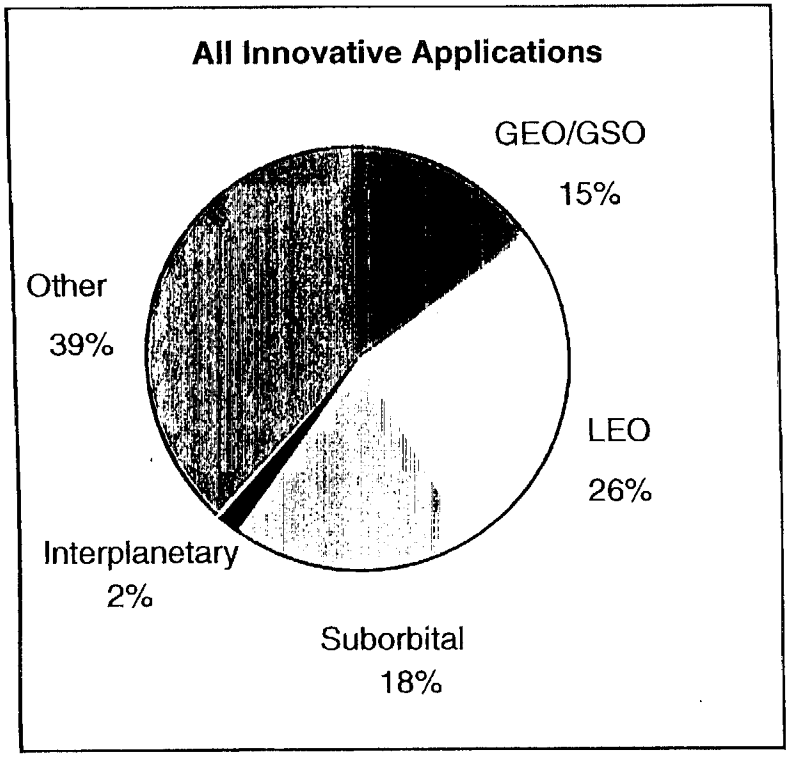
List of STEI < 3 Applications

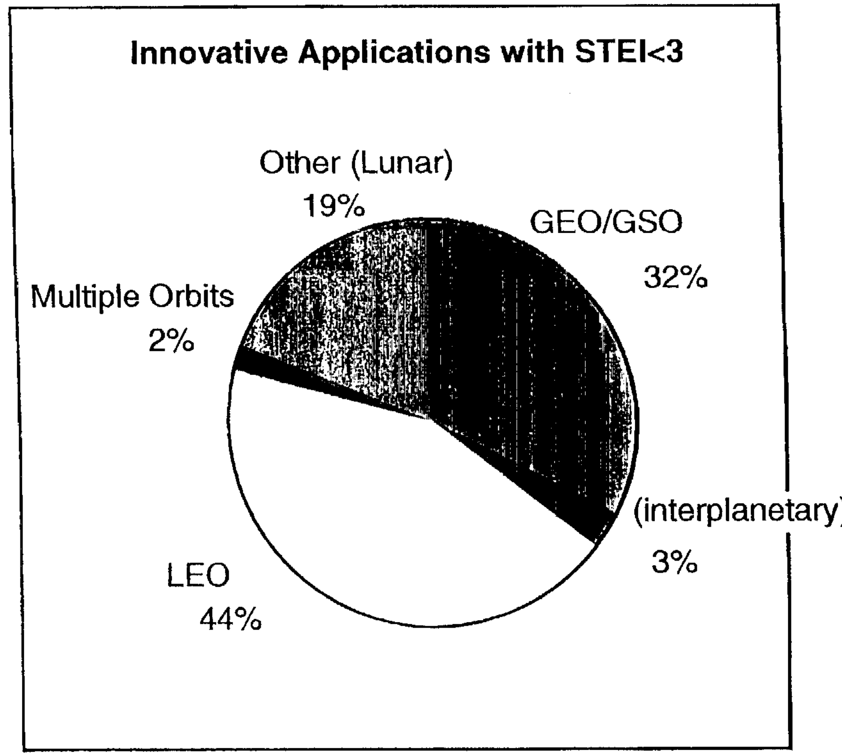
Global Surv, Recon, and Targeting System - servicing
KEW Kinetic Energy Weapons
Remote Sensing
Space Burial
Global Surv, Recon, and Targeting System - deployment
Communications - Mobile Satellite Service - deployment
Communications - Mobile Satellite Service - servicing
Space Surveillance
Super GPS
Nanosat Applications
Communications - Fixed Satellite Services
Space Advertising
Hyperspectral
Communications - Broadcast Satellite Services
Military Spaceplane
Communications - Positioning Satellite Services
Space Mine
Space Traffic Control
Communications
Entertainment - Digital Movie Satellite
Interceptors
Transportation - Space Rescue

Government - Space Science Outwards
Missile Warning
Planetary Defense -- System Development
Government Missions - Space Station Missions - servicing
Force (PGM) Delivery from Space
Light, Affordable, On-demand Surveillance Sats
Space Control
Planetary Defense -- Sky Survey
Transportation - Space Servicing and Transfer
Space Utility - GEO - servicing
Government Missions - Space Station Missions - deployment
Bi-Static Radar
Solar-Powered High Energy Laser System. - servicing
Ground-Based High Energy Laser System - deployment
Ground-Based High Energy Laser System - servicing
Planetary Defense -- Sky Guard
Global Area Strike System (GASS)
Space Utility - Space-to-Space Power Beaming
Space Product Demonstration
Space-Based High Energy Laser System - servicing
Space Utility - Lunar - deployment mission

Threshold Characteristics: Orbit Types

(% breakdown based on total weight to LEO per year)





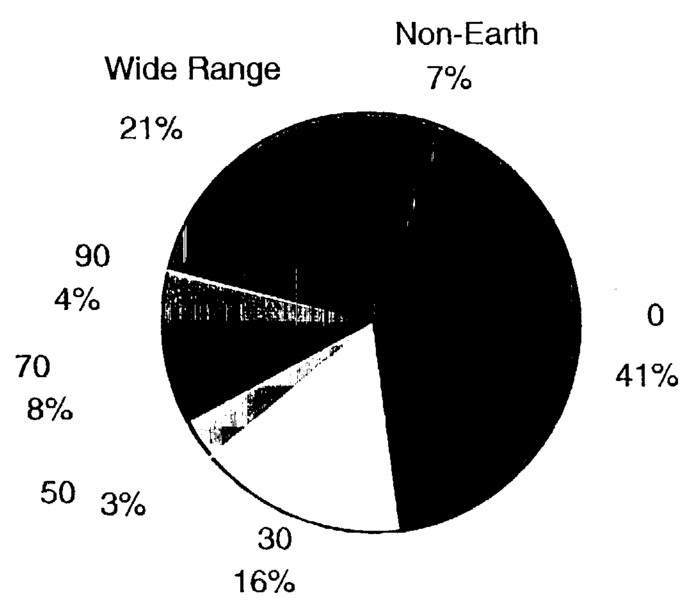
- **Significant number of missions to LEO, suborbital, GEO, and lunar orbits**

- **Significant number of missions to LEO, GEO, and lunar orbits**

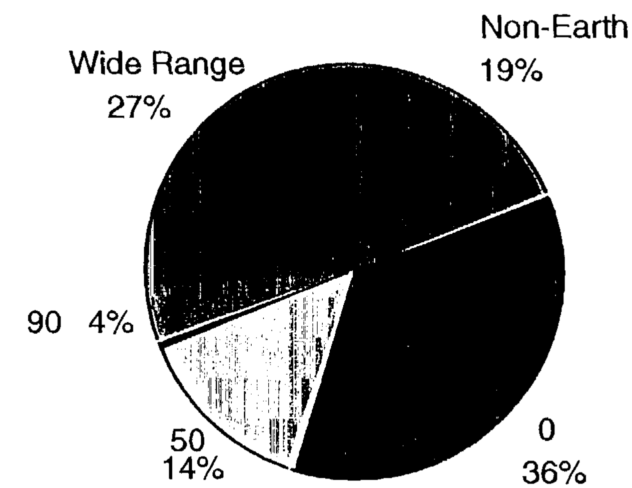
Threshold Characteristics: Inclination

(% breakdown based on total weight to LEO per year)

All Innovative Applications



Innovative Applications with STEI<3

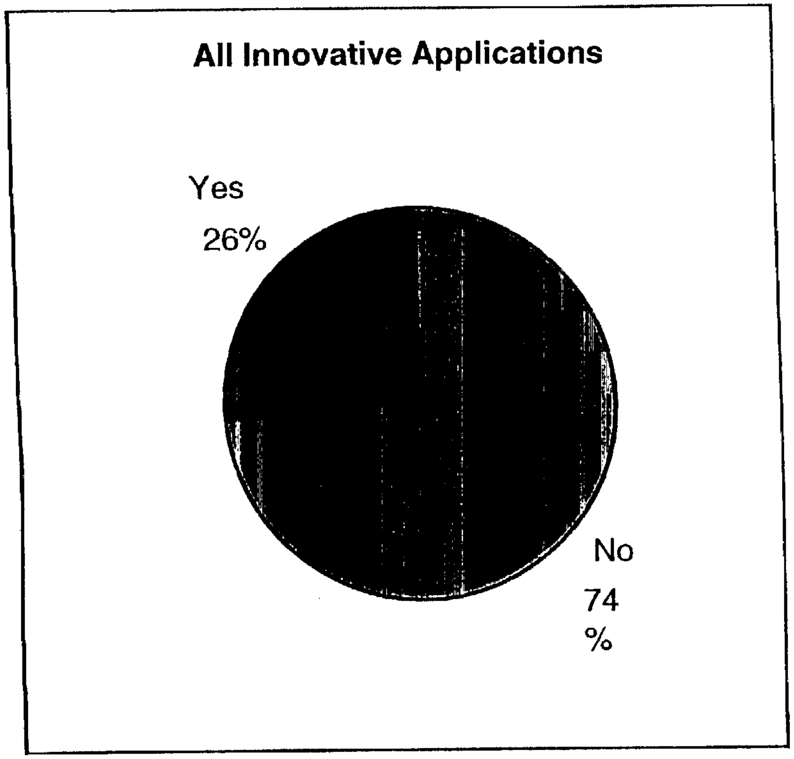


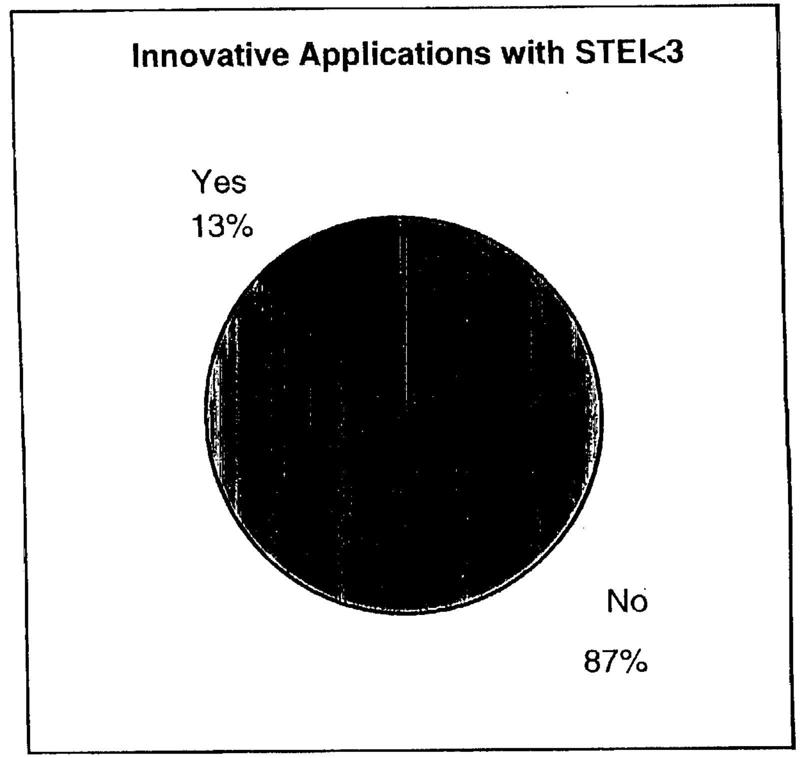
- Many equatorial missions
- Some mid-latitude missions
- Few polar missions
- Some requirement for wide-range capability

- Many equatorial missions
- Some mid-latitude missions
- Few polar missions
- Some requirement for wide-range capability

Threshold Characteristics: Pilot Required?

(% breakdown based on total weight to LEO per year)

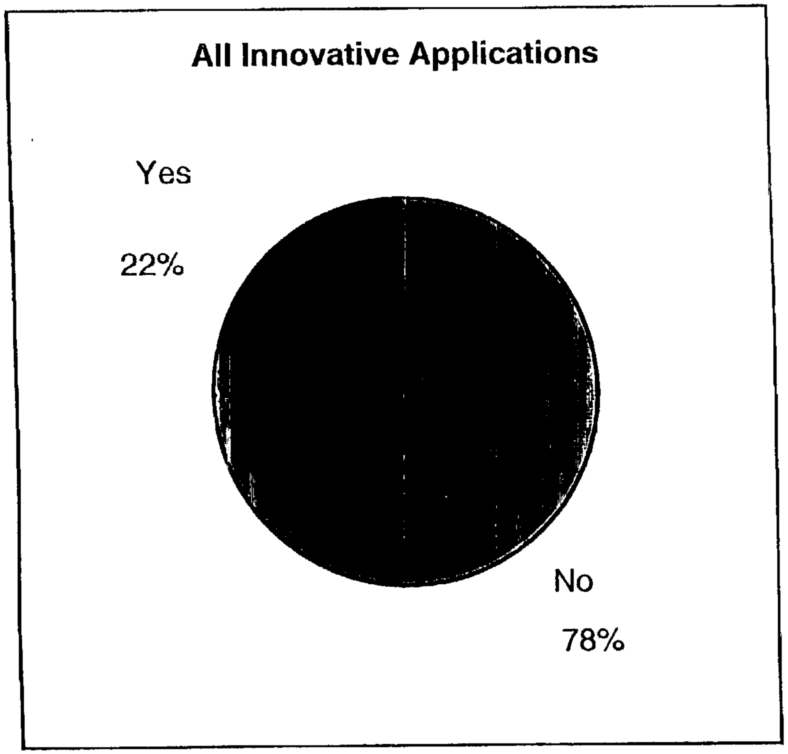


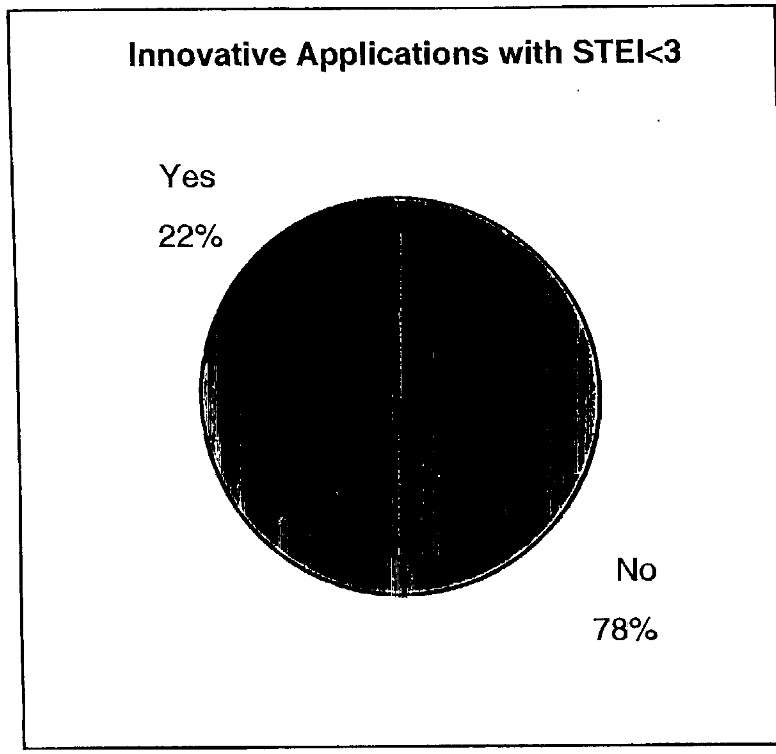


- Majority of missions do not require a pilot
- Majority of missions do not require a pilot

Threshold Characteristics: Multi-Azimuth Required?

(% breakdown based on total weight to LEO per year)



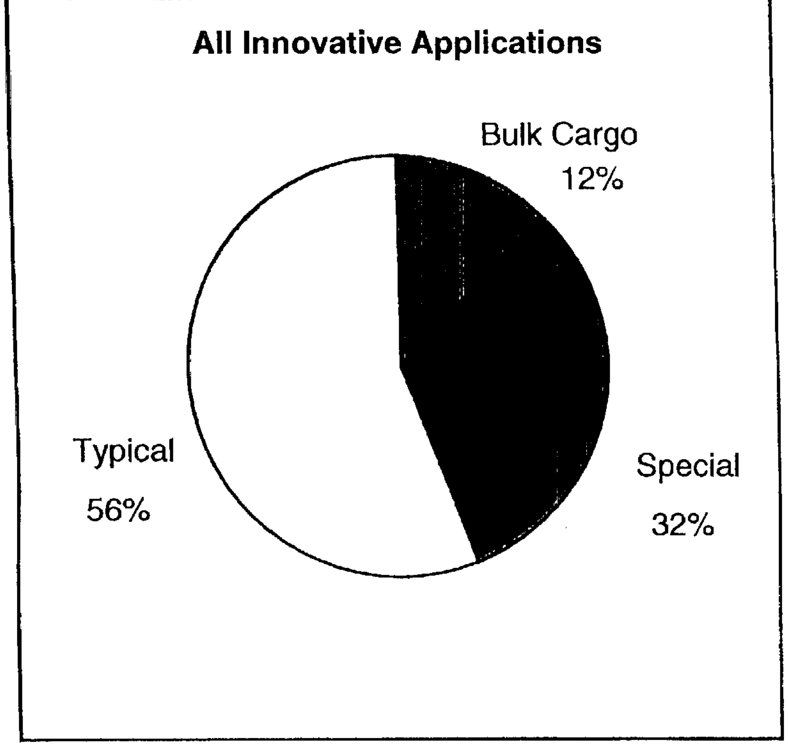


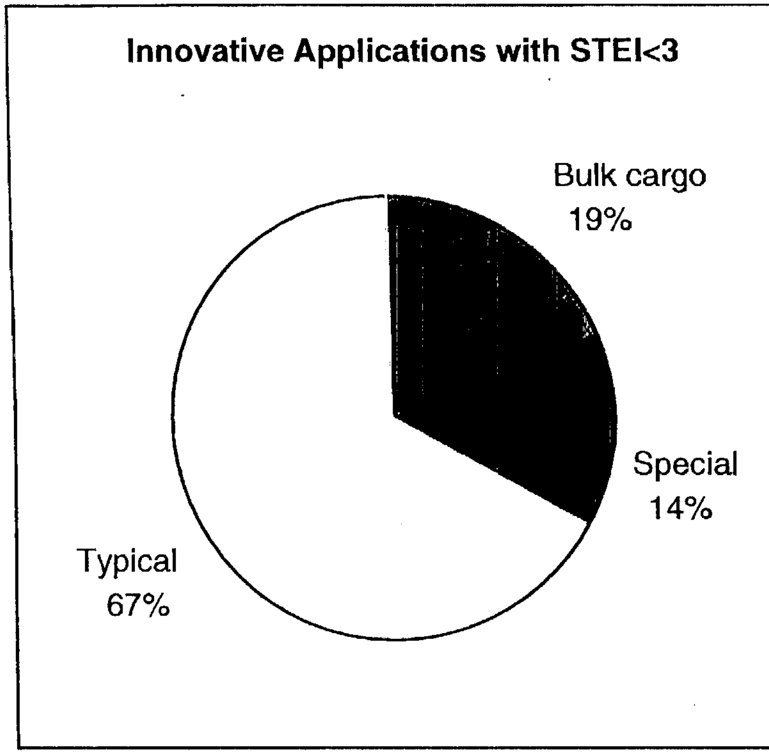
– Majority of missions do not require multi-azimuth capability

