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FINANCIAL RESPONSIBILITY FOR REENTRY VEHICLE OPERATIONS

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ABSTRACT

The Department of Transportation's Office of Commercial Space Transportation is in the process of assessing the safety of a reentry vehicle and its operation and is developing an associated regulatory framework for ensuring public safety while minimizing regulatory burdens, delays, or uncertainties that could hamper or prevent development of commercial space transportation and reentry capabilities.

As part of this overall activity, the existing statutory ceilings on third-party liability and government property insurance requirements were examined to establish their appropriateness for licensed reentry operations. Specifically, the Commercial Space Launch Act's existing ceilings and risk-based determination of the maximum probable loss that would result from licensed reentries were examined to establish their appropriateness to licensed reentry operations.

It was found that the current statutory requirements are more than adequate for ensuring third-party and government property against the risks likely to be encountered from licensed reentry operations. It was concluded that the current methods employed for the setting of financial responsibility, i.e., the determination and use of maximum probable loss, is also appropriate for reentry operations. It was determined, based upon extensive conversations with the space insurance industry, that insurance industry capacity for providing third-party and government property coverage at a reasonable price is adequate and is not likely to pose a problem, at least in the near-term. The recommendation was therefore made that the existing ceilings and method for setting financial responsibility requirements for launches be used for setting financial requirements for reentry operations.

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1. Introduction

The Department of Transportation's (DOT's) Office of Commercial Space Transportation (OCST) has been in the process of assessing the safety of a reentry vehicle and its operation. The vehicle was designed with the intent to reenter from orbit after approximately 30 days in space and land at a designated landing site within the United States. Although there were some questions regarding the authority of the Office to review and approve such vehicles/operations, Congress indicated that the Office should proceed with the review process, but it was not appropriate to issue a license as was planned. The Secretary of Transportation subsequently submitted to Congress in a re-authorization request the specific inclusion of reentry vehicles within DOT's licensing authority. The proposed amendments were to create a regulatory framework for ensuring public safety while minimizing regulatory burdens, delays, or uncertainties that could hamper or prevent development of these commercial space transportation and reentry capabilities.

As part of this effort the Secretary indicated the intent to examine whether existing statutory ceilings on third-party liability and government property insurance requirements are appropriate for licensed reentries. Methodologies for setting financial responsibility requirements for these activities would also be evaluated. The Commercial Space Launch Act's[1] existing ceilings and risk-based determination of the maximum probable loss that would result from licensed reentries would apply, pending the results of the evaluation and any DOT recommendations for change.

The purpose of this report is to document the findings of a study to carry out these examinations and evaluations leading to the establishment of financial responsibility for reentry operations. Princeton Synergetics, Inc. (PSI) examined the existing statutory ceilings on third-party liability and government property insurance requirements by reviewing the associated legislation, hearings, and Congressional reports and by talking with individuals in the insurance industry and in government who were familiar with the history of the current statutory ceilings. The appropriateness of these ceilings for licensed reentry operations were assessed by considering the risks associated with reentry operations, reviewing the report language associated with Congressional actions relating to financial responsibility requirements for licensed commercial launches and by talking with representatives of the insurance industry to acquire insight into the status of the industry and the availability of coverage at a reasonable cost.

The methodologies for setting financial responsibility requirements for licensed commercial launch operations were also examined and the appropriateness of these

[1] The Commercial Space Launch Act of 1984, 49 U.S.C. App. §§ 2601-2623, as recodified at 49 U.S.C. Subtitle IX, ch. 701--Commercial Space Launch Activities, 49 U.S.C. §§ 70101-70119 (1994).

methodologies assessed for application to licensed reentry operations. It is concluded that the current statutory requirements are more than adequate for insuring third-party and government property against the risks likely to be encountered from the type of licensed reentry operations currently being contemplated. It is also concluded that the current methods employed for the setting of financial responsibility, i.e., the determination and use of maximum probable loss, is also appropriate for reentry operations. It was determined, based upon extensive conversations with the space insurance industry, that insurance industry capacity for providing third-party liability and government property cover at a reasonable price is adequate and is not likely to pose a problem, at least in the near-term.

This report first examines the history behind the requirement that providers of commercial space transportation services be responsible for a designated level of liability coverage and the government's position on indemnifying losses beyond that level (to a specified upper limit subject to approval of a compensation plan and an appropriation Act of Congress). Background from NASA's practice of requiring third-party liability insurance and the international treaties that induced that practice are discussed in Section 3. The rationale behind the statutory ceilings manifested in the Commercial Space Launch Act Amendments of 1988 are also discussed in Section 3 as are the space insurance industry capacity and pricing. The risks associated with reentry operations are addressed in Section 4. Section 4 also describes the maximum probable loss (MPL) methodology. Section 5 discusses the appropriateness of the existing statutory requirements and MPL methodology that have been used for launch operations for setting financial responsibility requirements for reentry operations. A summary of findings relative to the appropriateness of the current statutory requirements and MPL methodology for reentry operations is presented in Section 6 and specific recommendations are presented in Section 7.

2. Background

Throughout the study a number of terms are employed which, for the purposes of this study, have specific definitions. These definitions are presented below.

Third-Party - is defined in section 70102 of 49 U.S.C. Subtitle IX, ch. 701, Commercial Space Launch Activities as "any person or entity other than the United States, its agencies, or its contractors or subcontractors involved in launch services; the licensee or transferee; the licensee's or transferee's contractors, subcontractors, or customers involved in launch service; or, any such customer's contractors or subcontractors involved in launch services." It appears that this definition, by not listing the employees of the U.S. government with those excluded from the list of third-parties, defines government employees involved in providing launch services as third-parties.

For the purposes of calculating maximum probable loss, *third-party* includes any person other than on-range employees of an entity involved in the licensed commercial launch activities[2] under consideration. The term also includes on-range government and government contractor employees; although these persons may be involved in the licensed activities, they are considered third-parties.

[2] Launch Licenses define this term to include launch and launch site operations associated with the commercial launch operation(s).

Other on-range third-parties include the personnel of commercial launch firms not involved in the activities under consideration, and any other persons or entities that are not private party launch participants (where private party launch participants includes contractors and subcontractors) in the licensed activities.

NOTE: Range policies generally prohibit the exposure of such third-parties to significant support and launch risks.

All persons off the launch range are considered to be third-parties.

Third-Party Liability Claims: refer to claims by a third-party for death, bodily injury, or loss of or damage to property resulting from activities carried out under the license in connection with any particular launch.

Maximum Probable Loss (MPL): Maximum magnitude of loss such that there is less than a specified probability (i.e., the threshold probability) of exceeding this level, as illustrated in Figure 1 and 2. This is also referred to as the threshold accident.

Threshold Probability: Represents the probability that loss or damage will exceed a specified dollar value. The threshold probability is a quantitative measure selected by DOT as representing the probability of occurrence associated with "unlikely" events of levels of damage due to launch and launch related activities. The values currently in use by DOT are 10^{-5} for government property and 10^{-7} for third-party damage. This is illustrated in Figures 1 and 2 as the cross-hatched areas under the loss probability density function.

Licensed Activities: The term licensed activities as used in this study refers to the activities on a launch range by a commercial firm which are covered by a Department of Transportation license. Such activities may include launch activities, support activities in preparation for a specific launch or the commercial activities of a company with a permanent facility on a launch range. Licensed activities may also include the disposition of launch vehicle components and payloads following a launch (see *Launch Activities*). For example, at federal launch ranges, DOT's licenses address launch activities which include two different operations, the launch operation and the launch site operations. Both types of operations are examined in the determination of the MPL values and the resultant requirements implemented through License Orders.[3]

Finally, licensed activities are not necessarily limited to a launch range; for example, airborne launch activities may include as licensed activities the preparation and takeoff of the associated aircraft (for the purposes of releasing the attached launch vehicle for flight) from an air field not generally used for space launches.

With respect to reentry activities, proposed licensed activities would include the reentry of the reentry vehicle system through impact and removal of hazardous materials (if any).

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[3] For Launch Specific Licenses, the requirements are set based on the MPL values for third-parties and government property across both activities. For Launch Operators Licenses, the third-party and government property insurance requirements are set separately for the launch site operations and the launch operations.

Launch Activities : Activities occurring during the launch period for a specific launch. The launch period generally begins at ignition, and continues through flight of the launch vehicle and delivery (release) of the spacecraft on orbit. For orbital missions, launch activities are considered to be completed after spacecraft separation and any subsequent flight operations taken by the launch vehicle, however, insurance requirements remain in place for 30 days after the launch in most cases in order to allow time to assess any flight anomalies that might affect the exposure to liabilities. For sub-orbital launches, launch activities are considered to be completed when the launch vehicle returns to Earth, or when the payload is recovered, whichever occurs later.