– Majority of applications do not require multi-azimuth capability

Threshold Characteristics: Payload Fairing Size

(% breakdown based on total weight to LEO per year)



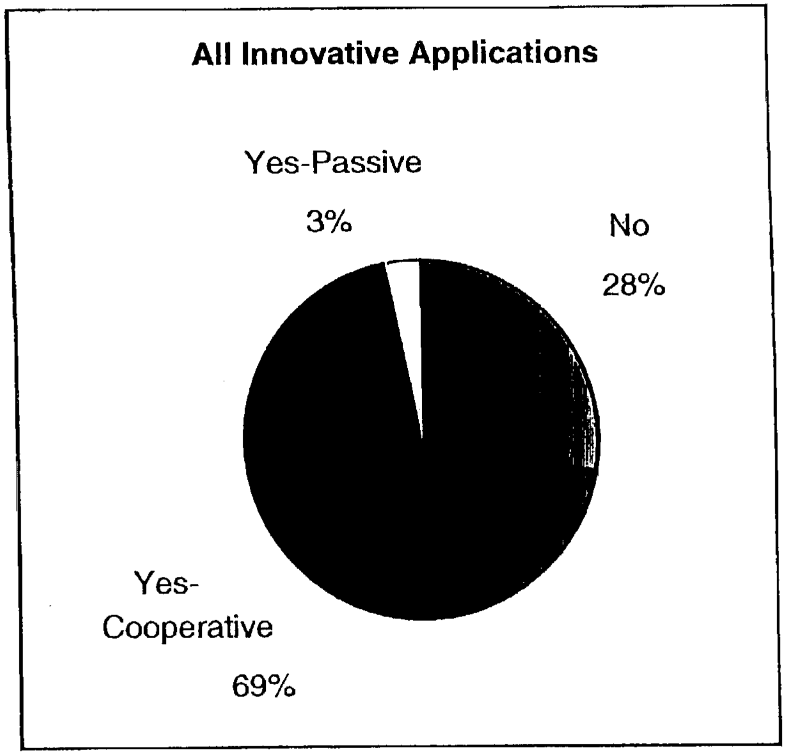


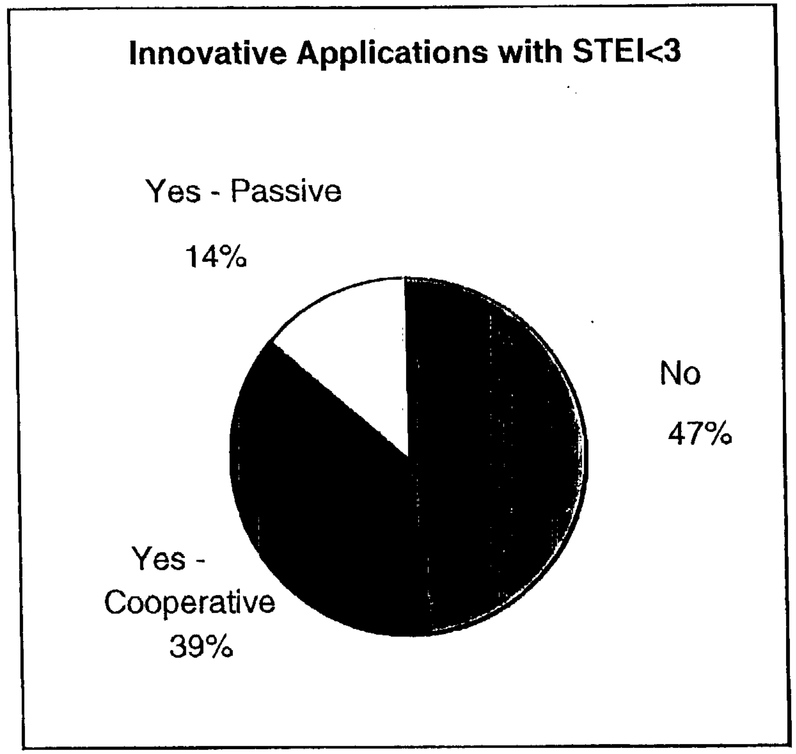
- Typical payload fairing size is acceptable to more than half the missions
- Significant requirement for special payload fairing

- Typical payload fairing size is acceptable to majority of missions
- Some requirement for special payload fairing

Threshold Characteristics: Rendezvous?

(% breakdown based on total weight to LEO per year)





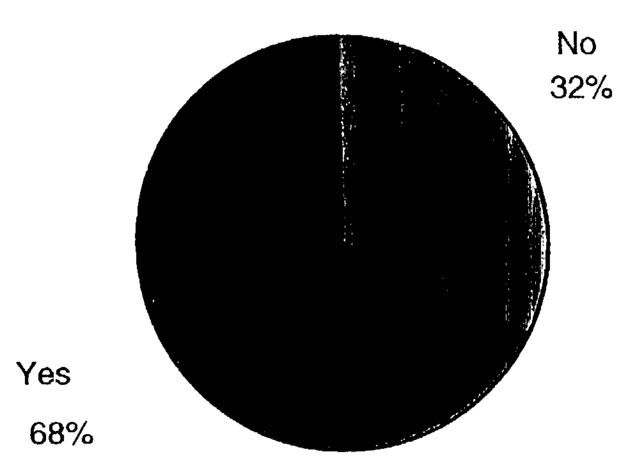
- Majority of missions require rendezvous capability, and can cooperate in the docking

- Half the missions do not need to rendezvous
- Majority of missions that do require rendezvous can cooperate in the docking

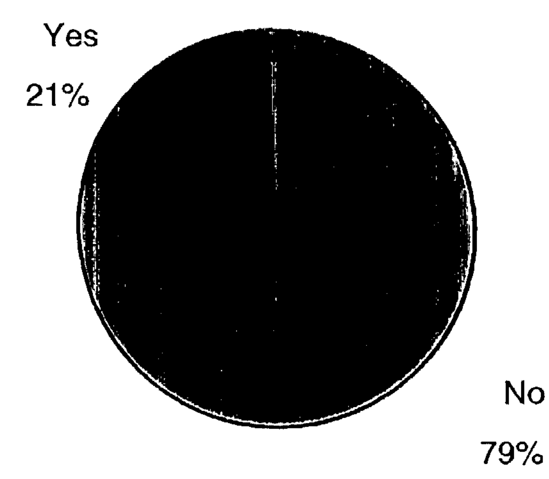
Threshold Characteristics: Return to Launch Site

(% breakdown based on total weight to LEO per year)

All Innovative Applications



Innovative Applications with STEI<3

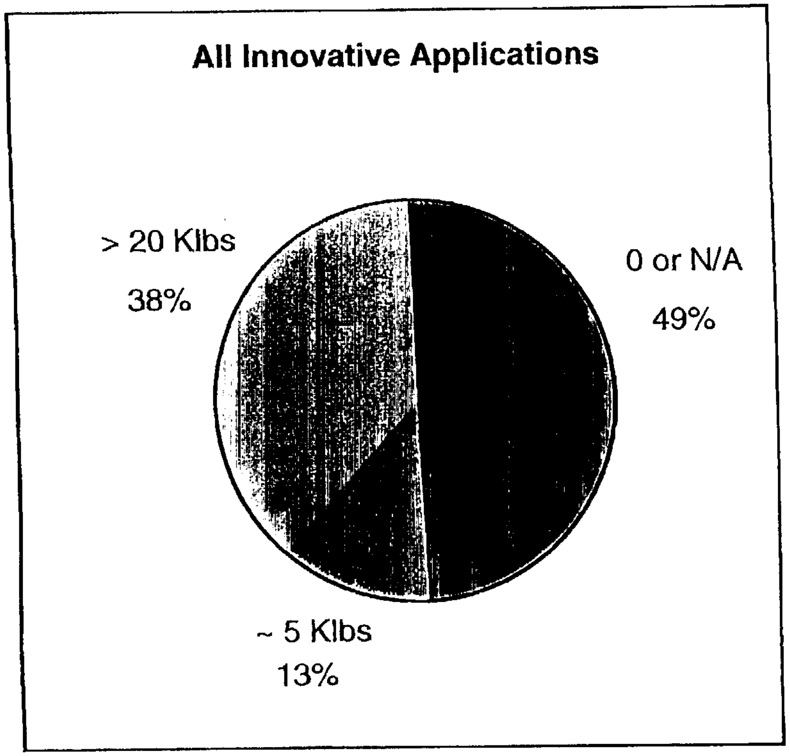


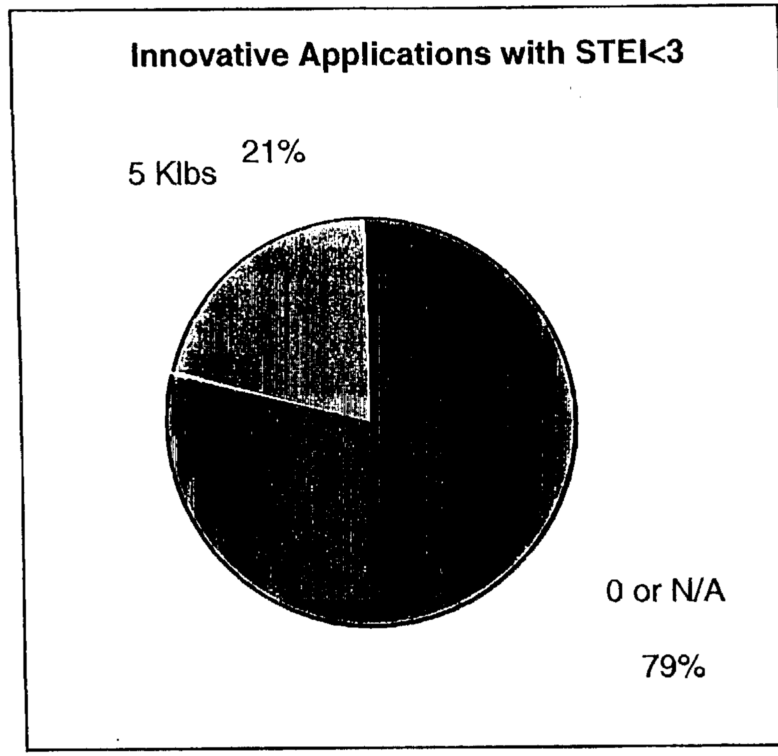
– Majority of missions need to return to launch site

– Majority of missions do not need to return to launch site

Threshold Characteristics: Return Payload Mass

(% breakdown based on total weight to LEO per year)



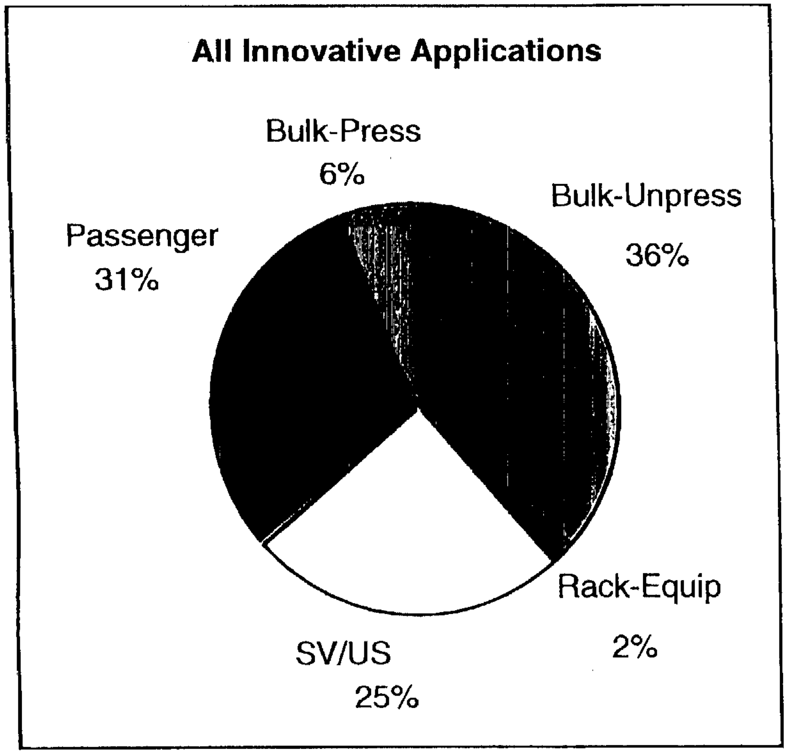


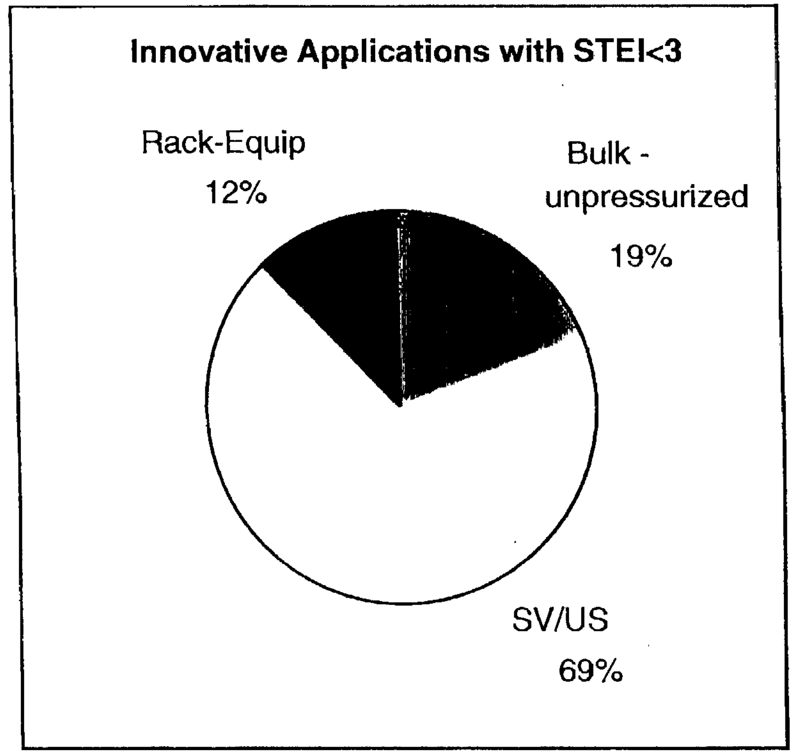
- About half the missions need to return with payload
- Of these, a majority require mass greater than 20000 lb

- Of the 21% of missions that need to return with mass, the mass requirement is 5000 lb or less

Threshold Characteristics: Payload Types

(% breakdown based on total weight to LEO per year)

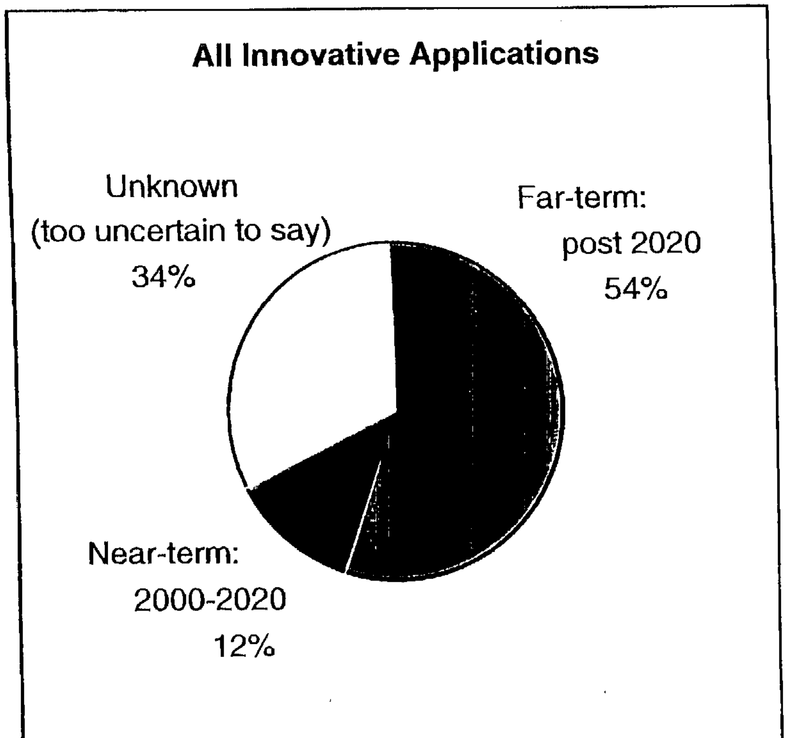


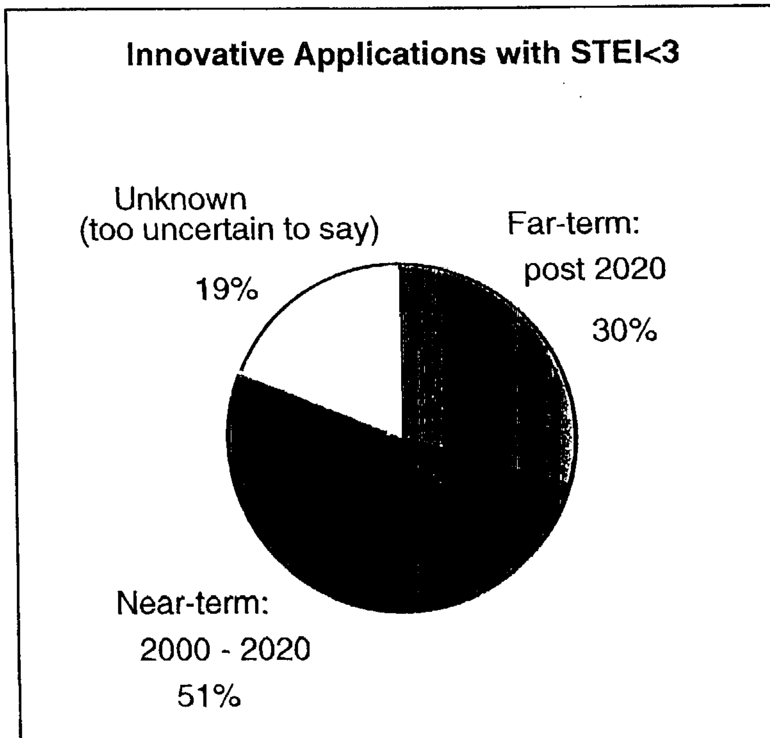


- Payloads about evenly broken up into passengers, spacecraft, and bulk cargo
- Standard spacecraft (or upper stage) make up majority of payloads

Threshold Characteristics: Likely Deployment Period

(% breakdown based on total weight to LEO per year)





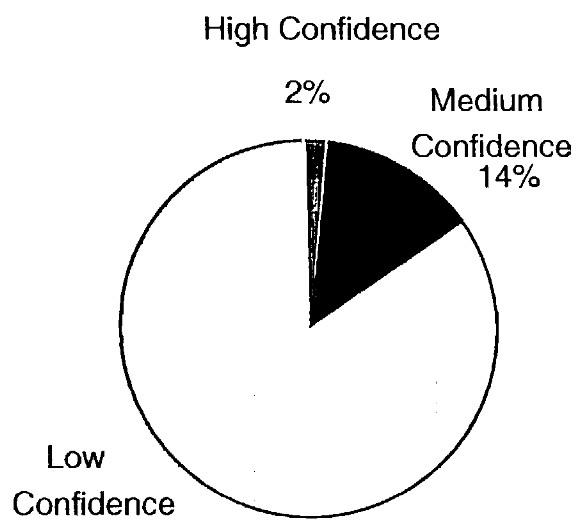
- **About half the missions are considered far-term**
- **Significant portion is considered unknown**
- **Small portion can be considered near-term**

- **About half the missions are considered near-term**
- **The rest are evenly divided between far-term and unknown**

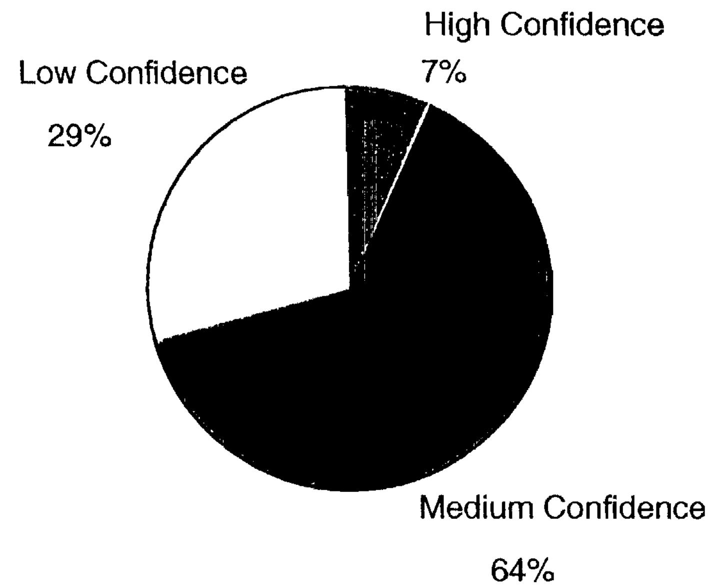
Threshold Characteristics: Confidence in Flt Rates

(% breakdown based on total weight to LEO per year)

All Innovative Applications



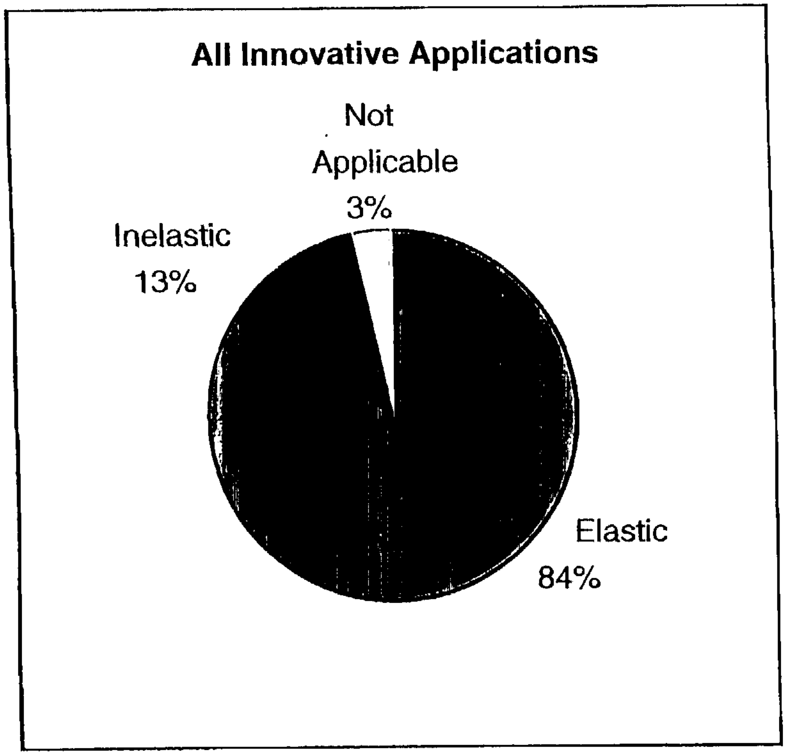
Innovative Applications with STEI<3

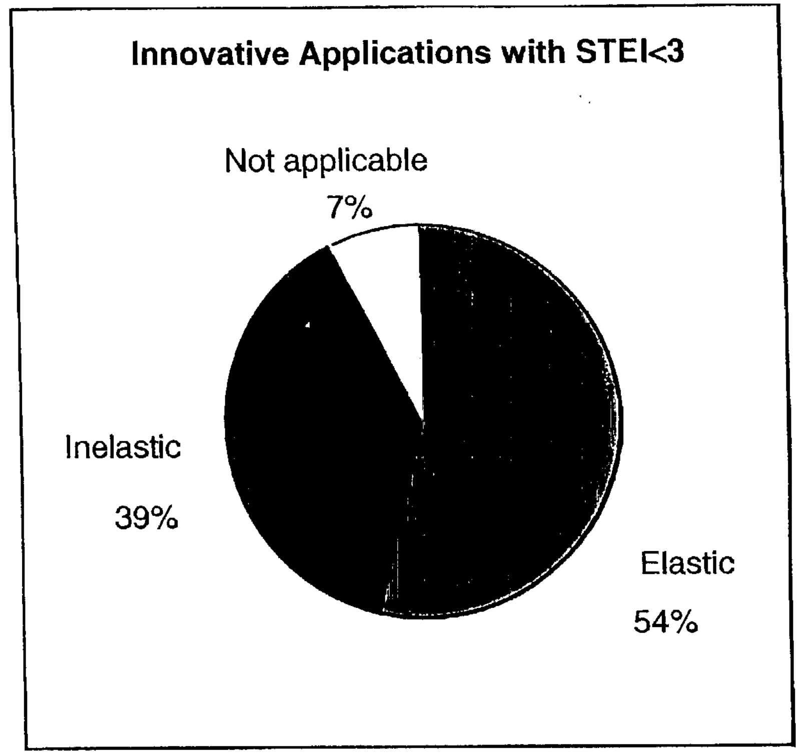


- **Most flight rate estimates are very uncertain**
- **There is medium confidence in a majority of flight rate estimates**

Threshold Characteristics: Launch Price Elasticity

(% breakdown based on total weight to LEO per year)



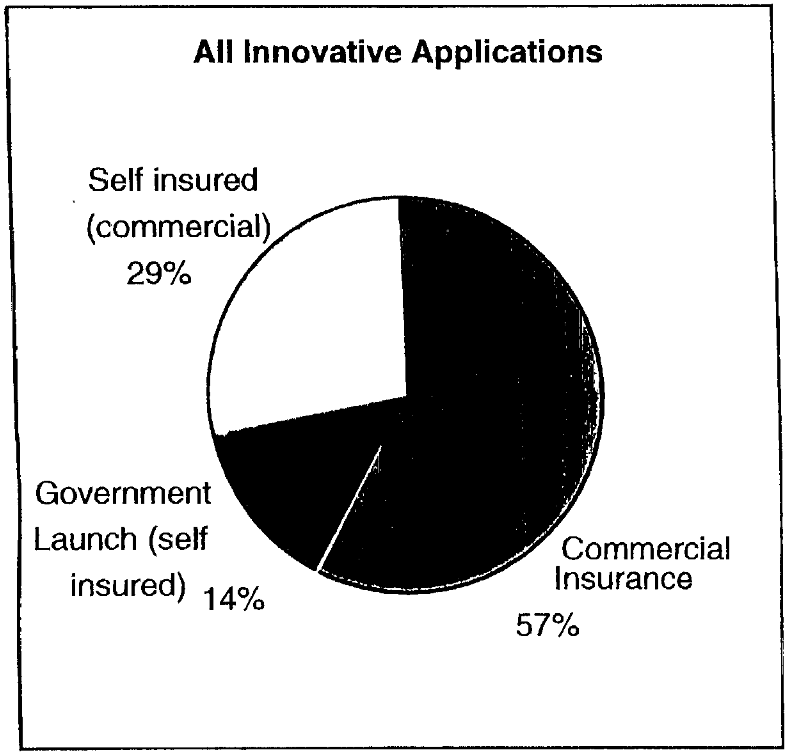


- Most applications have price elasticity

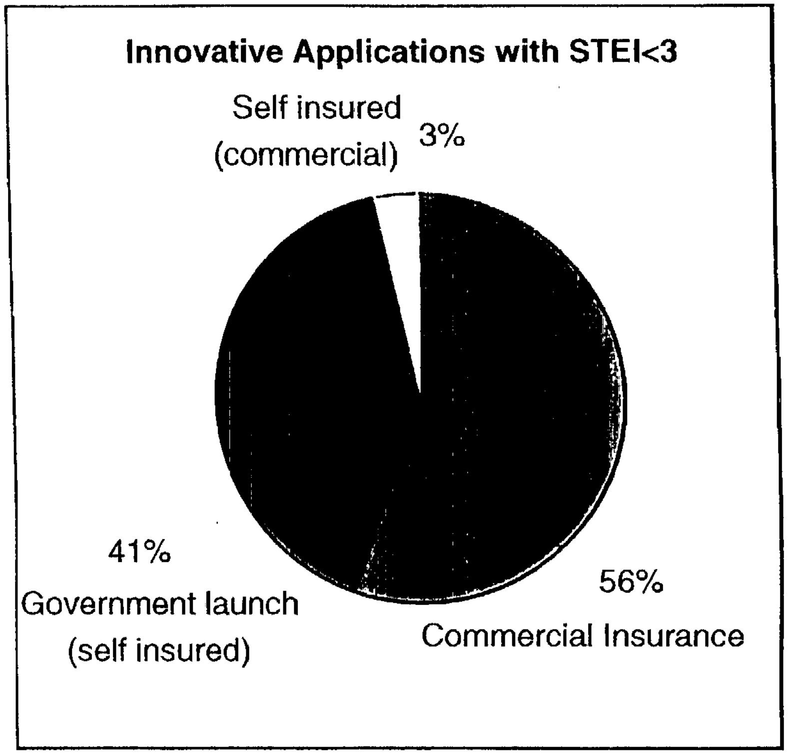
- More than half the missions have price elasticity
- Large fraction of the missions are not price elastic

Threshold Characteristics: Launch Insurance

(% breakdown based on total weight to LEO per year)



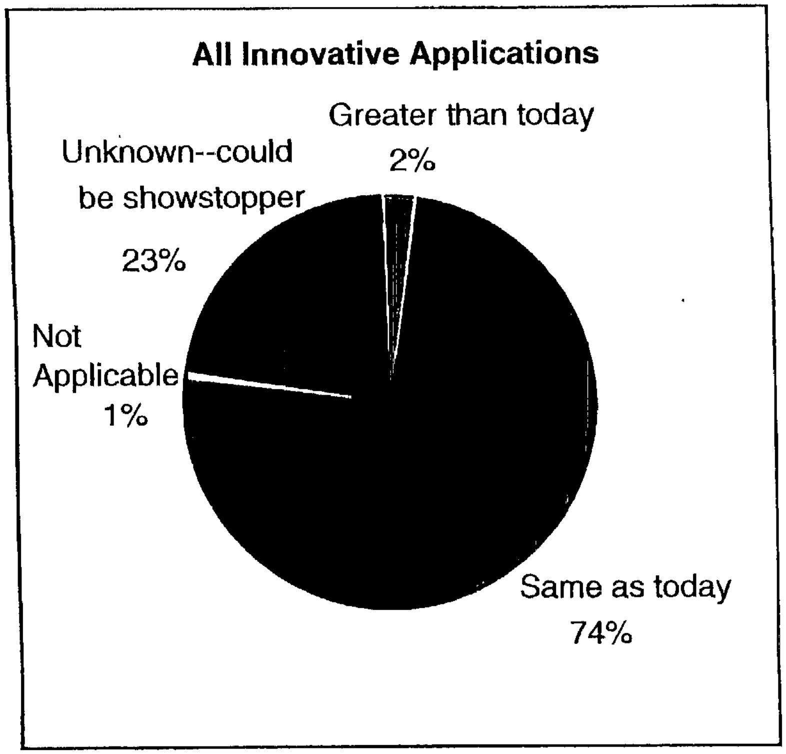
- More than half the missions have commercial insurance
- Rest are self-insured, either by government or commercial ventures

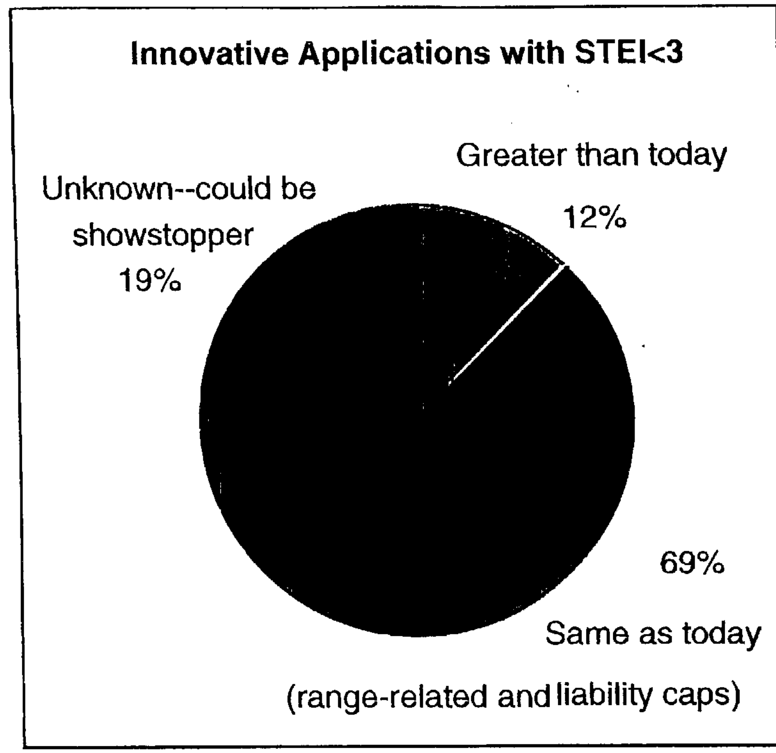


- More than half the missions have commercial insurance
- Rest are mostly self-insured by government

Threshold Characteristics: Govt Indemnification

(% breakdown based on total weight to LEO per year)



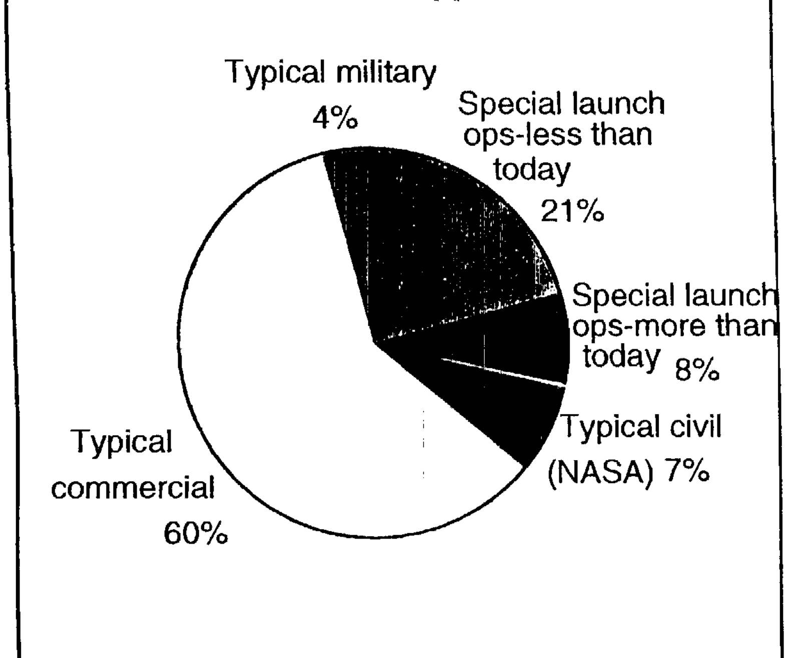


- Majority of missions have the same level as today
- Significant number of missions that are unknown

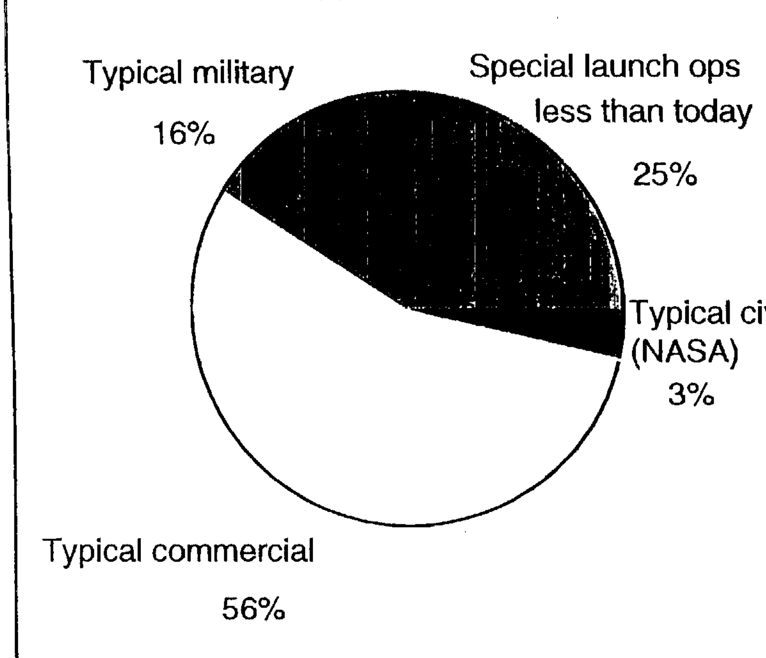
- Majority of missions have the same level as today
- Significant number of missions that are unknown
- Significant number of missions require more than today

Threshold Characteristics: Launch and Range Operations

(% breakdown based on total weight to LEO per year)



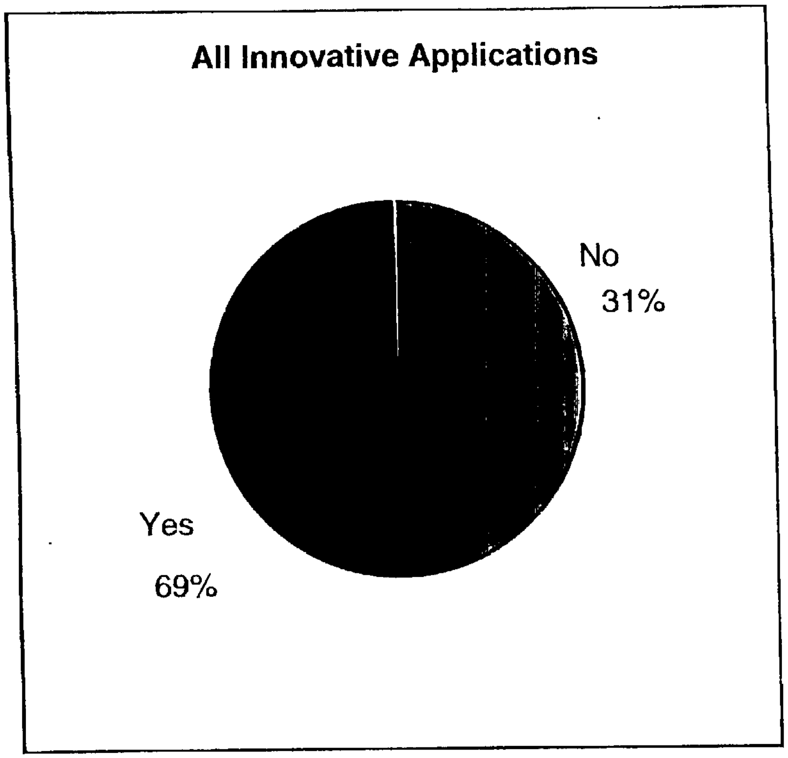
- Majority of missions require today's typical launch & range ops
- Some require less than today's
- Some require more than today's

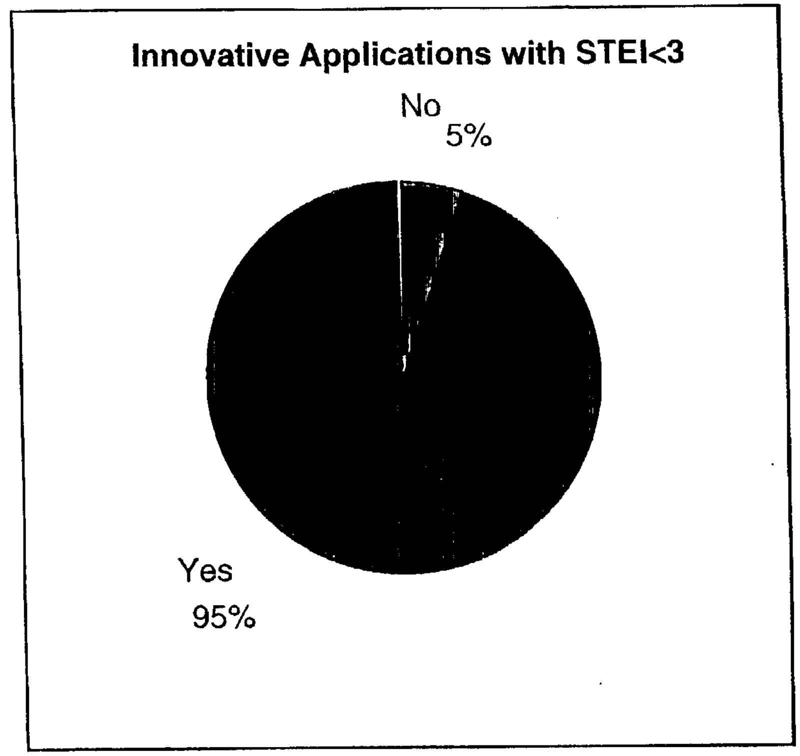


- Majority of missions require today's typical launch & range ops
- Some require less than today's

Threshold Characteristics: Final Orbit Injection Req.