Reentry Activities: The reentry of the reentry vehicle system through impact and removal of hazardous materials (if any). Those related reentry vehicle activities that, for example, occur during pre-launch operations, such as mating of the reentry vehicle propulsion system, and those on-orbit reentry preparation activities that may affect the performance and safety of reentry operations are assessed and monitored in order to ensure public health and safety.

Support Activities: Support activities begin with the arrival of a firm (its vehicle components, payload, or personnel) on the launch (or reentry) range in preparation for commercial launch or reentry operations. Support activities end when the licensed entity leaves the launch range or reentry operations have been completed.

Government Property: Fixed property, such as buildings and launch pads, and non-fixed property such as equipment and launch vehicle and spacecraft components, which are owned by the government or government contractors on the launch or reentry range are considered to be government property for the purposes of determining maximum probable loss. No property off the launch range is included, except for the special case of airborne space launches. In this case, the aircraft used to launch the space vehicle (if the aircraft is owned by the government) is to be considered government property (for the purposes of MPL) throughout the launch, even when the aircraft is not on the launch range. In addition, transient property (e.g., payload and/or launch vehicle on an adjacent pad) is not considered in the determination of maximum probable loss since the risk to the transient property is a government choice and also would depend on whether, on any particular date, the property is exposed to potential damage or loss. This is unknown as of the time OCST determines MPL values.

Casualty: A casualty is a person suffering death or serious injury as the result of an accident associated with licensed activities. The value of life is estimated as $3 million for the purposes of determining MPL.

Property Damage: For government property, property damage is defined as damage to fixed and non-fixed property owned by the government or its contractors. For property

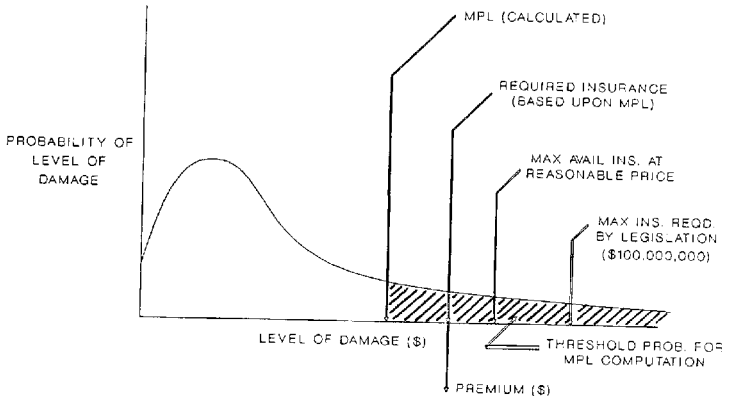

Figure 1 Government Facility Damage (Function of Launch Vehicle and Range)

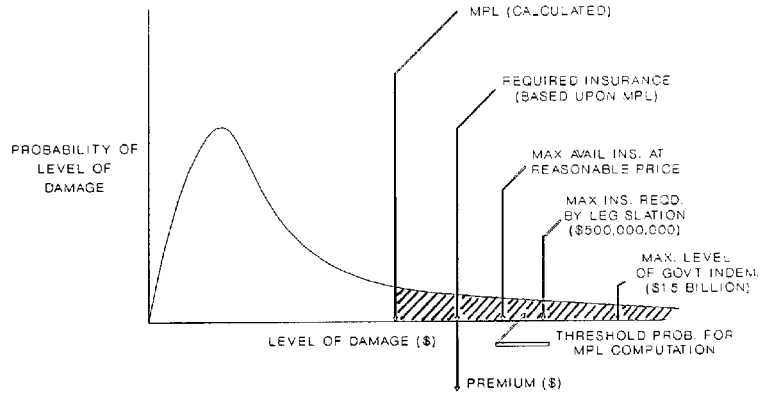

Figure 2 Third-Party Damage (Function of Launch Vehicle and Range)

Property Damage: For government property, property damage is defined as damage to fixed and non-fixed property owned by the government or its contractors. For property owned by third-parties, property damage is defined as any damage to any property. The cost of property damage is calculated when possible based on the replacement value of the property. As in the above definition of government property, transient property is not considered in determining the MPL value and insurance requirement.

Also, when used throughout this report, the term *Secretary* will refer to the Secretary of Transportation.

3. Existing Statutory Ceilings for Launch Operations

Background of Government Involvement in Liability Insurance

To provide background on the Government's control of liability, a brief review is presented of the Price-Anderson Act[4], the U.S. obligations with regard to liability under international treaties, and the NASA's history of requiring a limited amount of liability protection for commercial users of its launch vehicles. The Price-Anderson Act is important since it deals with the indemnification of an industry with attributes similar to those of the space launch industry: very low probability of potentially very damaging events and little data to indicate likelihood and magnitude of damages. U.S. obligations with regard to liability under United Nations (Outer Space Treaties) international treaties is of concern because the U.S. would be expected to pay for damages caused by its space objects, as stated in the Treaty, and this provided motivation to ensure the funds are available.

The Price-Anderson Act

As with the possibility of an accident causing liability damages from a space launch, the probability of occurrence and maximum possible magnitude of damages from a nuclear power accident are both unknown. In the 1950's the Nuclear Regulatory Commission concluded that property damage from a nuclear incident might range from half a million dollars to a worse case limit of $7 billion (which would be due mostly to contamination of land with fissionable products). Later studies estimated far greater damages. The NRC's Reactor Safety Study [1975] estimated damages from a major accident could reach $17 billion.[5] Although the probability of a catastrophic nuclear incident is extremely low, it is desirable that insurance be available to provide for such a possibility.

The Price-Anderson Act of 1957 was enacted to overcome industry reluctance to participate in nuclear power generation due to fear of the possibility of catastrophic, uninsured claims from a nuclear accident, and to avoid delay or failure to provide compensation to the public in the event of a nuclear incident.

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[4] The Price-Anderson Act, 42 U.S.C., 1957.

[5] "Hearings Before the Joint Committee on Atomic Energy on Governmental Indemnity for Private Licensee and AEC Contractors Against Reactor Hazards," 84th Congress, 2nd Session, May 15, 16, 17, 18, 21, and June 14, 1956.

The Price-Anderson Act, involves a two tier system for liability payments. The first consists of primary nuclear liability insurance available on the private market for which each nuclear reactor owner now pays a premium annually for $200 million worth of coverage for each large power reactor site.[6] The second tier, which applies only to operators of large licensed reactors, would come into play in the event of an accident causing damages in excess of $200 million. Each operator would be assessed a prorated share of damages in excess of the primary insurance coverage of up to $63 million[7] per reactor per accident. With 115 commercial reactors under the system, the secondary level would total $7.245 billion.[8] When the original version of the Act was passed in 1957, liability insurance in the private market was $60 million and the government agreed to be liable for $500 million.[9,10] The rationale behind the $500 million limitation on government indemnification was that $500 million would not significantly disturb the Federal budget.[11] For many years the limit of liability was the sum of private insurance coverage plus government indemnity and totaled $560 million. In 1982, when the primary and secondary layers for large reactors reached $560 million, the government's indemnity was basically eliminated.[8]

International Treaties Relating to Liability

Both the 1967 Outer Space Treaty and the Liability Convention require that a launching country be liable for any damages caused by an object that is launched from that country. These treaties provided some of the impetus for NASA's requirement that commercial users of the shuttle and ELV's procure liability insurance.

Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies

The so-called "Moon Treaty" states that each State party to the Treaty that launches or procures the launch of an object into outer space, or from whose territory or facility an object is launched, is internationally liable for damage caused by the launched object (or its component parts) on the Earth, in air space or in outer space, to another State party to the Treaty or to its citizens.

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[6] When the Act was first enacted this level was $60 million per reactor. Later it increased to $160 million per reactor.

[7] This was increased from $5 million in the 1988 Amendments to the Act.

[8] "The Price-Anderson System," Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission

[9] "AIF, Background Info, Public Affairs and Information Program, The Price-Anderson Act: Questions and Answers," Atomic Industrial Forum, Inc., September 1983.

[10] "Nuclear Power and Insurance," Marguerite Shea, Chicago Bar Association Young Lawyers Journal, Vol. 13, No. 4, January 1984.

[11] Analysis of the Price-Anderson Act, General Accounting Office, August 18, 1980.

Convention on International Liability for Damage Caused by Space Objects, United Nations, October 9, 1973.

The Liability Convention allocates liability for damage caused by space objects. It states that a launching State is absolutely liable for damages caused by its space objects on the surface of the Earth or to aircraft in flight. In the event of damage being caused elsewhere, the launching State is liable if fault can be shown. The Convention also provides for the establishment of a claims commission to regulate and decide these claims. This treaty formed the basis for consequent NASA action regarding third-party liability insurance requirements.

NASA History Related to Third-Party Liability Insurance and Indemnification

It had been NASA's policy since the late 1970's[12] to require commercial users of launch vehicles to obtain third-party liability insurance to protect the user and the U.S. government. NASA usually specified in the launch services agreement that its customers obtain the maximum liability insurance available on the market at a reasonable cost.[13] No first-party property insurance was required since the Government conducted all of the launch operations.[14]

Section 308 of the 1980 NASA Authorization Act directed NASA to use appropriations for third-party liability insurance to cover space vehicle users and to seek reimbursement by the user to the maximum extent possible. Section 308 also authorized the U.S. government to indemnify successful claims above the user's liability insurance. Specifically, **Section 308 of the 1980 NASA Authorization Act (Public Law 96-48)** authorized the Administration to use appropriations to provide liability insurance to any user of a space vehicle to compensate third-party claims arising from activities connected with the launch, operations or recovery of the space vehicle but stipulated that such appropriations had to be reimbursed by the users to the maximum extent practicable under reimbursement policies established in the Space Act. Section 308 also allows that the U.S. government may indemnify the user against third-party liability claims that are not compensated by the user's liability insurance (such indemnification may be limited to claims resulting from other than the actual negligence or willful misconduct of the user).

Because $500 million was the amount that was commercially available at the time of the first commercial launches on the shuttle (Lloyd's of London told NASA's General Counsel at the time that they'd have no trouble finding $500 million per launch coverage) and because this level was believed to be more than sufficient to cover potential third-party damages from flights that were headed over the ocean (in other

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[12] Discussion with Robert Wojtal, Office of the Counsel, NASA, September 25, 1994.

[13] Mossinghoff, Gerald J., "Managing Tort Liability Risks in the Era of the Space Shuttle," Journal of Space Law, Vol. 7, No. 2, 1979.

[14] "Commercial Space Launch Act Amendments of 1988," Report of the Senate Committee on Commerce, Science, and Transportation on H.R. 4399, Report 100-593, October 7, 1988.

words, because of the trajectory of the shuttle flights, the risk of damages was felt to be extremely low), $500 million was normally required to cover one payload[15] ($750 million for a multiple payload launch[14]).

Legislative Background on the Financial Responsibility Requirements for Commercial ELV's

The financial responsibility requirements governing commercial launches were enacted into law by the Commercial Space Launch Act of 1984 and by the 1988 Amendments to the Act.

The Commercial Space Launch Act of 1984 (Public Law 98-575), October 30, 1984[16]

The Commercial Space Launch Act of 1984 required licensees (or transferees) licensed under the Act to be covered by liability insurance, but left it to the Secretary of Transportation to determine the amount of insurance considering the international obligations of the U.S. It also allowed the Secretary to establish requirements for liability insurance, hold harmless agreements, proof of financial responsibility and other necessary assurances to protect the United States (and its agencies and personnel) from liability, loss, or injury resulting from a launch or launch site operation involving Government facilities or personnel.

It was DOT practice to set a third-party liability requirement based on maximum probable loss while considering the insurance available on the world market.[17]

The Commercial Space Launch Act Amendments of 1988 (Public Law 100-657) November 15, 1988.[18]

The Act was amended in 1988 to mandate that insurance (or other demonstration of financial responsibility) to compensate third-party liability claims be of a sufficient amount to compensate maximum probable loss (as would be determined by the Secretary for each license) for claims resulting from activities carried out under a license in connection with any particular launch. Liability insurance could not be required in excess of the lesser of $500 million or the maximum liability insurance available on the world market at a reasonable cost. Furthermore, the licensee (or transferee) would be required to obtain insurance (or otherwise demonstrate financial responsibility) to compensate maximum probable loss from claims against

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[15] Conversation with Neil Hosenball, David, Grahams and Stubbs, November, 1994.

[16] Public Law 98-575, 98th Congress, (The Commercial Space Launch Act) October 30, 1984.

[17] Maximum Probable Loss: Rationale and Supporting Information, prepared by Princeton Synergetics, Inc. for the Office of Commercial Space Transportation, U.S. Department of Transportation, April 29, 1991.

[18] "Commercial Space Launch Act Amendments of 1988," Public Law 100-657, November 15, 1988.

any person by the U.S. for loss of or damage to U.S. property resulting from licensed activities, but not in excess of the lesser of $100 million or the maximum liability insurance available on the world market at a reasonable cost.

In addition, the Amendments stated that to the extent that payment of claims is either provided for in advance in appropriations Acts or by additional legislative authority, subject to approval of a compensation plan, the Secretary shall provide for the payment of successful third-party liability claims against the licensee or transferee (or its contractors, subcontractors, or customers, or the contractors or subcontractors of such customers) to the extent that the aggregate of such claims arising out of a particular launch exceeds the required amount of insurance (or demonstrated financial responsibility) and is not in excess of $1,500,000,000 (adjusted for inflation) above such amount, except for those third-party damages that result from the willful misconduct by the licensee or transferee.

The Amendments also added the interparty waiver of claims provisions whereby "the Secretary, on behalf of the United States, its agencies involved in launch services, and contractors and subcontractors involved in launch services, shall enter into reciprocal waivers of claims with the licensee or transferee, its contractors, subcontractors, and customers, and the contractors and subcontractors of such customers, involved in launch services, under which each party to each such waiver agrees to be responsible for any property damage or loss it sustains or for any personal injury to, death of, or property damage or loss sustained by its own employees resulting from activities carried out under the license" to the extent that claims exceed the required amount of insurance or demonstration of financial responsibility.

Provisions also require the licensee or transferee to make a reciprocal waiver of claims with its contractors, subcontractors, and customers, and contractors and subcontractors of the customers, involved in launch services under which each party to the waiver agrees to be responsible for property damage or loss it sustains, or for personal injury to, death of, or property damage or loss sustained by its own employees resulting from an activity carried out under the license.

Congress' Intentions behind the Financial Responsibility Requirements of the Commercial Space Launch Act Amendments

According to the House[19] and Senate[20] reports accompanying H.R. 4399 issued in association with the 1988 Amendments, the amendments concerning financial responsibility requirements supported government policies to:

- recognize the commercial space launch industry as an essential component of the nation's efforts to assure access to space for government and commercial users;
- regulate launches and services to protect the public health and safety of property and national security and foreign policy interests of the U.S. (Commercial Space

[19] "Commercial Space Launch Act Amendments of 1988," Report 100-639, 100th Congress 2nd Session, May 19, 1988.

[20] "Commercial Space Launch Act Amendments of 1988," Report of the Senate Committee on Commerce, Science, and Transportation on H.R. 4399, Report 100-593, October 7, 1988.

Launch Act of 1984) and allow the Nation to fulfill its obligations under international treaties;

- limit liability of commercial launch operators for damage to Government property resulting from a commercial launch accident to the level of insurance required by DOT (President's Commercial Space Initiative of February 11, 1988).

Significant Administration and Legislative Actions

- May 1983 - In the National Security Decision Directive 94, the President announced Government support for facilitating and encouraging commercial launch activities of ELV's by the private sector.
- November 1983 the Department of Transportation was designated as the lead agency for commercial launch activities.
- February 1984 - Executive Order 12465 was signed directing DOT to act as the focal point within the Federal Government for private sector launch contracts.
- October 1984 - The Commercial Space Launch Act (Public Law 99-575) was signed into law.
- Summer of 1986 - National Security Decision Directive 254 stated that commercial and foreign payloads no longer would be launched by the shuttle.
- September 15 and 17, 1987, the Subcommittee on Space Science and Applications held hearings on the state of the commercial launch industry. Testimony received during the hearings led to the drafting and introduction on December 15, 1987 of H.R. 3765 (the predecessor to H.R. 4399).
- February 16 and 17, 1988 - a second set of hearings focusing on H.R. 3765 was conducted by the Subcommittee on Space Science and Applications.
- April 14, 1988 the Subcommittee marked up H.R. 3765 during which a refined text incorporating comments received from the Administration and industry witnesses was adopted.
- April 18, 1988 - a clean bill, H.R. 4399 was introduced incorporating the amendments adopted by the Subcommittee.
- April 21, 1988 - H.R. 4399 was thereupon approved by the full Committee on Science, Space and Technology and ordered reported.
- May 13, 1988 Senate bill 2395, "The Commercial Space Launch Act Amendments of 1988" were introduced as a companion measure to H.R. 4399.
- May 17, 1988 the Senate Science, Technology and Space Subcommittee held a hearing to obtain testimony on both House and Senate legislation.
- May 24, 1988 - H.R.4399 passed the House under a suspension of the rules by the House.
- September 20, 1988 - the Senate Committee ordered reported with amendments in the nature of a substitute, H.R. 4399. The language of the substitute is that of S. 2395 with some amendments agreed to by the Committee.
- October 7, 1988 - Full Senate Committee reported (Senate report 100-593) it out with recommended changes.
- October 14, 1988 - Laid before the Senate, H.R. 4399 passed with changes.
- October 21, 1988 - House agreed to Senate amendments.
- Nov. 15, 1988 - Amendments signed into law (Public Law 100-657)