(% breakdown based on total weight to LEO per year)





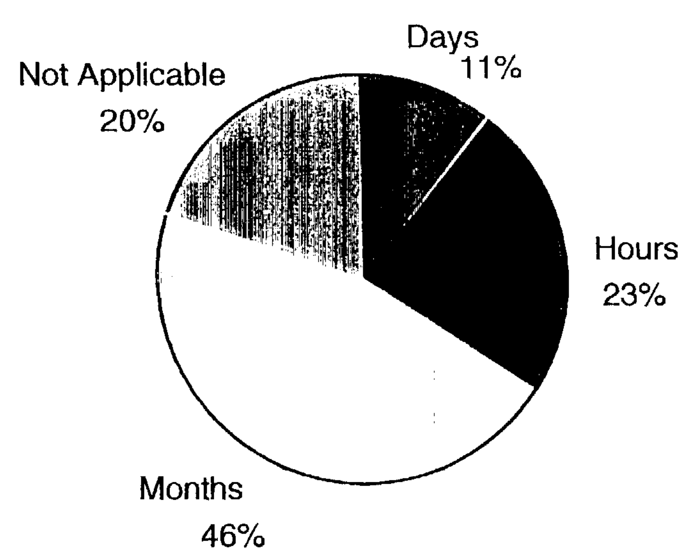
- Majority of missions require final orbit injection
- Some missions do not

- Most missions require final orbit injection

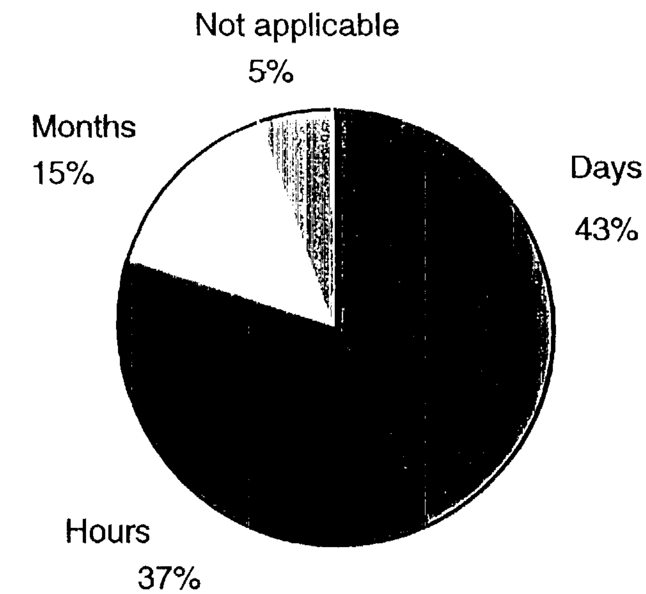
Threshold Characteristics: Acceptable Final Orbit Transfer Time

(% breakdown based on total weight to LEO per year)

All Innovative Applications



Innovative Applications with STEI<3

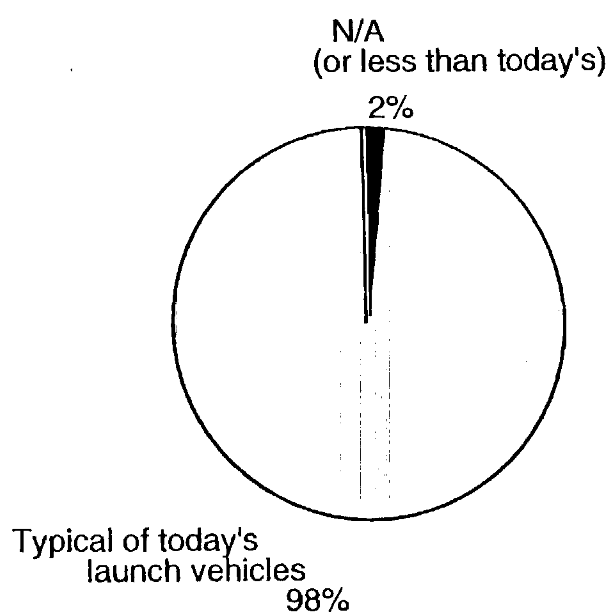


- Final orbit transfer times of months is acceptable to almost half the missions
- Significant number of missions can accept transfer times of days or hours
- Majority of missions can accept transfer time of days or weeks

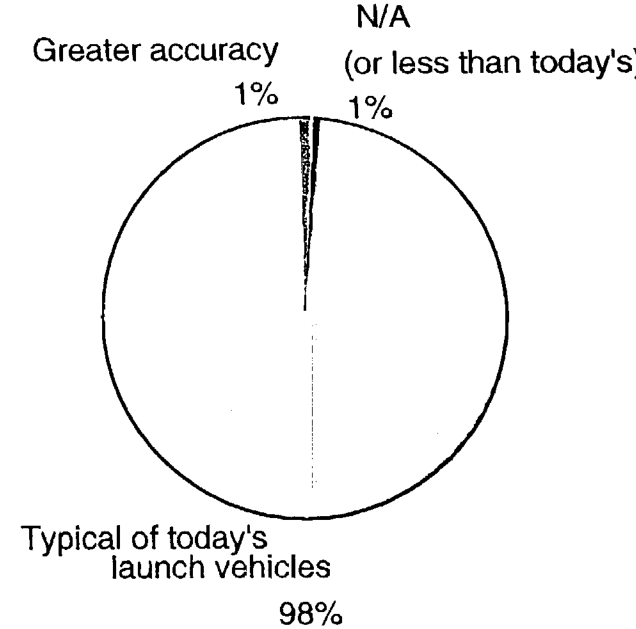
Threshold Characteristics: Orbit Injection Accuracy

(% breakdown based on total weight to LEO per year)

All Innovative Applications



Innovative Applications with STEI<3



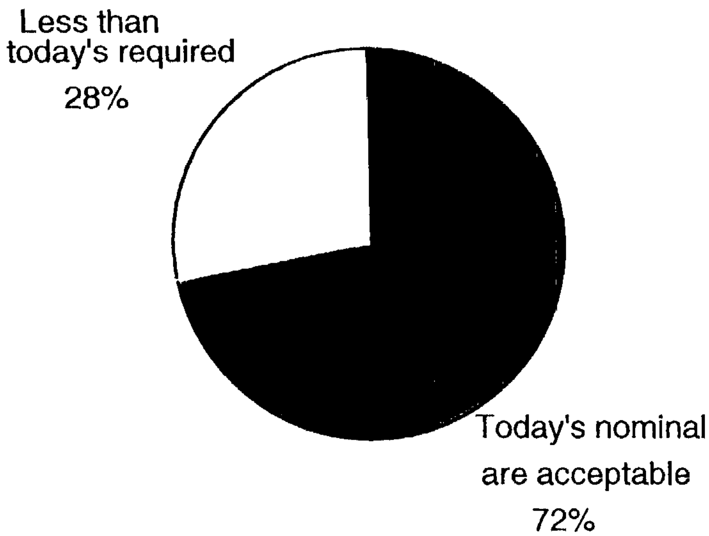
- Today's orbit injection accuracy is acceptable to almost all the missions

- Today's orbit injection accuracy is acceptable to almost all the missions

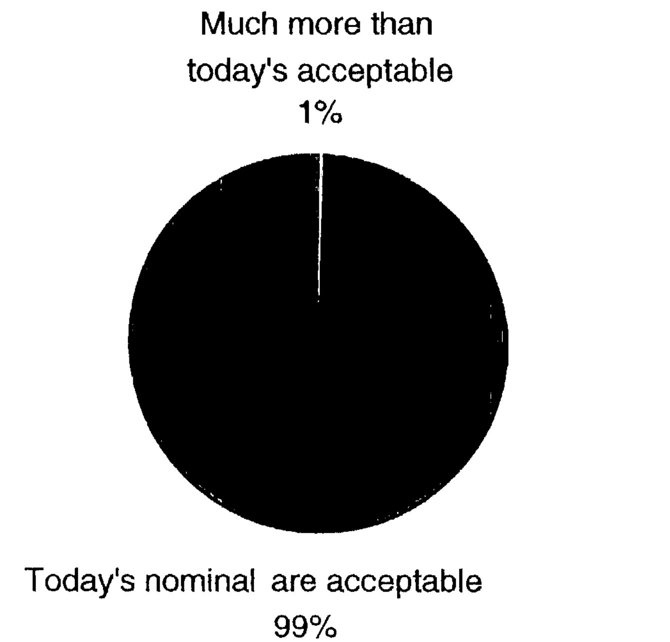
Threshold Characteristics: G-Load & Vibration

(% breakdown based on total weight to LEO per year)

All Innovative Applications



Innovative Applications with STEI<3

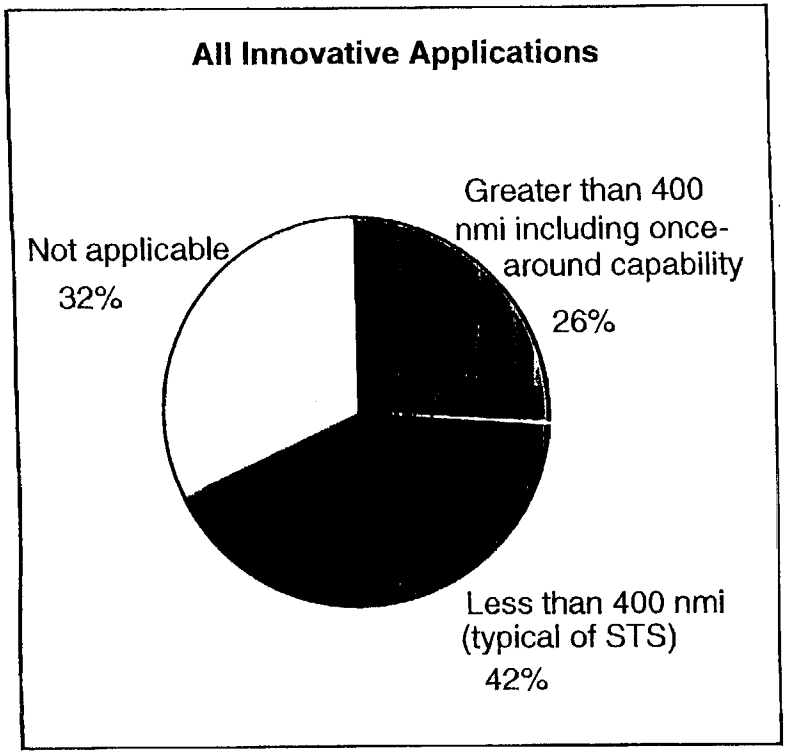


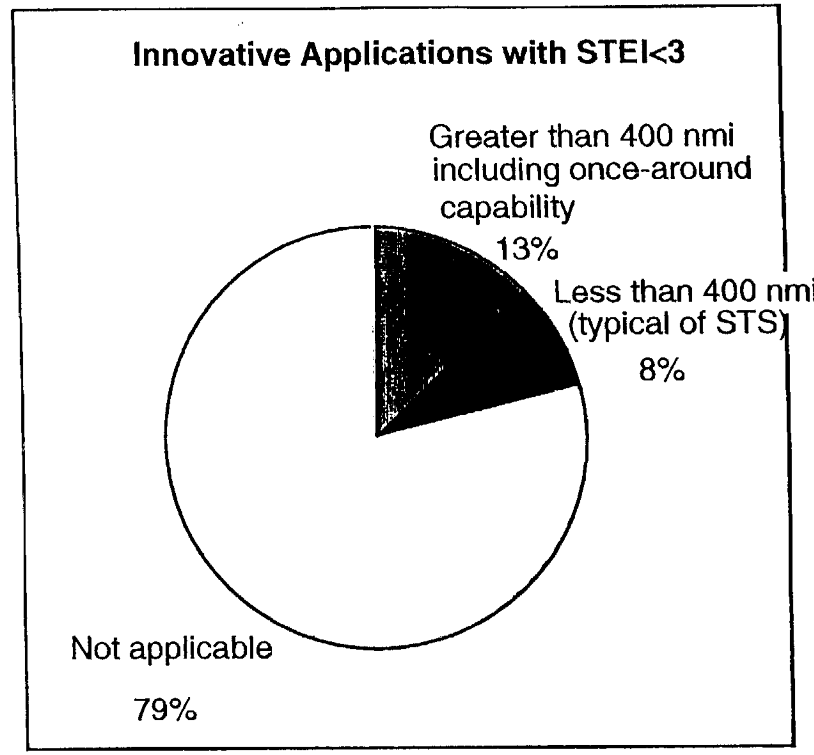
- **Today's load and vibration levels are acceptable to a majority of the missions**
- **Some missions require less than today's load and vibration levels**

- **Today's load and vibration levels are acceptable to almost all the missions**

Threshold Characteristics: Return Crossrange

(% breakdown based on total weight to LEO per year)





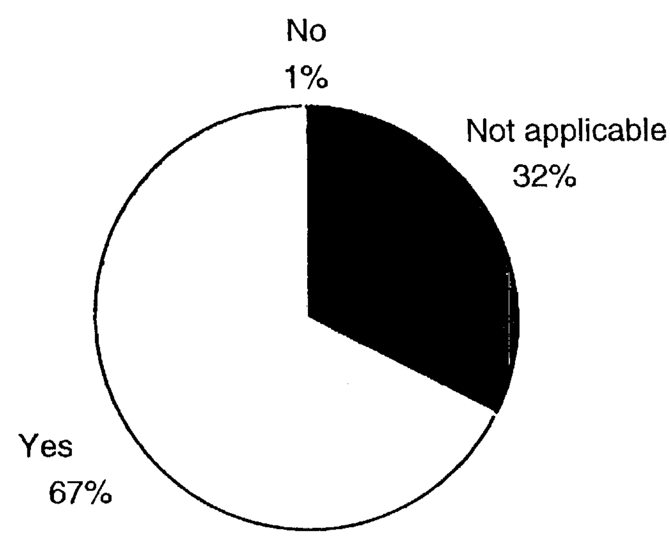
– **Majority of missions require crossrange capability**

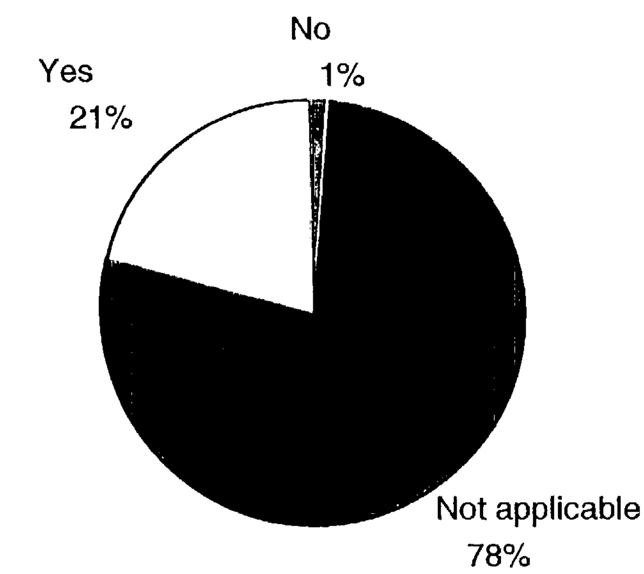
– **Majority of applications do not require crossrange capability**

– **Military spaceplane may require greater crossrange capability than the shuttle**

Threshold Characteristics: Alternate Landing Site Required

(% breakdown based on total weight to LEO per year)

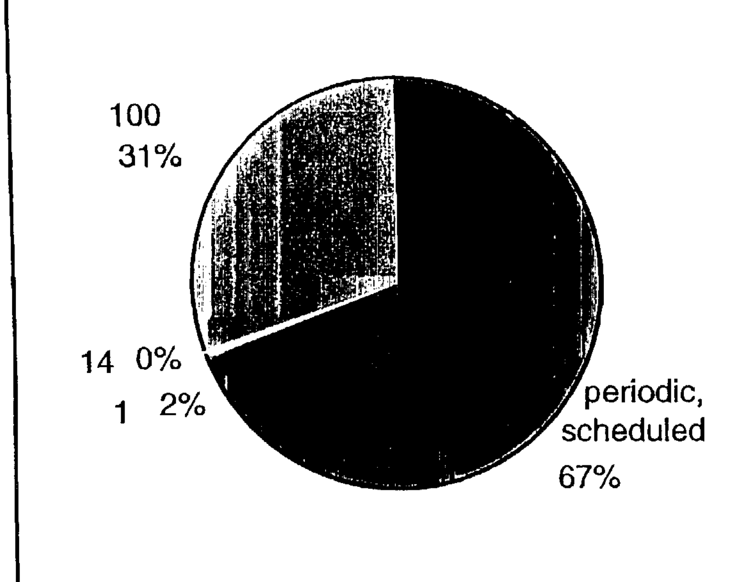


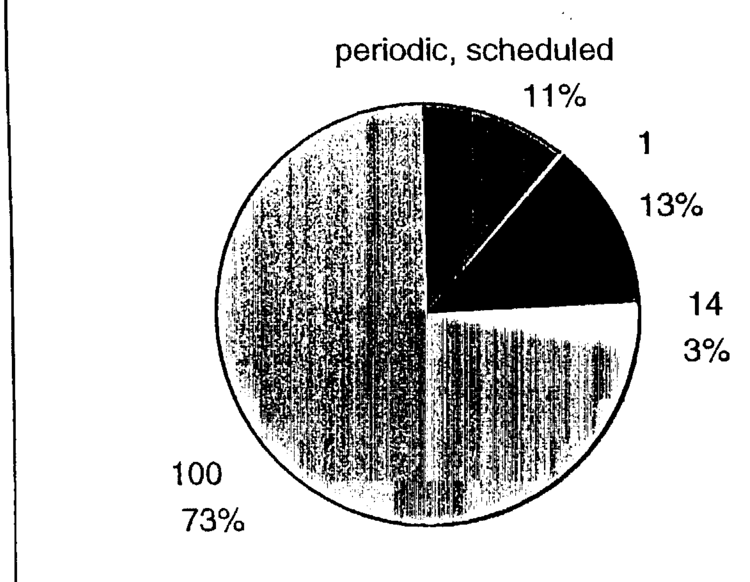


- Majority of missions require alternate landing site
- Some missions, such as military spaceplane may require alternate landing site

Threshold Characteristics: Call-up Time (Days)

(% breakdown based on total weight to LEO per year)



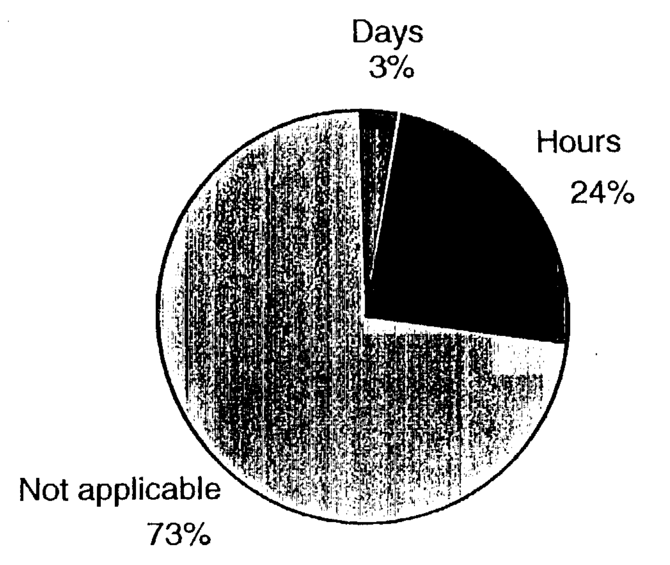


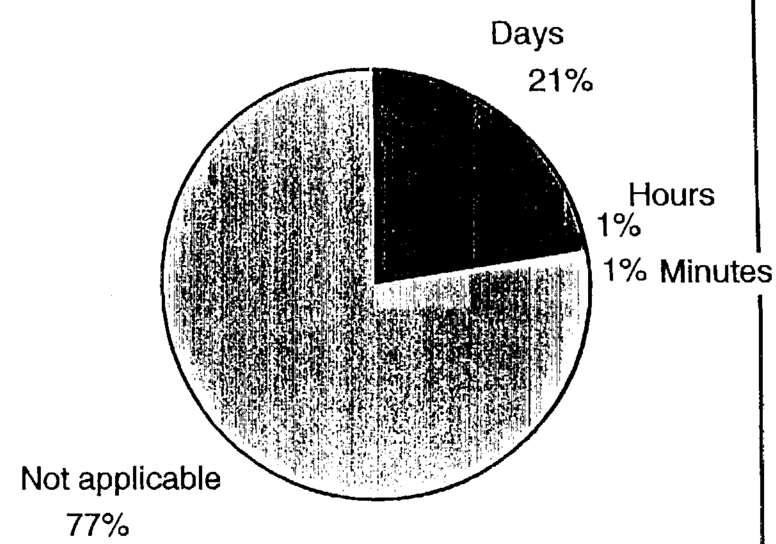
- **Majority of the missions are periodic or scheduled**
- **Call-up times of about 100 days are acceptable for 31% of the missions**

- **Call-up times of about 100 days are acceptable for a majority of missions**
- **Military spaceplane requires much shorter call-up times**
- **Some periodic, scheduled missions**

Threshold Characteristics: Standing Alert Capability

(% breakdown based on total weight to LEO per year)



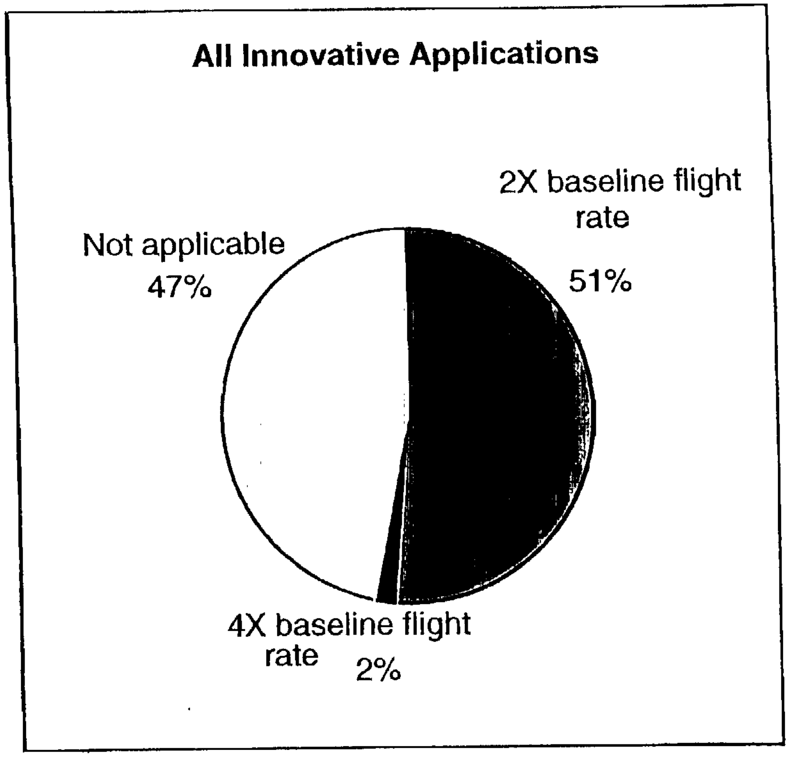


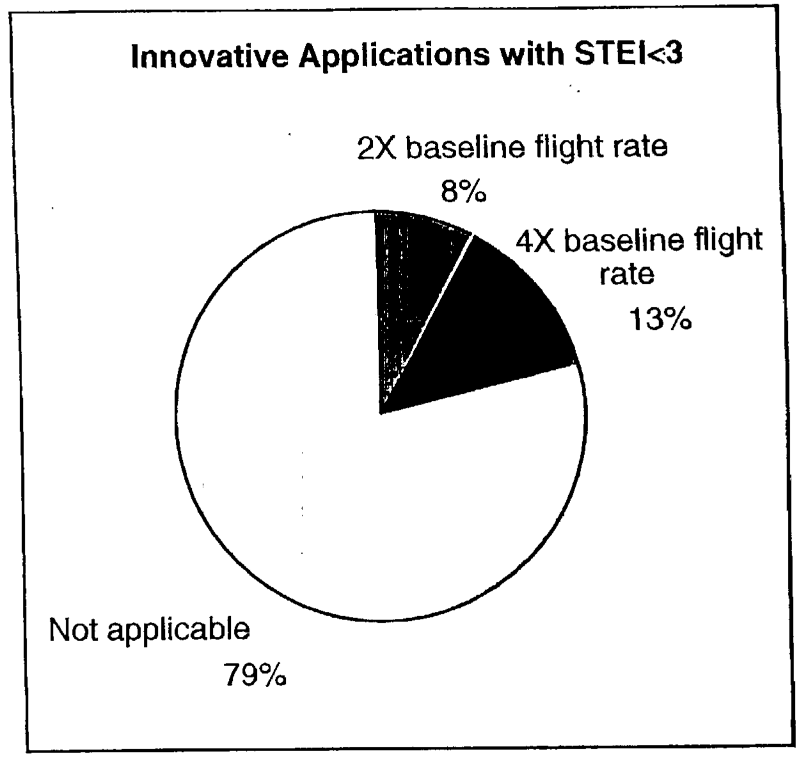
- Majority of the missions do not require standing alert capability
- Some missions have standing alert capability of hours

- Majority of the missions do not require standing alert capability
- Military spaceplane has standing alert capability of days

Threshold Characteristics: Surge Requirement

(% breakdown based on total weight to LEO per year)



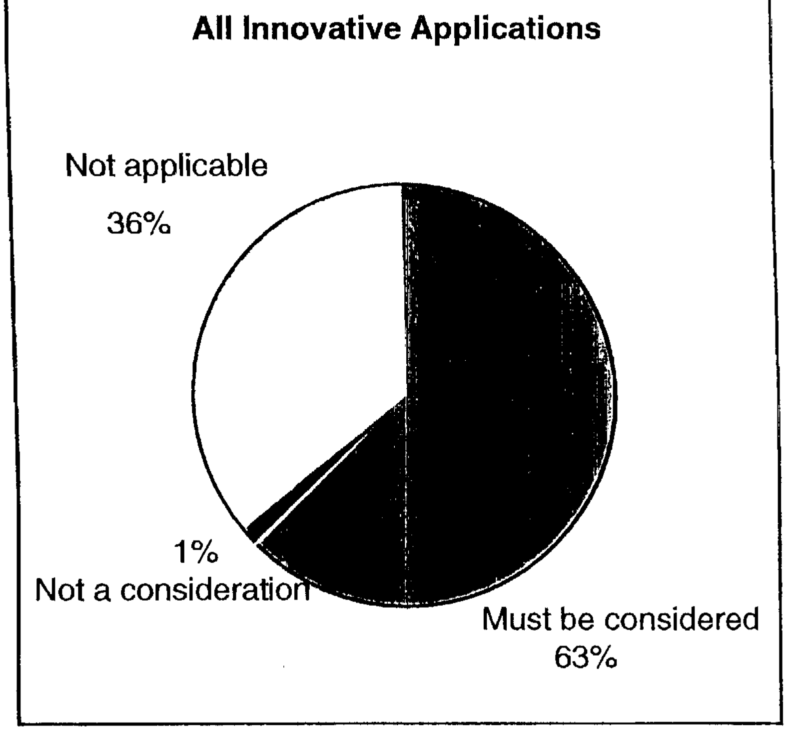


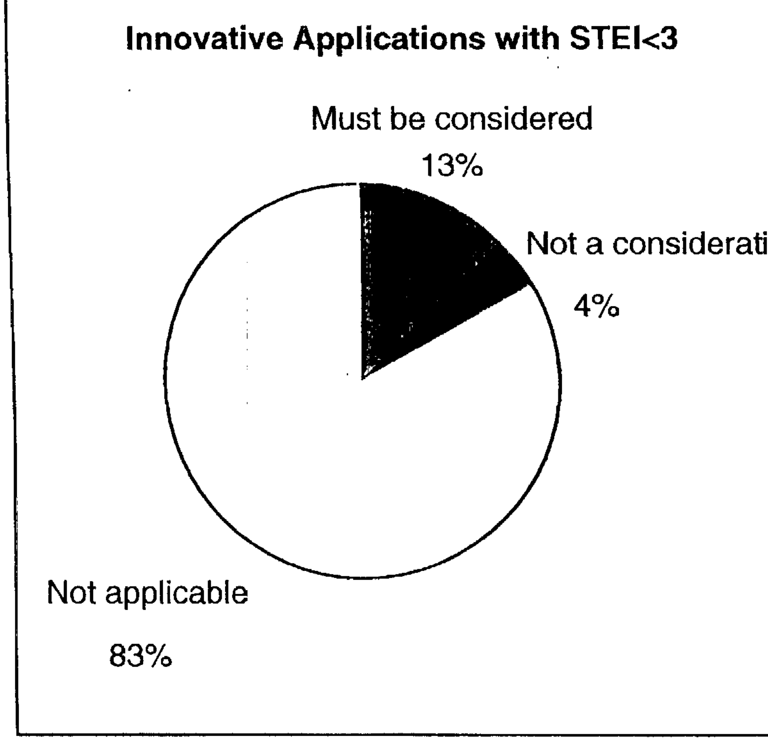
- About half the missions do not have surge requirements
- About half the missions require 2 times the baseline flight rate

- Majority of the missions do not have surge requirements
- Rest of missions require 2~4 times the baseline flight rate

Threshold Characteristics: Rapid Cooldown for Return Payload

(% breakdown based on total weight to LEO per year)





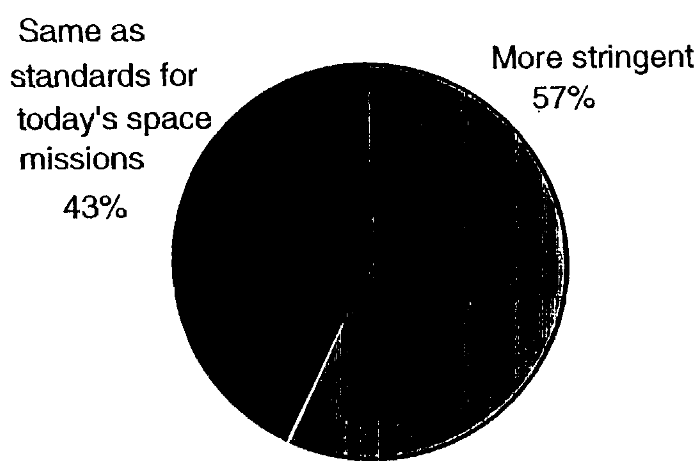
- Majority of the missions must consider rapid cooldown for return payload

- Majority of the missions do not require rapid cooldown capability
- Military spaceplane may require rapid cooldown

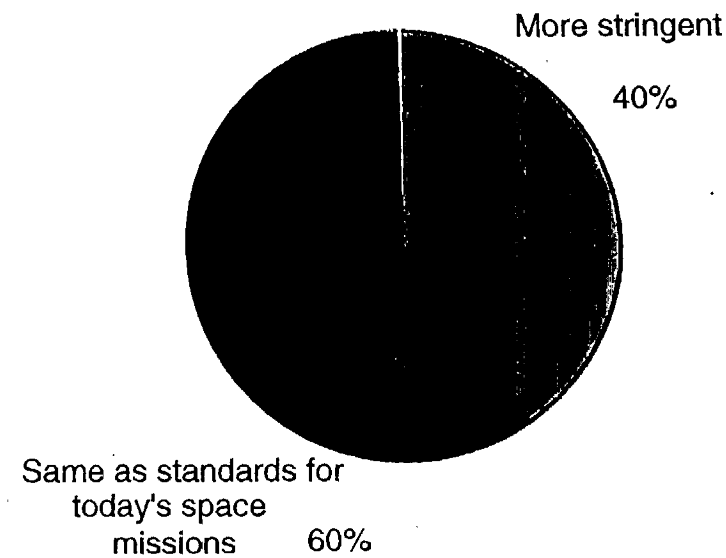
Threshold Characteristics: Environmental Standards

(% breakdown based on total weight to LEO per year)

All Innovative Applications



Innovative Applications with STEI<3

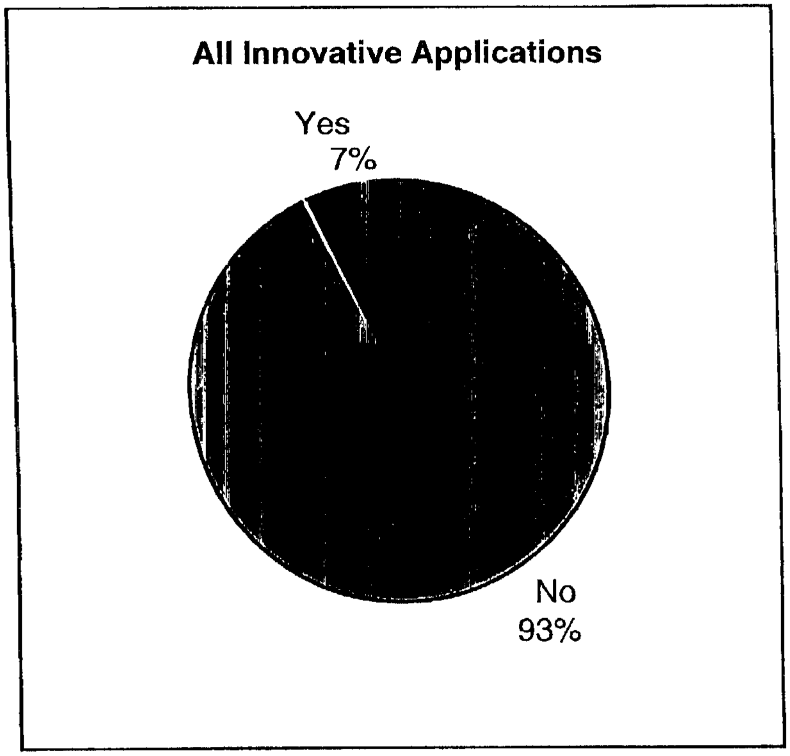


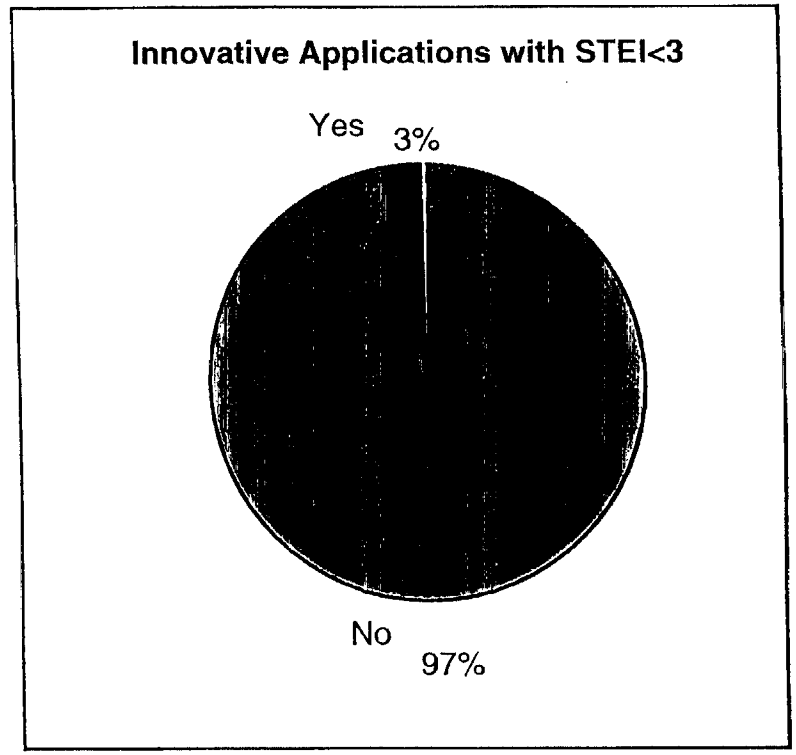
- More than half the missions may require environmental standards more stringent than today's
- Today's standards are acceptable to rest

- Today's environmental standards are acceptable to more than half the missions
- Rest of the missions require more stringent standards

Threshold Characteristics: Nuclear Material Onboard

(% breakdown based on total weight to LEO per year)