The burden that the launch industry faced, of exposure to unknown risks of a launch accident, especially given that the policy at the time required the industry to assume all risks, and the uncertainty of insurance availability, was viewed as an intolerable risk that posed "a major threat to the emergence of an internationally competitive launch industry" and was therefore in contradiction to government policies to foster the development of the commercial launch industry. In light of foreign competition, where foreign government supports of national launch providers included charging less than full cost or not at all for insurance, the Senate report stated that it was compelled to address launch property and liability issues associated with implementation of the Commercial Space Launch Act. Foreign launch providers, like Arianespace,[21] allocated risk between the provider and the customer. It was hoped that the bill would provide an adequate risk-sharing arrangement between industry and Government to enable the emerging launch industry to better compete with foreign launch providers.

Also the method of determining property and liability insurance requirements based on maximum probable loss that could result from the launch activities to be licensed, allowed individual risk determinations to be made on the basis of launch vehicle size and type; launch site and trajectory; and payload characteristics. This would be consistent with the CSLA's declaration that the public health and safety, safety of property and national security and foreign policy interests of the U.S. be protected.

Rationale Behind the Statutory Ceilings

The statutory ceilings of $500,000,000 (or the maximum amount available on the market at a reasonable cost) represented "the upper limits of liability insurance capacity available in the market today" according to the House Committee on Science, Space and Technology report[22] accompanying the Commercial Space Launch Act Amendments of 1988 (at the time estimates of launch liability insurance ranged from $300 - $500 million per launch and it was noted that no launch accident had resulted in successful third-party liability claims). In the event that insurance capacity was insufficient to cover the maximum probable loss, the Committee would consider that a "severe" situation existed and directed the Secretary of Transportation to report such an event to the relevant House and Senate Committees.

The Senate Committee on Commerce, Science and Transportation also noted in its report[23] on the Commercial Space Launch Act Amendments of 1988, that NASA required $500 million in liability insurance for a payload on the shuttle (and $750 million for multiple payloads). The Senate Committee also pointed out that liability insurance in the amount of $500 million is routinely available to airlines and that there had never been an incident resulting in claims in excess of $500 million. Therefore given no "precise methodology available to assess risks in ELV operations, a limitation must be established that reflects analogous experience in other industries and practical considerations in the world insurance markets." The Committee concluded that "$500 million is a reasonable

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[21] Arianespace required liability insurance of 400 million French francs, or $63 million at the time, with full indemnification above that level and did not require launch property insurance.

[22] "Commercial Space Launch Act Amendments of 1988," Report 100-639, 100th Congress 2nd Session, May 19, 1988.

[23] "Commercial Space Launch Act Amendments of 1988," Report of the Senate Committee on Commerce, Science, and Transportation on H.R. 4399, Report 100-593, October 7, 1988.

initial limitation on the total amount of liability insurance that might be required," but that this might be increased as the world insurance market grows.

The statutory ceiling of $100,000,000 for damage to government property was viewed by the House Committee as more than adequate based on its review of historical damage to government ranges resulting from launch failures. The 1986 failure of a Titan 34D at Vandenberg Air Force Base caused $58.1 million in damages and closed the launch pad for 9 months. The Senate Committee noted that although the Air Force testified that damage to government property could reach $300 million, they also received testimony that property insurance to protect government facilities would not likely be available in excess of $120 million because it had never been required before as a condition of launch. The Committee concluded that $100 million would protect the government from the most probable losses that might occur and was an amount that the world insurance markets could provide at a reasonable rate.

Current Status of the Insurance Industry - Rates and Availability[24]

Capacity to insure for $500 million per launch for third-party liability insurance should be readily available and some mention has even been made of up to $1 billion of capacity being available.[25] Rates of under 1% of the value of insurance were cited. The following is a summary of insurance rates.

Insurance Level	Cost
$300M - $500M	$175K - $400K
$500M - $750M	$400K - $550K
$750M - $1B	$500K - $750K

[24] Based on conversations with representatives of the insurance industry familiar with third-party and government property insurance for licensed activities.

[25] Based on conversations with representatives of the insurance industry.

The larger launch companies usually cover the government facilities under their general property insurance for which they are charged annually. Smaller companies like Orbital Sciences, EER, and Lockheed usually include government property insurance with their third-party liability coverage. For instance there might be a policy covering a launch on a smaller vehicle for $100 million third-party liability and $20 million government property and the total cost might be $50,000 to $75,000. Overall the space insurance market has become strong and agile in spite of losses.

An insurance industry source indicated that about $300 million - $400 million liability coverage per launch is expected to be available for reentry vehicles at a cost of about .075% of the value of the policy. Other insurance industry sources thought the same capacity and rates might be available for reentry as is available for launch (liability insurance). Another broker estimated the cost to cover liability during LEO and the reentry phase of the proposed COMET at $50K-$75K for $25 million.

Legislative Initiatives Pertaining to Reentry Vehicles

Amendments to the Commercial Space Launch Act were proposed by the House in H.R. 2200 (National Aeronautics and Space Administration Authorization Act, Fiscal Years 1994 and 1995) and in H.R. 4489 (National Aeronautics and Space Administration Authorization and Space Policy Act, Fiscal Year 1995). H.R. 2200 passed the House on July 29, 1993. H.R. 4489 passed the House on August 8, 1994, and an amended version passed the Senate on October 5, 1994. These initiatives were not passed by Congress for reasons not related to the proposed amendments to the Commercial Space Launch Act. These proposed amendments defined reenter, reentry and reentry vehicle, clarified the definition of launch and would give the Secretary the same authority with regard to regulation and licensing of reentry and reentry vehicles as the existing law gives the Secretary with regard to launches and launch vehicles.[26,27] (Amendments covering similar changes with respect to reentry operations of reentry vehicles are currently being proposed to Congress for consideration by DOT.)

A review of Congressional language associated with licensing launches and reentry vehicles from these bills, the associated reports and earlier proposed legislation[28] reveals the intentions of 103rd Congress. When the Commercial Space Launch Act was passed (1984) and amended (1988), Congress did not consider commercial space activities using reentry vehicles that returned to Earth from orbit. It has since become apparent to Congress that commercial reentry services may emerge in the future and therefore an appropriate regulatory and licensing framework needs to be established. Also, in light of potential commercial reentry services, the definition of the term "launch" needs to be clarified, as does the extent to which activities before reentry must be regulated or licensed and the applicability of the third-party liability provisions of the Act to reentry activities.

The proposed amendments would have clarified many of these issues by including reentry as a licensable activity that must conform to certain requirements (including

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[26] H.R. 2200 In the Senate of the U.S., 103rd Congress, 1st Session, August 2, 1993.

[27] H.R. 4489 In the Senate of the U.S., 103rd Congress, 2nd Session, August 9, 1994.

[28] 1993 Legislation that never passed but reflects the thoughts of the 103rd Congress (House).

payload compliance and financial responsibility), as must launches; by adding definitions concerning reentry, and by clarifying the definition of launch.

For the most part, these amendments insert the terms "*reentry vehicles*" after "*launch vehicles*"; "*reentry*" after "*launch*" and define terms such as [25,26,29] :

- reenter or reentry - "to return purposefully, or attempt to return, a reentry vehicle and payload, if any, from Earth orbit or outer space to Earth;"

- reentry vehicle - "any vehicle designed to return from Earth orbit or outer space to Earth substantially intact."

The Committee intended to clarify the definition of launch (which is defined in the Act[30] as "to place, or attempt to place, a launch vehicle and payload, if any, in a suborbital trajectory, in Earth orbit in outer space, or otherwise in outer space") by adding the phrase "from Earth" after "and any payload" so there was no doubt that launches take place from Earth and not from Earth orbit. This stemmed from concern that DOT would license reentries as though they were a launch by maintaining that the placing of a vehicle in a suborbital trajectory "from Earth orbit" might be included under the definition of launch.[31]

The Committee intended commercial suborbital launches to continue to be licensed as launches and not as launches and reentries. For this reason the definitions of reentry and reentry vehicle only included "the return to Earth from Earth orbit or from outer space" and specifically excluded return from suborbital trajectories.[32]

The Committee intended the term "reentry" to consist of the "discrete phase of the overall space mission during which the reentry vehicle is intentionally reentered." That is, the Committee intended that reentry would begin when the vehicle is prepared specifically for reentry, though this may vary slightly from vehicle system to vehicle system (such as when the reentry vehicle's attitude is oriented for the propulsion firing that places the vehicle on a reentry trajectory). The Committee also indicated that pre-reentry procedures, such as when an applicant for a license demonstrates capability to safely carry out reentry and the Department examines the applicant's procedures and activities preceding initiation of reentry, do not require a license.[33]

For launches, given different preparatory processes associated with individual launch vehicle systems, the Committee recognized that it may be difficult to pinpoint the same commencement of launch for all proposals, but was concerned about DOT's attempt to

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[29] Letter to Al Gore from Federico Peña regarding OCST.

[30] Public Law 98-575, 98th Congress, (The Commercial Space Launch Act) October 30, 1984.

[31] 1993 Legislation that never passed but reflects the thoughts of the 103rd Congress (House).

[32] NASA Authorization Act, Fiscal Years 1995, and 1996, Report 103-654, 103rd Congress, 2nd Session, August 3, 1994.

[33] NASA Authorization Act, Fiscal Years 1995, and 1996, Report 103-654, 103rd Congress, 2nd Session, August 3, 1994.

use a license to cover indiscriminately all activities of a licensee at a launch facility "from the gate" (before, during and after a launch).

Also the Committee intended, that the Secretary have no authority to regulate or license activities such as maneuvers between two Earth orbits or other non-reentry operations in Earth orbit, that take place between the end of the launch phase and the beginning of the reentry phase, or after the end of the launch phase in the case of missions that don't include a reentry vehicle. However, just as in the launch of an ELV from earth, where certain pre launch activities are critical to the public health and safety of the launch event, DOT intends to consider certain on-orbit preparatory activities and the effect they have on the safety of the licensed reentry because of the importance to the safety of the reentry event.

Proposed amendments to other sections of the Act would give the Secretary the same authorities with respect to regulation and licensing of reentry of reentry vehicles as existing law gives the Secretary with regard to launches of launch vehicles. With regard to payloads, the proposed amendments to Section 70104 would provide that the Secretary only regulate payloads of reentry vehicles to the extent that they affect the safety of the reentry, as the Secretary may only regulate the payloads of launch vehicles to the extent that the payloads affect the safety of the launch.

Sections 70112 and 70113 (in 49 U.S.C., Chapter 701) which concerns the financial responsibility requirement and allocation of risk would be amended to cover reentry in the same way launches are covered and would not apply to activities before launch, between launch and reentry, or after reentry, which is consistent with the current handling of the launch alone, whereby once the launch is completed there is no liability protection for the launch under the Act.[34]

4. Methodology for Setting Financial Responsibility Requirements

The methodology for setting financial responsibility requirements for commercial launch activities was developed to protect launch participants from maximum probable loss due to claims by third-parties and loss of government property exposed to potential damage or loss during commercial launch activities. The goals were to provide protection against such losses that might occur from the launch activities, establish conditions that make it very unlikely that the government would be called upon to augment the financial requirements imposed by the government upon industry, and to provide financial responsibility requirements upon industry that are not unreasonable and within which industry can comfortably operate.

These goals were achieved for the commercial launch activities through OCST's implementation of legislation (the Commercial Space Launch Act of 1984, as Amended in 1988). The 1988 Amendments to the Act replaced very general insurance requirements with a financial responsibility and allocation of risk regime for commercial space

[34] Unless there is a clear causal nexus between the loss and the behavior of the launch or reentry vehicle.

transportation activities at federal and other facilities.[35] These requirements encompassed financial responsibility to cover both damage to government facilities and third-parties (persons and property) resulting from the licensed activities. The insurance requirements were to be based upon: the determination of maximum probable loss (MPL) (the maximum magnitude of loss such that there is less than a specified probability, referred to as the threshold probability,[36] of losses exceeding this level); consideration of the maximum available insurance at reasonable prices; and the maximum insurance required as stated in the enabling legislation. A typical relationship between MPL, required insurance (based upon MPL), maximum available insurance at reasonable prices, and maximum insurance requirements and maximum level of government payment of excess 3rd party claims (i.e., so-called indemnification) are illustrated in Figures 1 and 2. The relative position of these are determined by many factors including the characteristics of the launch vehicle, mission, launch facility and range, and the host of market factors that affect insurance availability and price.

Figure 1 illustrates the probability of government facility damage as a function of the level of damage. This probability distribution indicates the chance that different levels of damage will result to the government launch facilities from a licensed activity. This probability distribution is conceptual (i.e., insufficient data are available to establish the specific shape for each launch vehicle) and is presented only to serve as the basis for illustrating general concepts. The damage probability distribution is independent of MPL, threshold probability, required level of insurance, etc. and is a function of many factors relating to the specific activity (e.g., characteristics of the launch vehicle, mission, and launch facility and range). The calculation of the maximum probable loss establishes the level of damage that, on average, will be exceeded with a stated probability. This level of probability, or risk, is referred to as the "threshold probability." The threshold probability was conservatively selected by DOT[37] as 10^{-5} for government property damage and 10^{-7} for third-party damage and is illustrated as the cross-hatched area to the right of the MPL level of damage.[38] The threshold probability represents the level of risk, i.e., the chance

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[35] Prior to the passage of the Amendments in 1988, OCST had already determined that insurance requirements should appropriately reflect the risk involved in the operation and the licenses issued by OCST prior to the Amendments set requirements based on the ability to cover all but the most unlikely losses.

[36] "Threshold probability" represents a specified probability (likelihood) that includes the possibility of all but the most improbable (unlikely) events among all possible events. The threshold probability is a quantitative measure selected by DOT as representing the probability of occurrence associated with "unlikely" events or levels of damage due to launch activities. For example, there may be only on the order of a 1 in 100,000 chance (threshold probability) that losses will exceed $10 Million.

[37] Maximum Probable Loss: Assessment of Conservatism, Prepared by Princeton Synergetics, Inc. for DOT's Office of Commercial Space Transportation, April 29, 1991.

[38] Because of the stringent safety requirements used at Government ranges, launch exposure to the public is typically limited to less than 1 in a million. Therefore, the likelihood for significant 3rd party losses is below 10^{-6}. By their nature, launch facilities are routinely exposed to hazardous activities and the expectation that such facilities will suffer some damage is higher. Also such facilities are not covered at all for government conducted launches. Therefore, a threshold probability on the order of 1 in 100,000 (10^{-5}) is considered appropriate for government property.

that damage will occur that is in excess of the computed MPL[39,40] (discussed in following paragraphs), that has been chosen as being acceptable.

Still referring to Figure 1, a required level of insurance is established that is based upon the MPL but less than the maximum available insurance at a reasonable price as established by the Secretary of Transportation. At no time can the amount of insurance exceed the maximum amount as stipulated in the enabling legislation (i.e., for government property - $100,000,000). It should be noted that setting the required level of insurance in excess of the computed MPL is tantamount to changing the acceptable threshold probability.[41]

In a similar manner, the probability distribution of third-party damage is illustrated in Figure 2. The relationship between MPL, required level of insurance (based upon MPL), maximum available insurance at a reasonable price, and the limit placed upon maximum insurance required by the enabling legislation ($500,000,000) is illustrated. In addition, the maximum level of government indemnification ($1,500,000,000 above the insurance requirement) is also indicated. Figures 3 and 4 illustrate the general framework of the payouts and level of risk associated with (assumed by) insurers, providers of launch services and the government for government property and third-party damage, respectively.

Figure 3 disaggregates the probability of government facility damage into probability distributions of costs (e.g., claims, but not including payment of premiums) from the points of view of the licensee, the insurance company and the government. (Note: This is not intended to be a legal argument on how costs would be allocated.) Figure 3A is a restatement of the probability distribution of level of damage as indicated in Figure 1. Figure 3B illustrates the probability distribution of insurance company payout. This probability distribution is truncated at the level of required insurance. This is equivalent to the point where the probability of all events occurring with losses in excess of the required amount is equal to the threshold probability (i.e., if a loss occurs in excess of the required level of insurance, the insurance company payout will be equal to the level of required insurance).

Figure 3C illustrates the probability distribution of licensee's cost[42] that may result from damage to government facilities. Since the licensee is held harmless, through a waiver of claims agreement, by the government for facility damage in excess of the level of required insurance, there is no chance that the licensee will incur a cost that results from the damage. Since there is a chance, albeit very small (i.e., the threshold probability), that damage will exceed the level of required insurance, the government is also at risk.