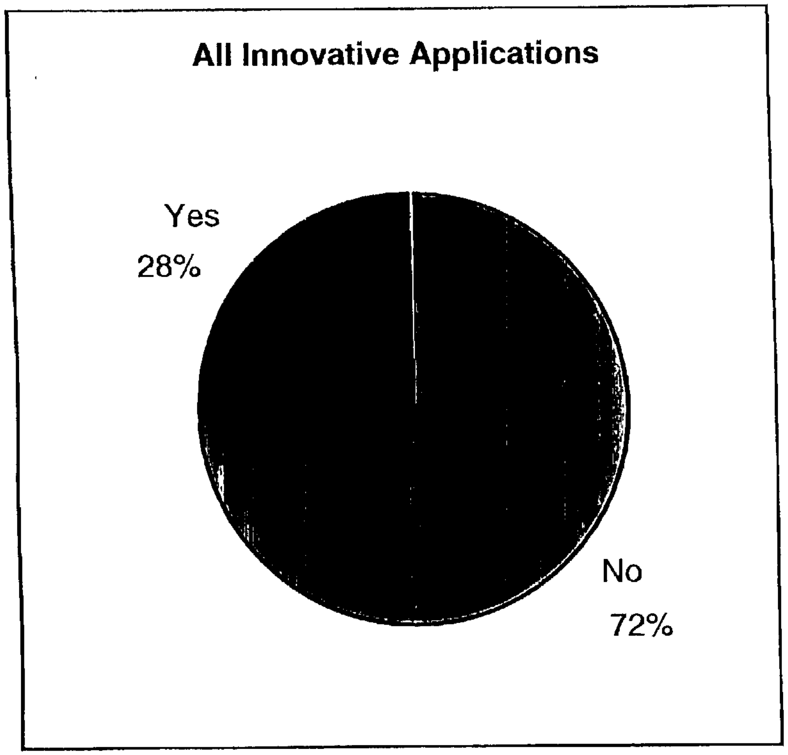


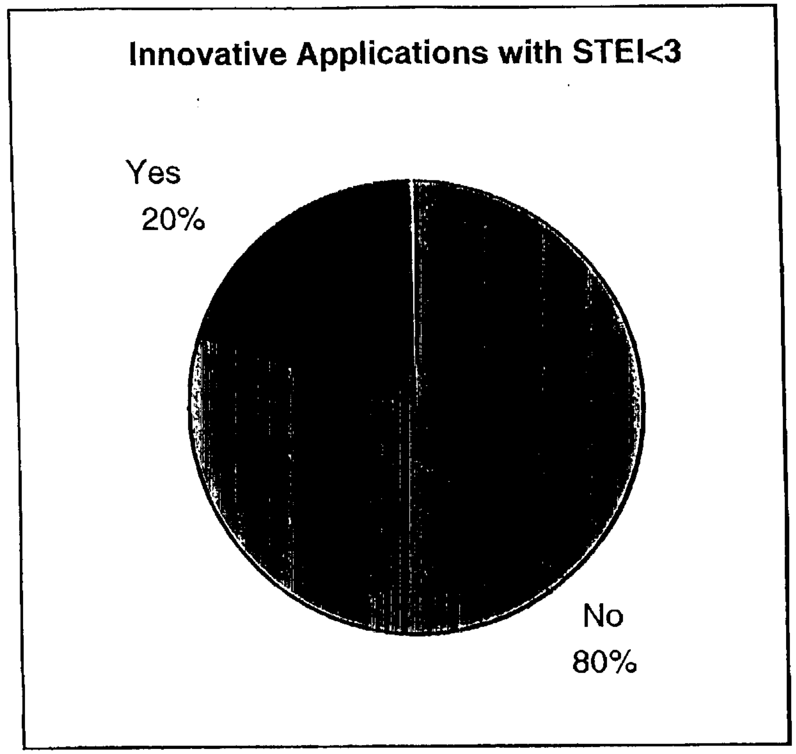
- Most missions will not have nuclear material on-board

- Most missions will not have nuclear material on-board

Threshold Characteristics: Overflight Populated Areas

(% breakdown based on total weight to LEO per year)





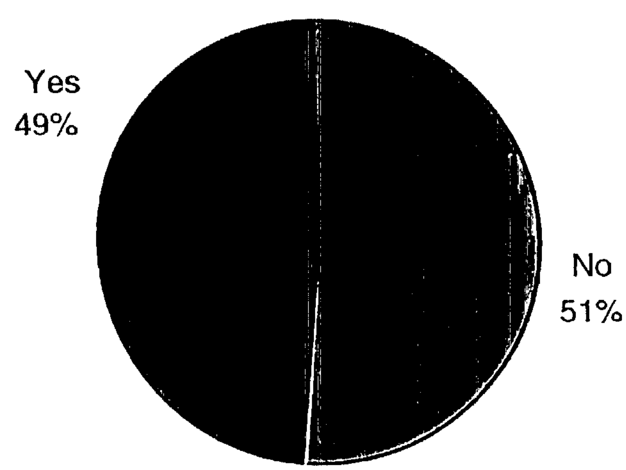
- Majority of missions will not overfly populated areas

- Majority of missions will not overfly populated areas

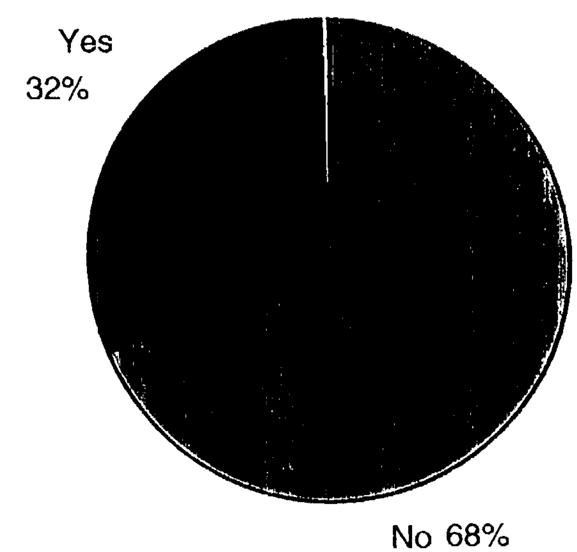
Threshold Characteristics: On-Orbit Refueling Required

(% breakdown based on total weight to LEO per year)

All Innovative Applications



Innovative Applications with STEI<3

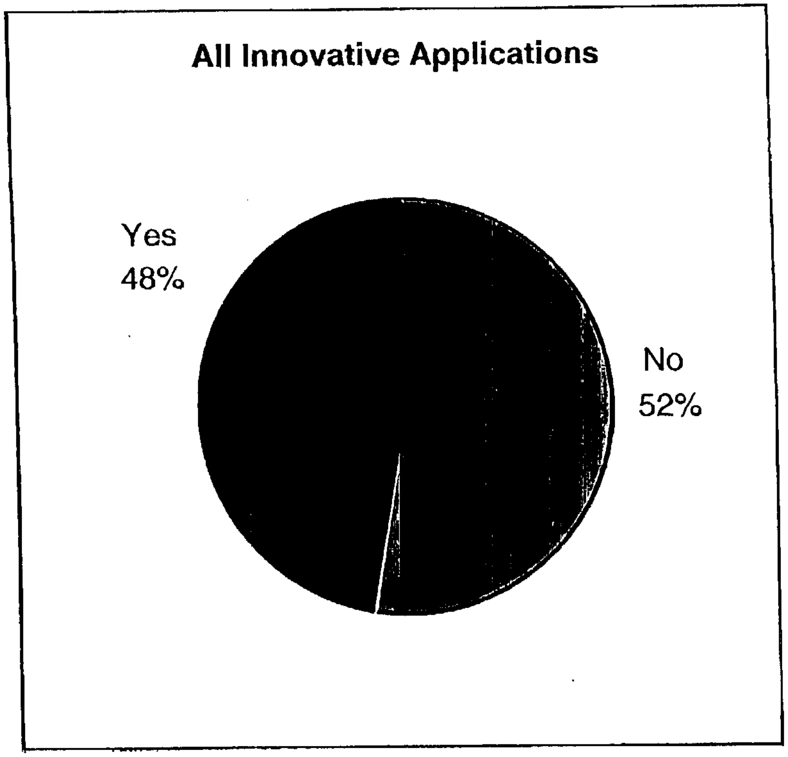


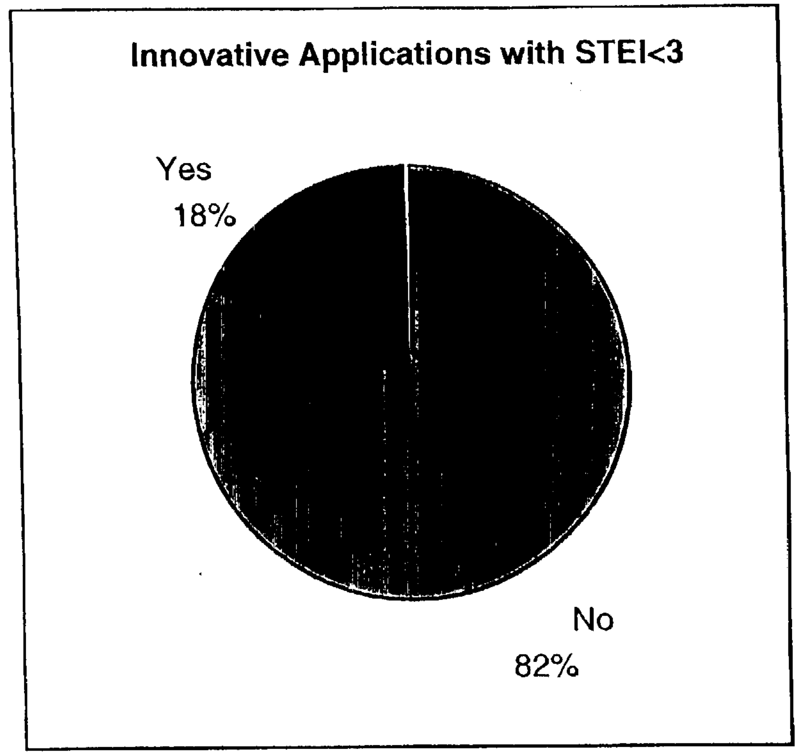
– Half the missions require on-orbit refueling

– Majority of missions will not require on-orbit refueling

Threshold Characteristics: On-Orbit Payload Changeout Required

(% breakdown based on total weight to LEO per year)



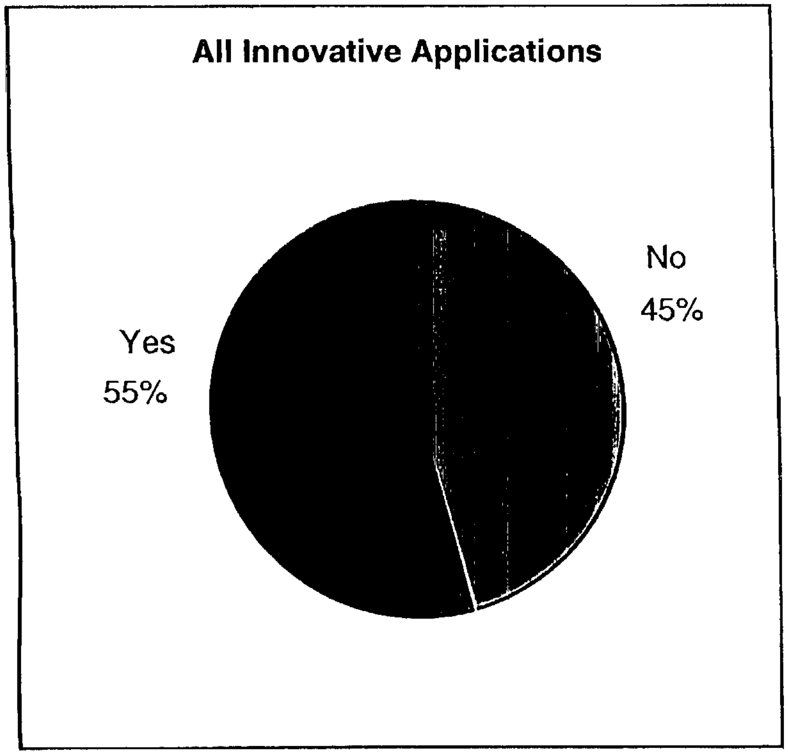


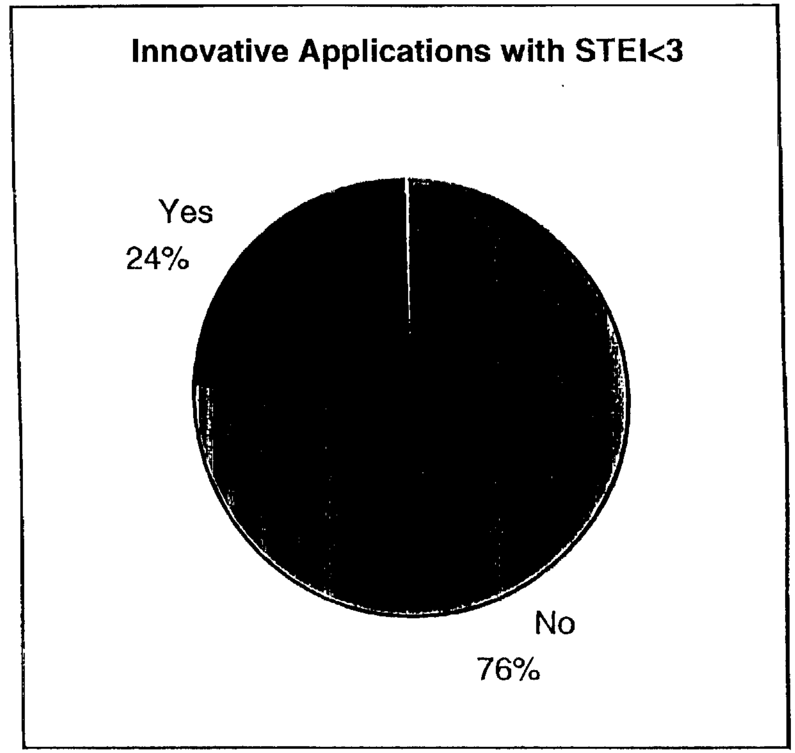
- Half the missions require on-orbit payload changeout

- Majority of missions will not require on-orbit payload changeout

Threshold Characteristics: On-Orbit Cargo Transfer

(% breakdown based on total weight to LEO per year)

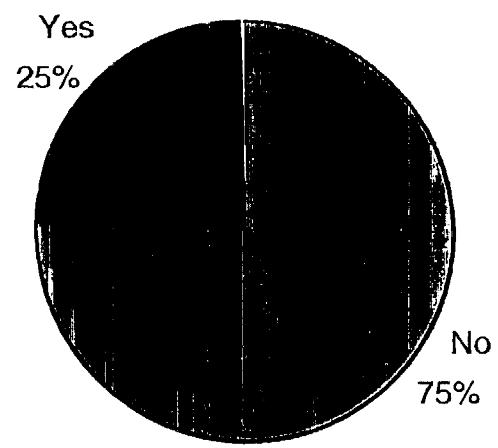


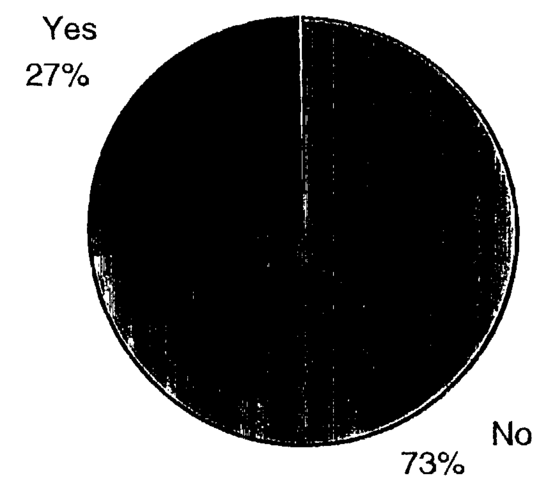


- More than half the missions may require on-orbit cargo transfer
- Majority of missions will not require on-orbit cargo transfer

Threshold Characteristics: On-Orbit Transfer (Space Suits)

(% breakdown based on total weight to LEO per year)

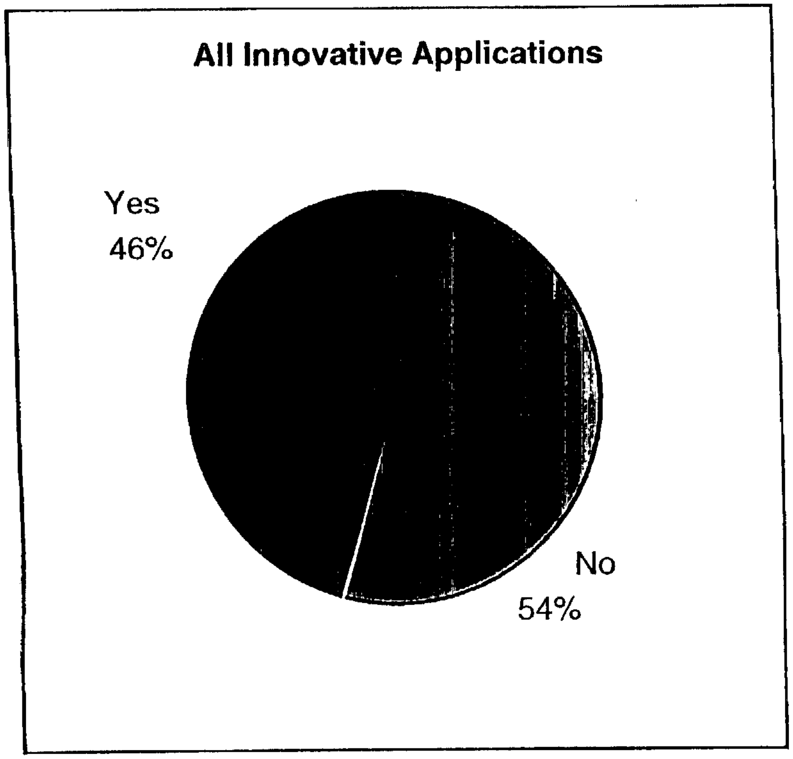


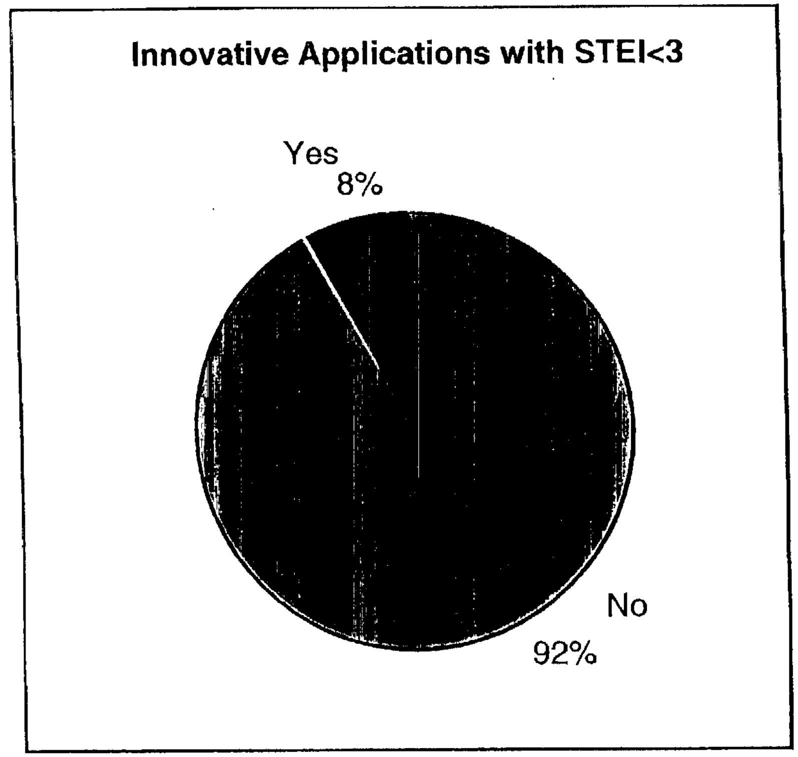


- Majority of missions will not require on-orbit transfer with space suits
- Majority of missions will not require on-orbit transfer with space suits

Threshold Characteristics: On-Orbit Transfer (Shirt Sleeves)

(% breakdown based on total weight to LEO per year)