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[39] Gress, R.K., "Derivation of Maximum Probable Losses for Commercial Launch Operations," DOT's Office of Commercial Space Transportation.

[40] Maximum Probable Loss: Rationale and Supporting Information, Prepared by Princeton Synergetics, Inc. for DOT's Office of Commercial Space Transportation, April 29, 1991.

[41] It is possible that MPL and required insurance levels may differ and are illustrated in this manner in Figures 1 and 2. Under normal circumstances it is anticipated that the MPL and required insurance levels will be the same.

[42] In the case of the licensee, "cost" is used to refer to the licensee's uninsured liability exposure. For government property, the "cost" refers to the government's exposure to loss without benefit of insurance protection.

The probability distribution of government cost is illustrated conceptually in Figure 3D where there is a high probability that the government will incur no cost (i.e., 1 - threshold probability) and a very small chance of incurring costs above the insurance level.

Figure 4 disaggregates the probability of level of third-party damage into probability distributions of cost from the points of view of the licensee, the insurance industry and the government. Figure 4A is a restatement of the probability distribution of level of third-party damage as indicated in Figure 2, Figure 4B illustrates the probability distribution of insurance company payout. This probability distribution is truncated at the level of required insurance with this occurring with a probability equal to the threshold probability (i.e., if a loss occurs in excess of the required level of insurance, the insurance company payout will be equal to the level of required insurance).

Figure 4C illustrates the probability distribution of licensee's cost that may result from third-party damage. Since the licensee is covered by insurance up to the required level of insurance and the government then indemnifies, subject to an appropriation Act of Congress, (in actuality, for losses in excess of the MPL value, the government will make payment if appropriations are available) to a maximum level of $1.5 Billion above this, only claims in excess of the government's level will be passed on to the licensee. The probability that the licensee will incur a cost is extremely small and unknown and likely to be significantly less than the threshold probability. Since there is a chance, albeit very small (i.e., the threshold probability), that damage will exceed the level of required insurance, the government is also at risk. The probability distribution of government cost is illustrated in Figure 4D where there is a high probability that the government will incur no cost (i.e., 1 - threshold probability) and a very small chance of incurring costs above the insured level but not exceeding the indemnification level.

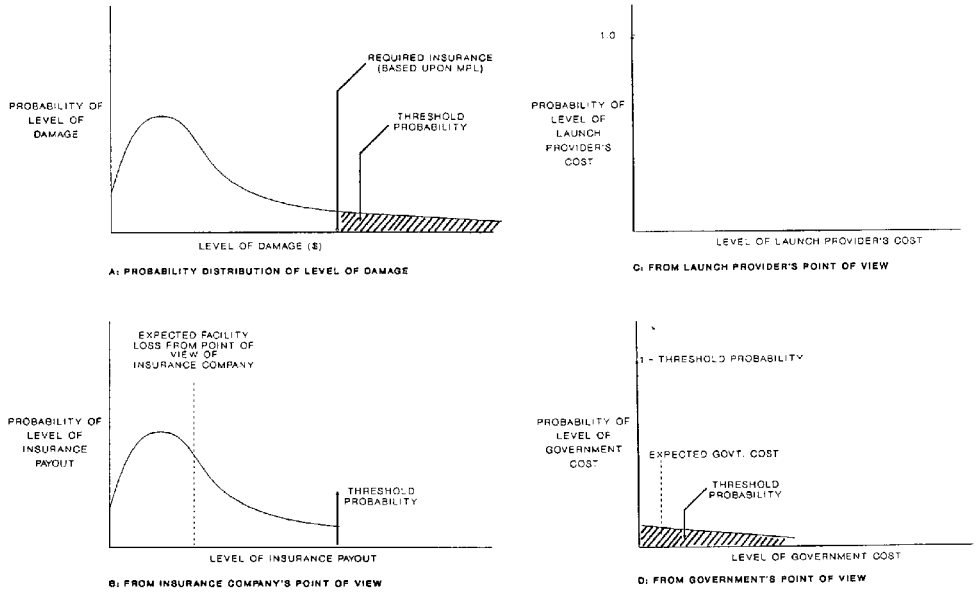

Figure 3 Insurance Payout and Government Cost as a Function of Required Level of Insurance: Property Damage
(Insurance Payout + Govt Cost = Constant)

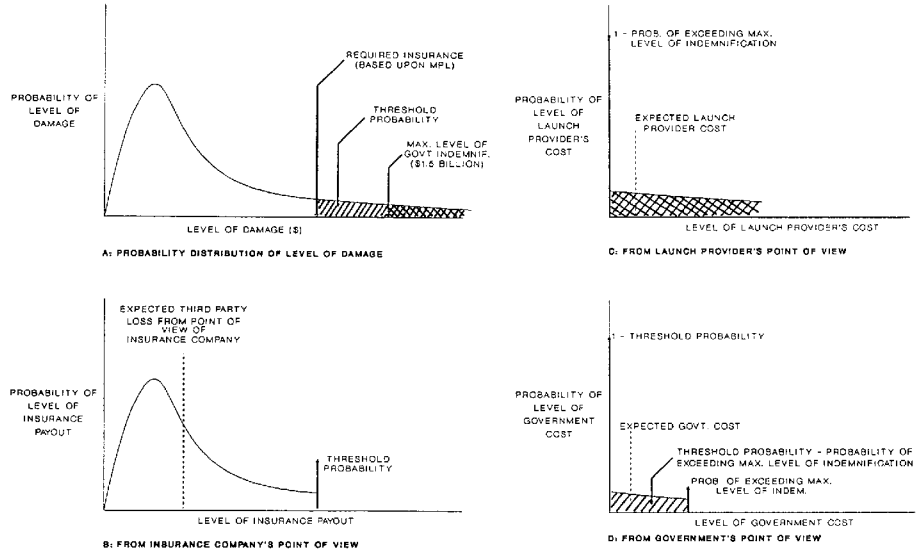

Figure 4 Insurance Payout and Government Cost as a Function of Required Level of Insurance: Third-Party Damage
(Insurance Payout + Launch Provider Cost + Govt Cost = Constant)

Given DOT's premise that insurance requirements should be based on the risks, there are a number of different approaches that can be used to determine the insurance coverage necessary to ensure that losses in excess of that dollar amount are likely to occur with a probability equal to or less than the threshold probability. Because third-party losses are extremely rare events, there is not really a preferred approach. The specific approach depends on the data available and the complexity of the specific mission and OCST tries to use the most efficient approach without being unduly conservative (i.e., an insurance requirement that greatly exceeds the true dollar value associated with the threshold probability). Some of these approaches are briefly described in the following paragraphs:[43] (Much of the descriptive material that follows has been abstracted from the referenced paper by R.K. Gress.)

Maximum probable loss is the maximum magnitude of loss at which there is less than a specified probability (i.e., the threshold probability) of exceeding this level. Exposure of government property during launch support and launch activities is routinely accepted by the government launch range as part of doing business. In determining the maximum probable loss for government property, focus of evaluation is on those highest cost facilities exposed at or just below the threshold level. The replacement costs of each facility are listed in descending order and the individual probabilities of loss accumulated until the probability threshold level (i.e., 10^{-5}) is reached. The facility loss at this level is determined to be the maximum probable loss. Losses of lesser amounts, no matter what their likelihood of occurrence, will be covered and the likelihood of losses exceeding the MPL level is the threshold probability. Given a commercial launch rate of 10 per year, the losses are expected to exceed the maximum probable loss on the average somewhere between once every 1,000 and 10,000 years. This is a very conservative interpretation of the concept of maximum probable loss.

In looking at the fatalities that might occur, various forms of the following equation are often used for expected casualties:

$$E_c = P_i * LA * P_d$$

where P_i is the probability of impact in a specific area,
LA is the lethal area of the impacting debris, and
P_d is the population density.