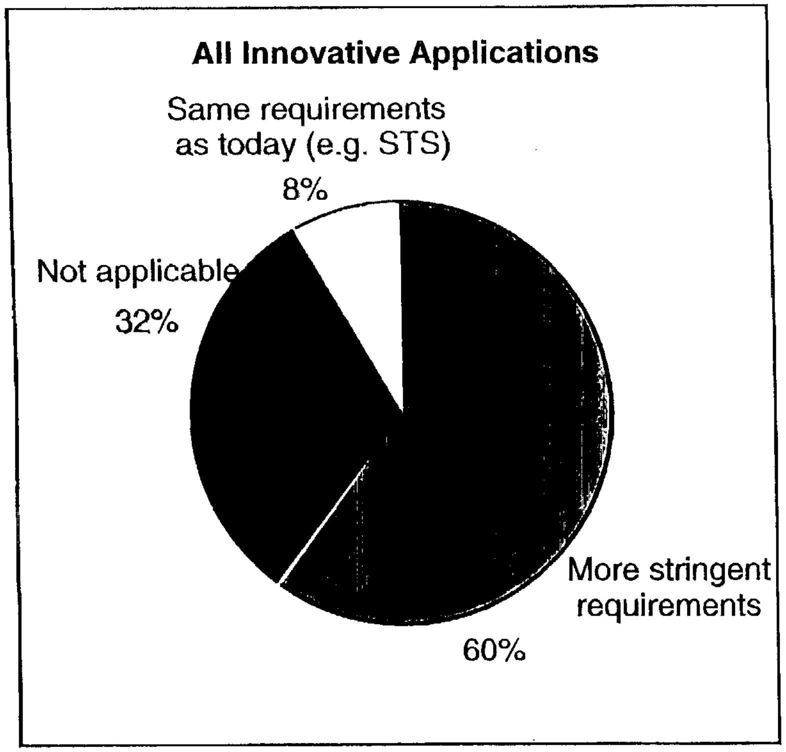


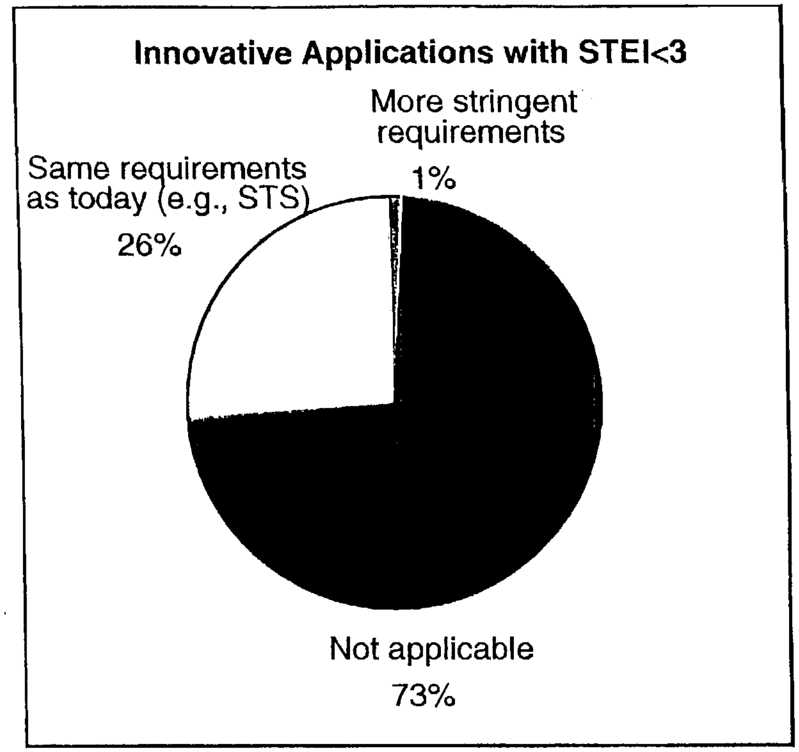


- Almost half the missions may require on-orbit transfer in shirt sleeves
- Majority of missions will not require on-orbit transfer with shirt sleeves

Threshold Characteristics: Safe Abort Requirement

(% breakdown based on total weight to LEO per year)



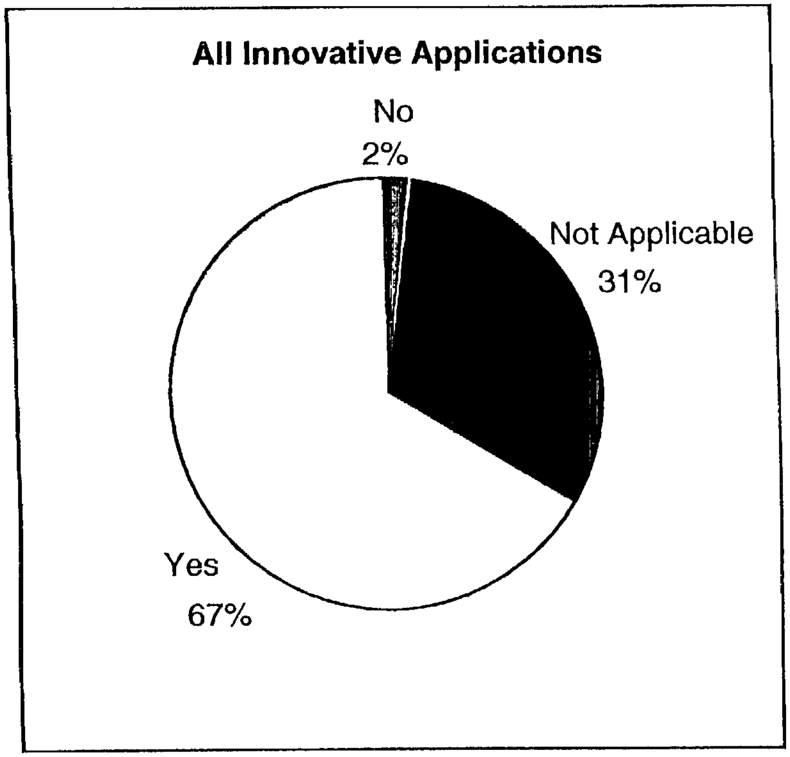


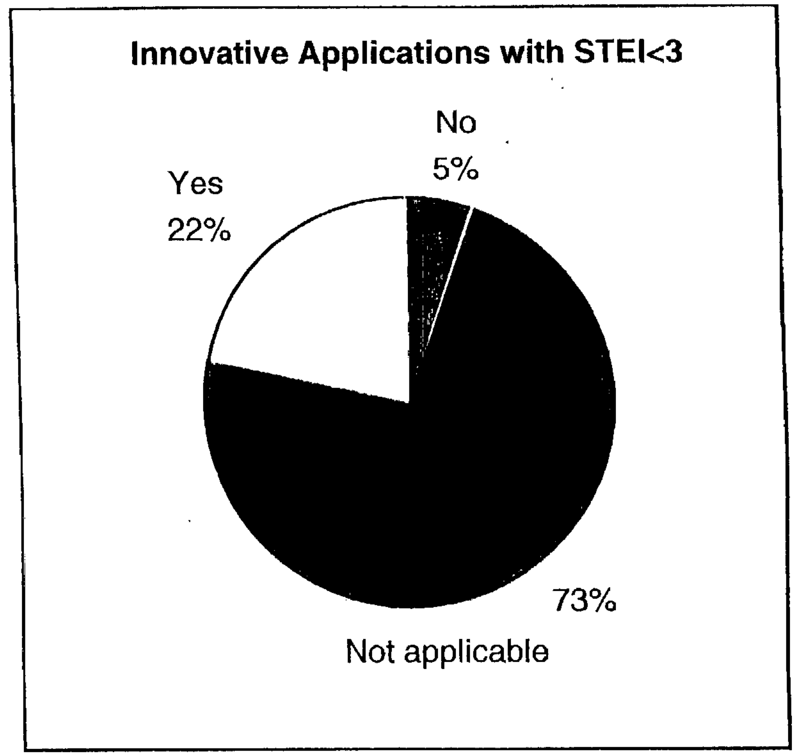
- Majority of missions require safe abort requirements that are more stringent than today's

- Today's safe abort requirements are acceptable to those missions that require safe abort capability

Threshold Characteristics: RTLS Capability After Abort

(% breakdown based on total weight to LEO per year)

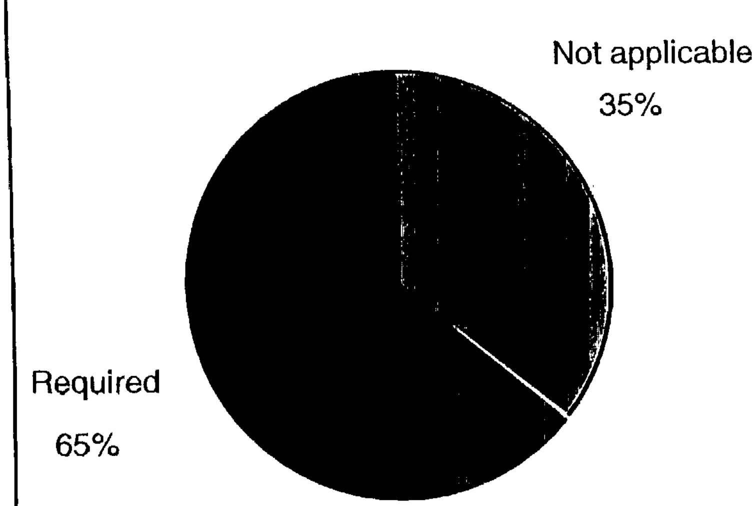


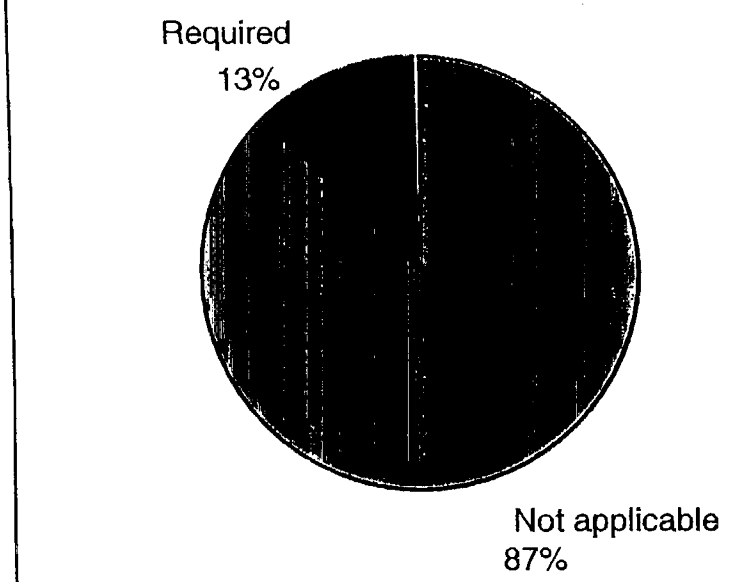


- **Majority of missions require return to launch site (RTLS) capability after abort**
- **Majority of missions do not need RTLS capability after abort**

Threshold Characteristics: Crew Safe Ejection during Flight

(% breakdown based on total weight to LEO per year)

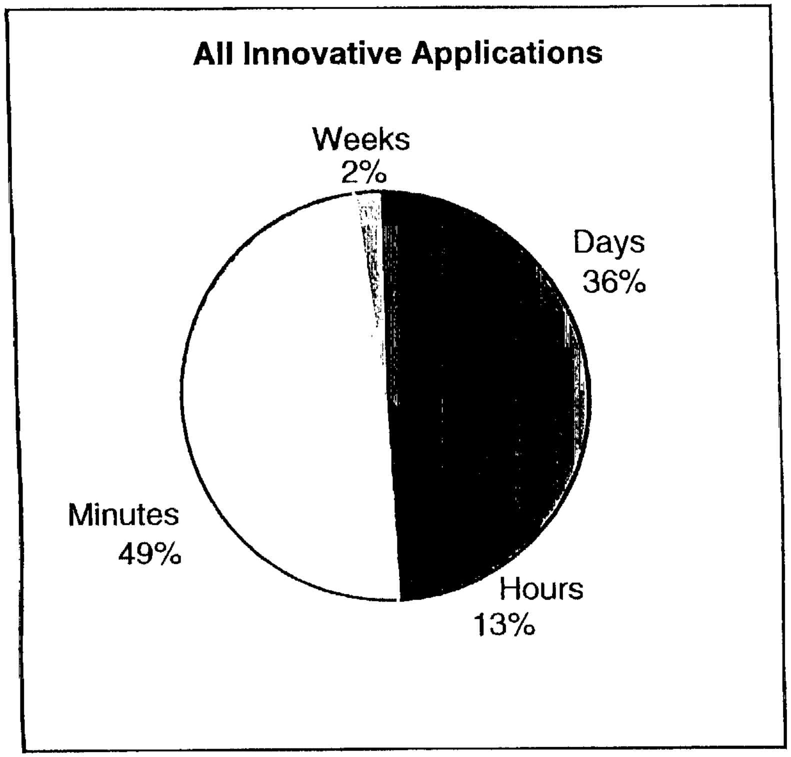


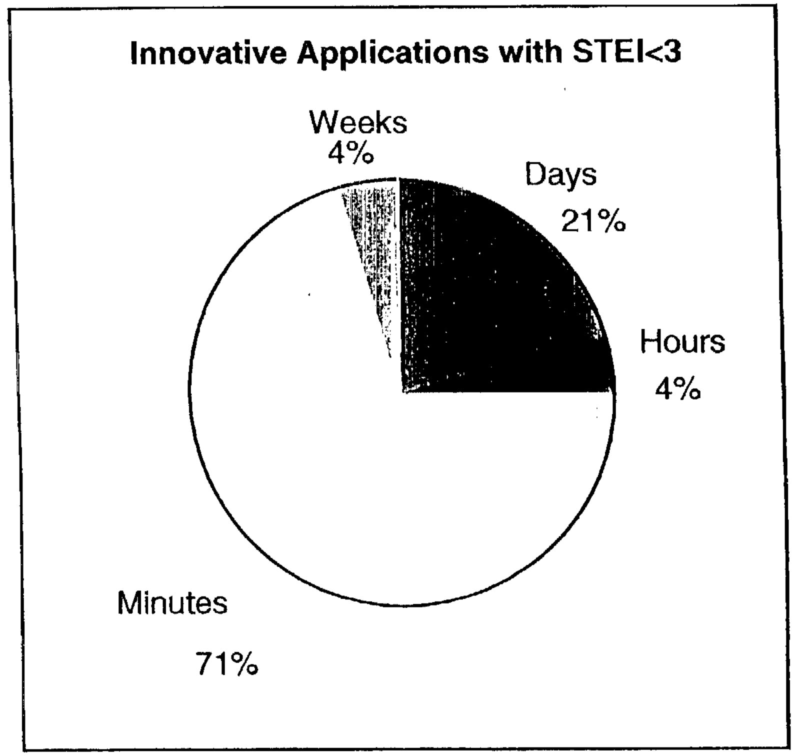


- **Majority of missions require crew safe ejection capability**
- **Majority of missions will not require crew ejection capability**

Threshold Characteristics: Transport Mission Duration

(% breakdown based on total weight to LEO per year)

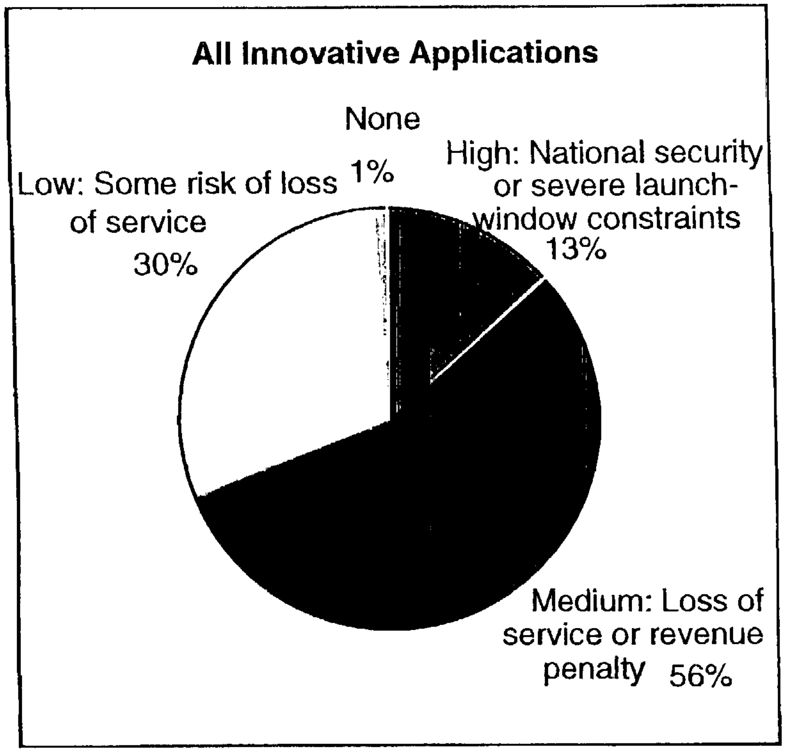


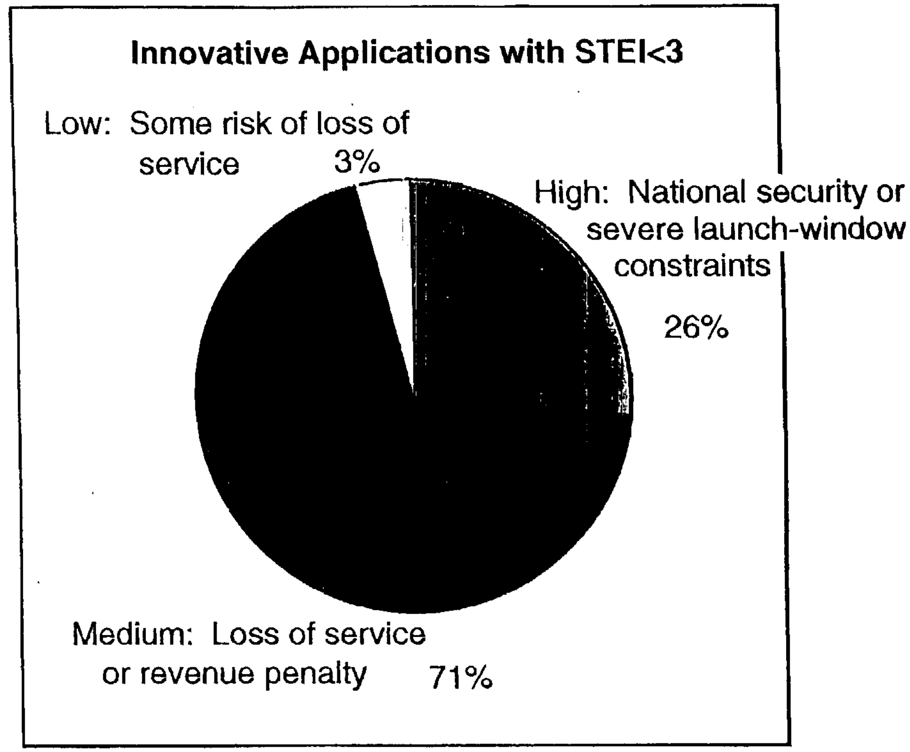


- Half the missions have transport times of minutes
- Majority of the transport missions last a few minutes

Threshold Characteristics: Schedule Reliability Importance

(% breakdown based on total weight to LEO per year)



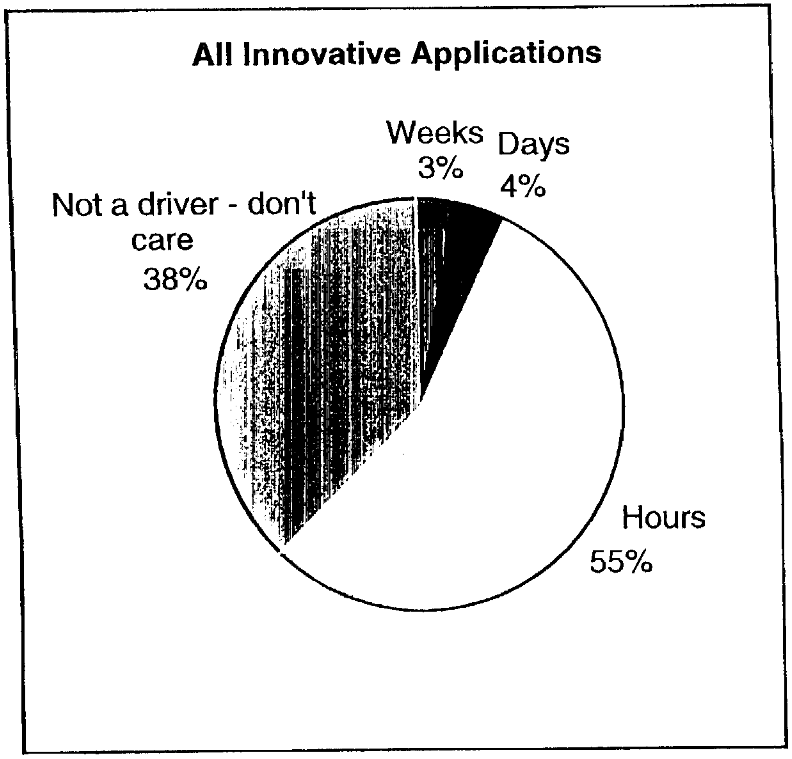


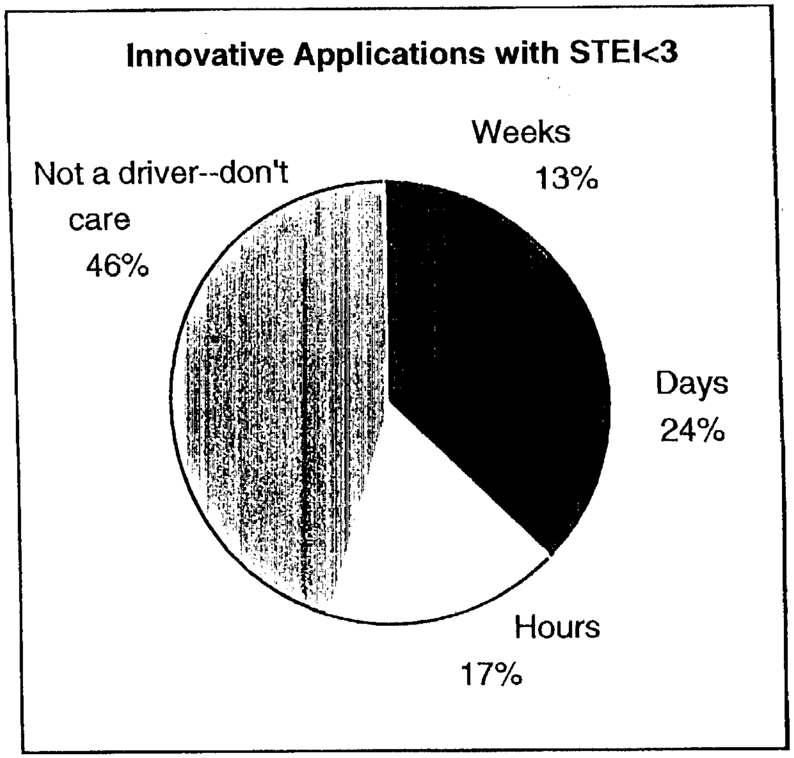
- Majority of missions will suffer revenue penalty if not launched on schedule
- 13% of missions have critical need to launch on schedule

- Majority of missions will suffer revenue penalty if not launched on schedule
- 26% of missions have critical need to launch on schedule

Threshold Characteristics: Time Required to Swap Payload

(% breakdown based on total weight to LEO per year)





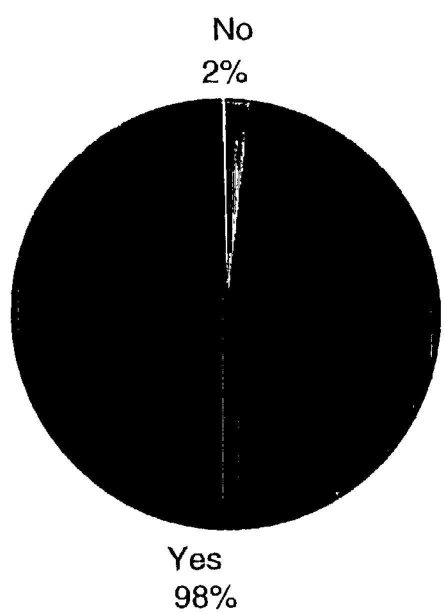
- **More than half the missions require payload swap time of hours**
- **A significant portion do not care**

- **Almost half the missions are not concerned about payload swap time**
- **Rest require weeks, days, or hours of payload swap time**

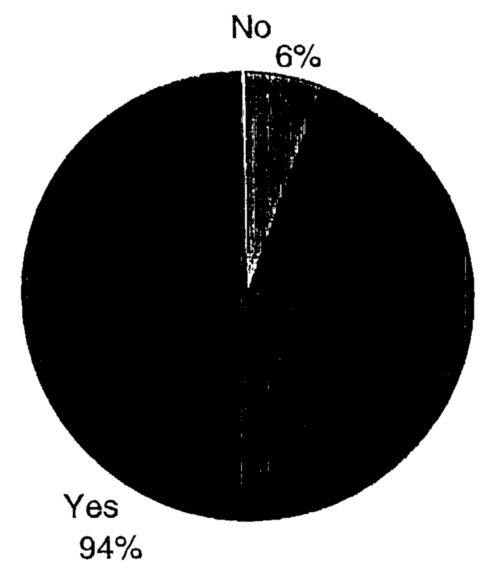
Threshold Characteristics: Encapsulated Payload

(% breakdown based on total weight to LEO per year)

All Innovative Applications



Innovative Applications with STEI<3

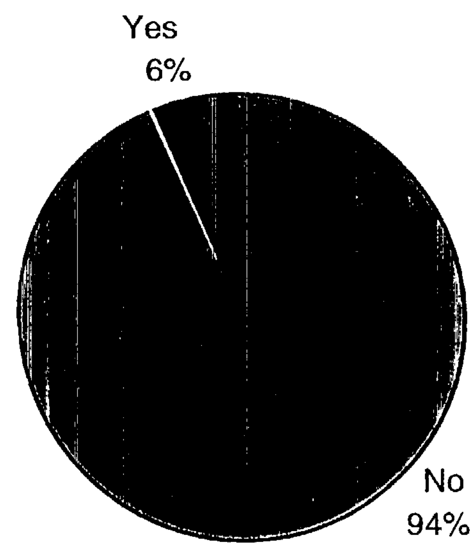


- Most missions will have encapsulated payloads
- Most missions will have encapsulated payloads

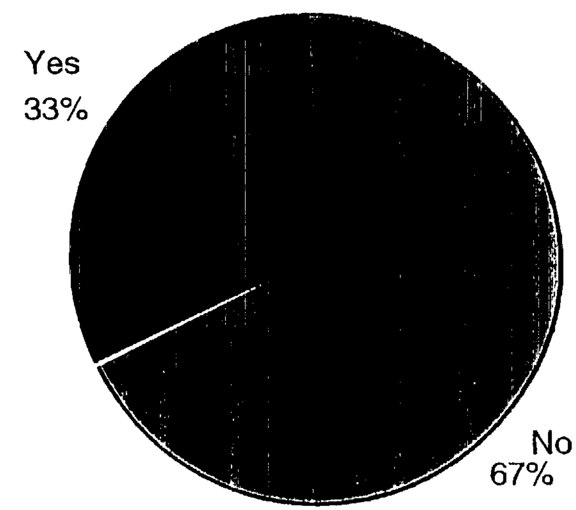
Threshold Characteristics: Payload Fuel Handling Prior to Launch

(% breakdown based on total weight to LEO per year)

All Innovative Applications



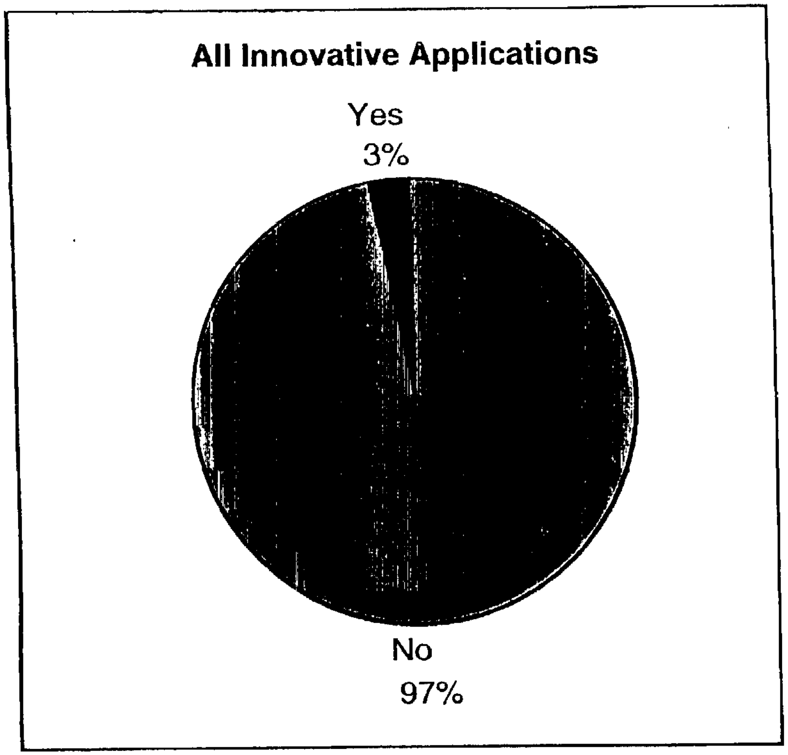
Innovative Applications with STEI<3

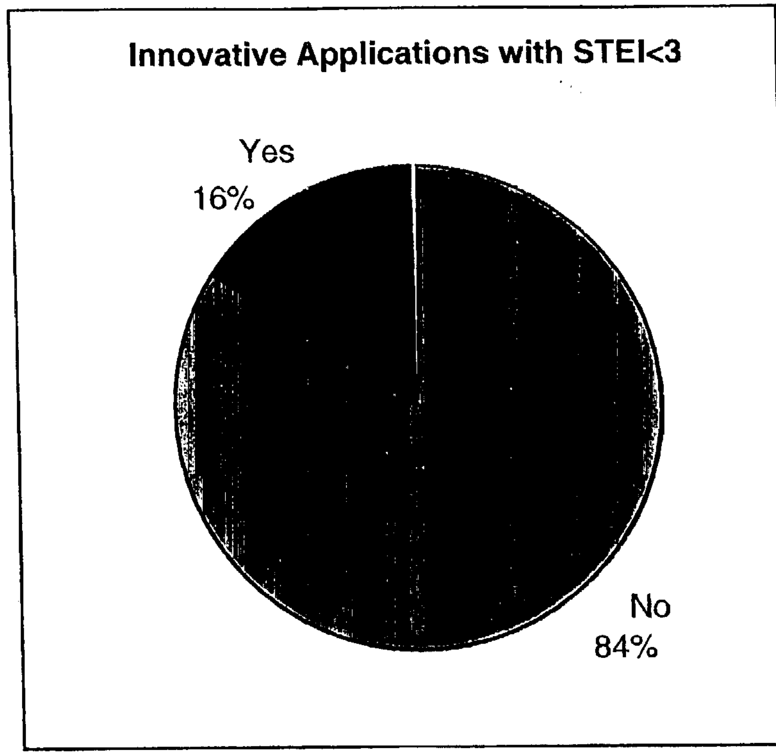


- Most missions do not need to handle payload fuel prior to launch
- Majority of missions do not need to handle payload fuel prior to launch

Threshold Characteristics: Payload Fuel Handling Inflight/Abort

(% breakdown based on total weight to LEO per year)

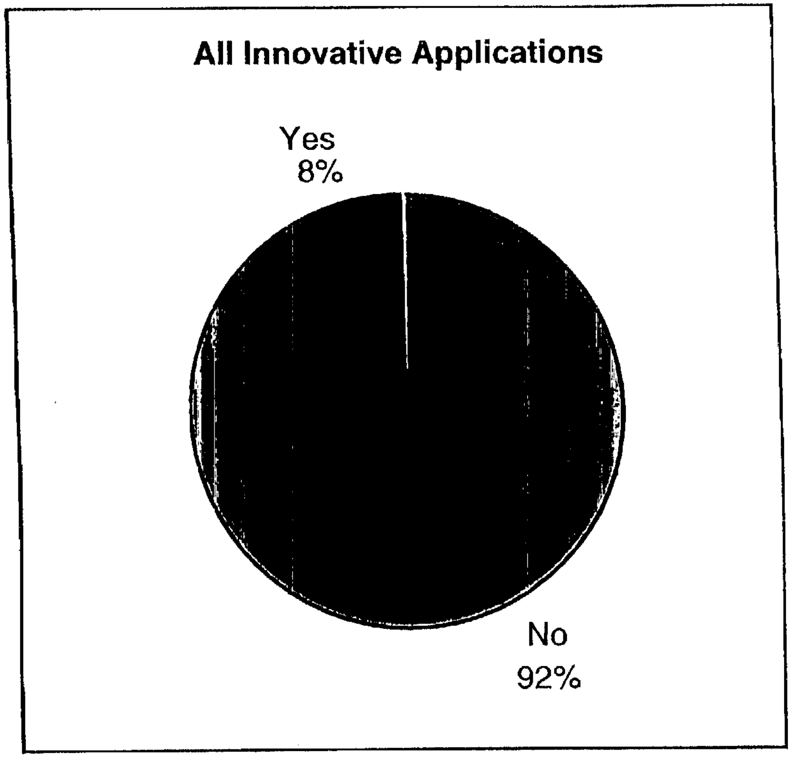


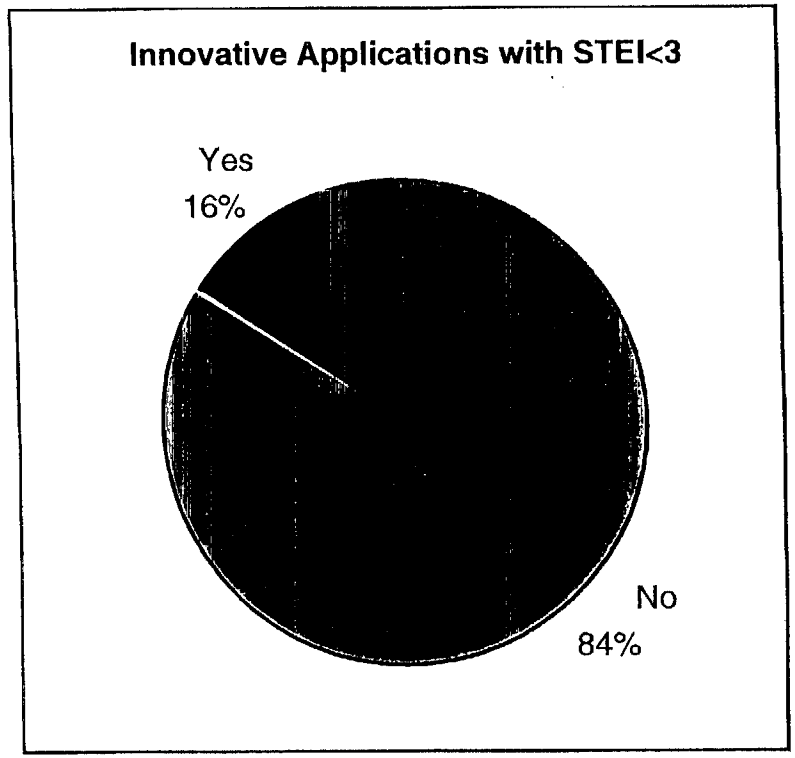


- Most missions do not need to handle payload fuel inflight or during abort
- Majority of missions do not need to handle payload fuel inflight or during abort

Threshold Characteristics: Payload Fuel Handling After Landing

(% breakdown based on total weight to LEO per year)

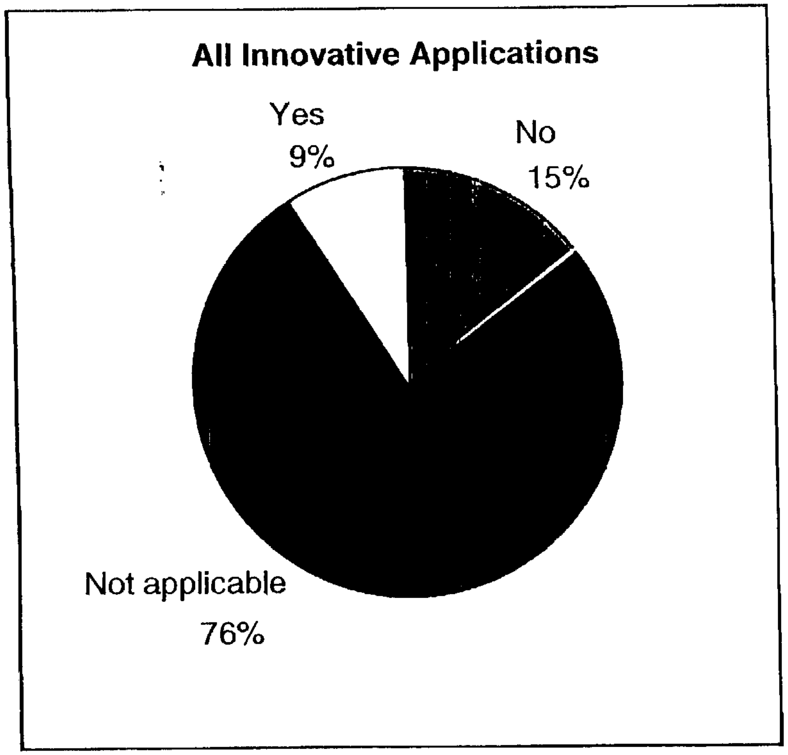


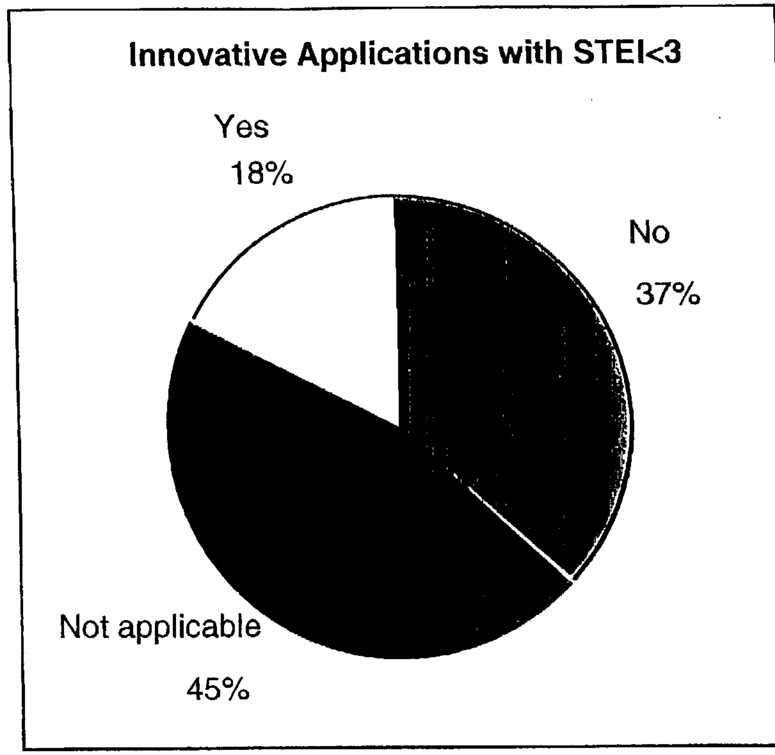


- Most missions do not need to handle payload fuel after landing
- Majority of missions do not need to handle payload fuel after landing

Threshold Characteristics: Launch during Conflict Conditions

(% breakdown based on total weight to LEO per year)





- **Small percentage of missions need launch capability during conflict conditions**

- **Small percentage of missions need launch capability during conflict conditions (military spaceplane)**