Given the correct inputs (for example, areas containing different population density and different probability of impact must be considered separately with results being additive), the approach provides a fairly reasonable estimation of the "expected number" of casualties. To obtain conservative results, the highest population density region may be used for the entire exposed region. (It should be noted that this approximation requires some care since in theory it can lead to unrealistically high insurance requirements with accompanying higher insurance costs with little or no added value.) When the complexity of the operation requires more detailed analyses, complex simulation models

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[43] Details of the methodology can be found in the following references:

- Maximum Probable Loss: Rationale and Supporting Information, prepared by Princeton Synergetics, Inc. for DOT's Office of Commercial Space Transportation, April 29, 1991.
- Guidelines for Determining Maximum Probable Loss, prepared by Princeton Synergetics, Inc. for DOT's Office of Commercial Space Transportation, April 29, 1991.
- Gress, R.K., "Derivation of Maximum Probable Losses for Commercial Launch Operations," DOT, Office of Commercial Space Transportation, February 1991.

are used which reflect the flight dynamics of the vehicle in question, failure probabilities and modes over the flight profiles and the vehicle's debris characteristics.[44]

Expected (average) loss, however, does not directly provide the information necessary to determine the probability of a particular loss level being exceeded. However, conservative estimates of the likelihoods of different numbers of fatalities can be derived from the expected loss using the definition of expected value,

$$E_c = \sum_{n=1}^{n=\infty} n * P_n$$

where P_n is the probability of n casualties occurring. Conservative estimates of the upper bounds of probabilities of an event or range of events (e.g., 3 casualties) can be made by assuming the probability of all other events are zero (zero values in other terms only serves to increase the probability term in question). By doing this each set of events (e.g., 1, 2, 3, ... casualties), the resultant estimated probabilities for each is greater than would be the case given some non-zero probability of each event occurring.

In developing the maximum probable loss values for launch support activities, the information about the hazardous activities that are performed, the policies and procedures followed, and the number of personnel and facilities (including replacement costs) that will be exposed are considered. For example, on government ranges, the siting of facilities is based on a quantity/distance relationship to ensure that a pre-launch accident in one facility will not affect another. There are various policies in place that correct past deficiencies and limitations on the number of people that may be present during the performance of certain hazardous activities.

Estimates of the likelihood of major accidents occurring during various phases of pre-launch activities have been made by range safety experts. These estimates are based on their years of experience and the refinement over the years of the policies and procedures in response to accidents or near accidents that have occurred.

For the flight of a launch vehicle, a more complex analytic approach is used to derive maximum probable losses for third-parties and government property. An approach is to use a failure event tree like that indicated in Figure 5. Over the years safety systems and procedures have been developed which assume that every vehicle launched is going to fail. For these reasons, systems like the flight termination system (FTS), the purpose of which is to stop a vehicle before it or its debris could reach a populated area, are designed and acceptance tested to have very high reliabilities (failure rates on the order of 10^{-3} or less). In performing the analyses for maximum probable loss, the reliability figure used for the FTS is the lesser of the historically demonstrated reliability and the design requirement. The failure event tree is used to estimate the probability of each of the possible outcomes and the consequences of each of the outcomes is then estimated.

[44] Such approaches require more data to be submitted by the applicant and collected from the range and the analysis is considerably more time consuming. Some models provide expected loss estimates while others directly provide probabilities of specific losses (e.g., the probability of a facility suffering a 50% loss).

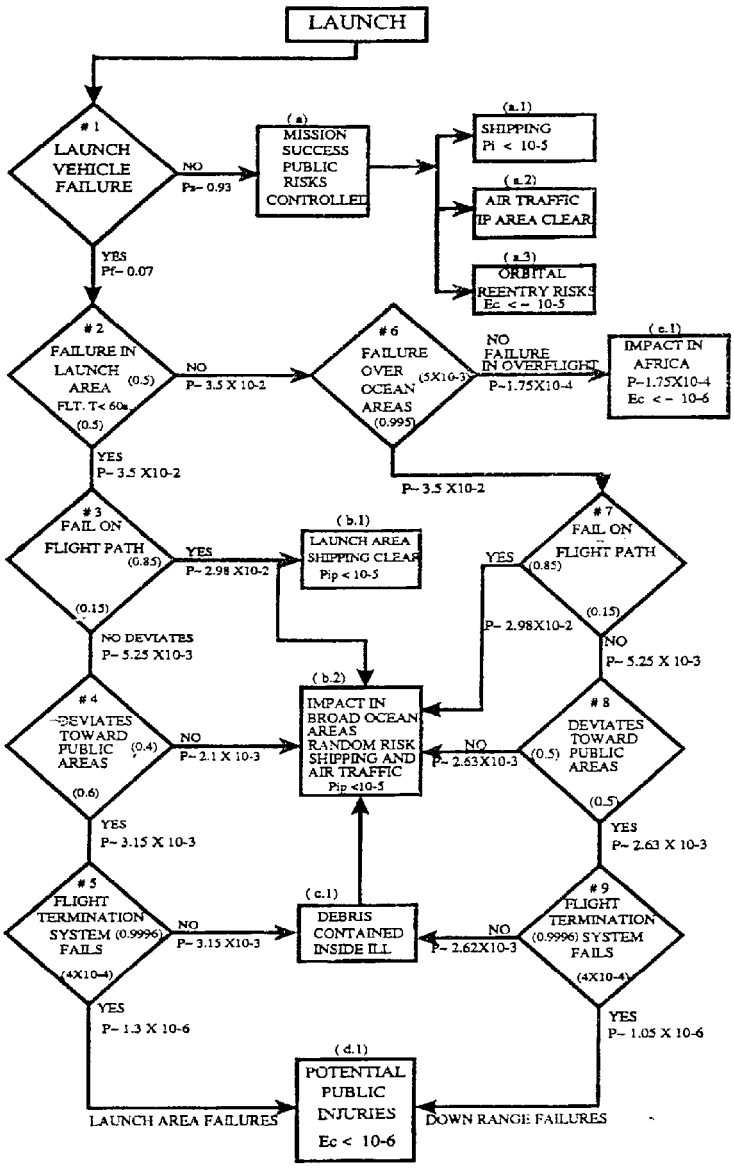

Figure 5 Typical Launch Failure Event Tree
(Source: Reference 37)

In summary, several different approaches may be appropriate for the determination of MPL requirements with the selected approach dependant upon the circumstances involved. In general, as uncertainty increases and/or the stakes get higher, the more rigorous techniques (as described above) apply that employ formal methods, procedures and models. The approach used may depend on the information available, the sensitivity of the situation (e.g., one or more very high valued facilities that might be exposed or affect MPL amounts, highly concentrated population centers versus low density widely distributed population, etc.) and may employ a range of analytic techniques that include complex models and data analysis or direct approaches that rely more upon judgement, experience and estimation (e.g., if one or more facilities are exposed and it is obvious that they each are exposed to risks that exceed the threshold probability, then it is appropriate to just select the largest loss as being the value of MPL if the loss of each is independent of the others). The overall objective is to identify the largest loss that could occur within a reasonably remote likelihood (the threshold probability) and to accomplish this in a conservative manner (i.e., when assumptions or estimates are made, conservatism is the rule) by utilizing the tools and techniques that are appropriate for analyzing the specific situation at hand.

5. Appropriateness of Statutory Measures and MPL Methodology for Reentries

For launch operations, the schema illustrated in Figures 1 and 2 together with the selected ceilings identified in the statute, the amounts of third-party and property damage anticipated at the selected threshold levels, and the availability of reasonably priced insurance, have achieved the goals of:

- protecting through insurance the launch participants and the government against large losses and potentially unlimited liability risks that might result from the launch activities,
- establishing conditions that make it very unlikely that the government would be called upon to augment the financial responsibility requirements imposed by the DOT upon industry, and
- imposing financial responsibility requirements upon industry that are not onerous and within which industry can comfortably operate and yet provide adequate protection for the launch participants and government interests.

It is assumed that the same basic goals will apply for establishing financial responsibility associated with reentry operations. However, one might question the importance of the third goal with respect to reentry operations. The implementation of these goals for launch operations included the "so-called" indemnification provisions. This was judged to be important[45] to ensure that there would continue to be a commercial space transportation industry in the U.S. Assured access to space was deemed to be extremely important; important enough to single out the industry to qualify for the indemnification provisions of the Act. The questions is whether reentry operations can be held to be as important to the Nation as is access to space. Yet when considering the

[45] In part because of the risk aversion attitudes of the U.S. space transportation industry and in part because Ariane provided indemnification. This latter fact, though of probably minor financial importance, was considered to have an effect on the international competitiveness of the U.S. space transportation industry.

scope of future reentry operations, which extend well beyond activities such as COMET to include commercial Single-Stage-To-Orbit (SSTO) reusable vehicles, such initiatives would certainly be developed more eagerly with the so-called indemnification. Even for reentry activities like COMET, the same "bet the company" rationale underlying the 1988 amendments still applies.

With the general background provided in the previous pages and given that insurance requirements should consider the risk of the activity, the appropriateness of the

- overall schema (including the use of MPL),
- specific selected threshold probabilities,
- specific levels of government indemnification; and
- specifics of the MPL computations

are considered for the setting of insurance requirements for reentry operations.

Figure 6 illustrates the general risks associated with reentry operations. It is assumed that licensed reentry operations cannot be initiated unless a satellite has been successfully placed into orbit. It is assumed that this satellite[46] (sometimes referred to as a reentry vehicle system when a portion of the satellite is designed for reentry) consists of a service module and a recovery system which contain a payload (P/L). The reentry vehicle system will remain in low Earth orbit for an extended period of time. At a desired point in time, ground personnel will cause the recovery system to separate from the service module. In carrying out these ground commands, the service module will point the recovery system in a selected inertially fixed attitude and may then spin the recovery system and release it with a very low relative velocity. A retro-motor will fire one or more times causing the reentry vehicle to be placed on a trajectory for its return to Earth. The service module will remain in orbit, continuing possibly to support other activities. The service module, while it remains in orbit, will be exposed to, and will expose other orbiting objects and property and third-parties to, the same risks encountered and caused by other satellites.

When a reentry vehicle system does not function properly and controlled reentry cannot be initiated, an uncontrolled reentry will eventually occur as the result of normal orbital decay. Under these circumstances there may be, however, a difference between the risks caused by the reentry vehicle system and those created by a normal satellite or vehicle stage reentry (due to orbit decay over time). Major portions, if not all, of other satellites normally burn-up during uncontrolled reentry. Since a portion of the reentry vehicle system is designed to survive reentry, the risks to property and third-parties on Earth may differ from those encountered from other satellite and vehicle stage reentries.

[46] The report entitled "Maximum Probable Loss Reentry and Recovery Activities Involving Commercial Experiment Transporter (Comet)," (Application No. 91-SII-031) DOT Office of Commercial Space Transportation, June 1994, has been used as a starting point to create a more general model that will be applicable for assessing a broad range of reentry opportunities.

The actual risk levels greatly depend on the size and content (e.g., hazardous substances such as propellants) of the objects that survive to impact the earth's surface.

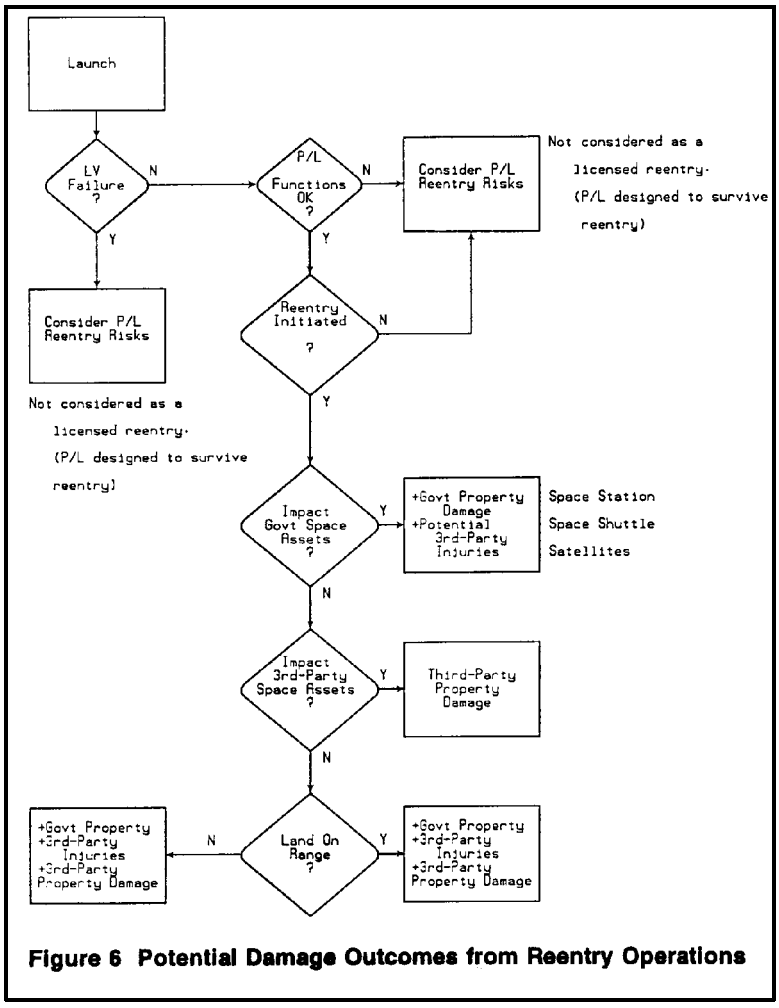

Figure 6 Potential Damage Outcomes from Reentry Operations

Sinc
e uncontrolled satellite reentry occurs and is not regulated, even in the case where it is unlikely that the entire satellite will burn-up prior to impact, the uncontrolled reentry of a reentry vehicle situation is outside the scope of the setting of financial responsibility for reentry vehicle operators.[47]

It is assumed that, in general, procedures will be initiated such that a reentry will not be attempted unless there is at least a predetermined expectation (i.e., probability) that the recovery system will land within a designated target area.[48] If this criteria is not met

[47] Current launch insurance required of commercial launch operators does not cover, for example, normal decayed reentry of satellites. The U.S. Government is, therefore, exposed to risks resulting from its space object (reentry vehicle), which designed to survive reentry.

[48] This is analogous to the use of the flight termination system during launch to limit possible damage from a failed flight.

reentry operations will not be attempted and the reentry vehicle system will remain in orbit (i.e., it will remain a satellite).

Appropriateness of the MPL Methodology

The Maximum Probable Loss (MPL) Methodology is based upon a risk analysis framework. Risk analysis is the technical process and procedures for identifying, characterizing, quantifying and evaluating hazards. This analysis process is widely used in industry and federal agencies to support regulatory and resource allocation decisions. The analysis of risk, also called risk assessment, consists of a qualitative step of hazard identification, characterization and ranking; and a quantitative risk evaluation entailing estimation of the occurrence probabilities and the consequences of hazardous events, including catastrophic events.[49] Following the quantification of risk, appropriate risk management options can be devised and considered, risk/benefit or cost analysis may be undertaken and risk management policies may be formulated and implemented. The main goals of risk management are to prevent the occurrence of accidents by reducing the probability of their occurrence (e.g., practice risk avoidance), to reduce the impacts of uncontrollable accidents (e.g., prepare and adopt emergency responses) and to transfer risk (e.g., via insurance coverage and the establishment of financial responsibility requirements). Most personnel safety and operational/handling precautions and requirements at hazardous facilities are intended to prevent, reduce the frequency or probability of occurrence of hazardous events and to minimize their potential impacts.

For reentry operations, specific safety criteria can be adopted and implemented during the payload determination approval process (i.e., approval will not be granted unless it is demonstrated that the safety criteria can be met). These criteria could be aimed at reducing the probability of government property and third-party loss to acceptable levels - small compared to the general background involuntary risks that are tolerated.[50] Such criteria could include, for example, specifying the probability that the reentry vehicle will not land outside of the designated landing site (i.e., accuracy), and stipulate that the reentry operation shall not create additional risks to the population higher than the normal background risks (10^{-6} per year). Additionally, coordination could be maintained to reduce, below specified levels, the probability during initiated reentry operations of impacting orbiting vehicles and aircraft.

Both normal operations and unforeseen conditions can lead to accidents which cannot be prevented or controlled. In such cases, the residual risk must be accepted and managed by preparing emergency response procedures to lessen the consequences of such accidents and the setting of financial responsibility requirements so as to ensure that compensation is available should an accident occur. Risk management, in a regulatory context, requires the evaluation of the impact and effectiveness of safety standards and regulations to impose additional controls or relax existing ones.

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[49] Specific tools used to estimate the likelihood of occurrence of events and their consequences depend on the data that is available and the unique circumstances of the particular situation. Therefore, there is no fixed detailed procedure for basing insurance requirements on risk. Given that the requirements should reflect the risk levels, what does remain to be determined (i.e., is an option), is what level of risk is to be covered by insurance and what risk exposure is to remain.

[50] Hazard Analysis of Commercial Space Transportation (Volume 3), prepared by Transportation Systems Center for DOT's Office of Commercial Space Transportation, May 1988.

As noted above, risk analysis is concerned with the identification of possible hazardous events, the probability of occurrence, and the level of the likely consequences. The setting of maximum probable loss utilizes this information together with the threshold probability (i.e., what is "probable") to establish the appropriate level of financial responsibility so that government property and third-party losses are adequately covered by insurance should a hazardous event actually occur. The magnitude of the coverage or compensation must be based upon the probable loss to be sustained and not the expected (average) value of the loss per mission. This is specifically the role of the MPL methodology which establishes the maximum probable loss that defines the required level of insurance coverage.

The MPL general methodology described in the previous paragraphs and employed for the setting of financial responsibility associated with launch operations is appropriate for use in setting financial responsibility for reentry operations. The risk based methodology aims to establish the maximum loss that is expected to occur at any threshold probability level. This is the essence of what must be done to support a financial responsibility scheme which is based on risk exposure which is fair and consistent in its application to the industry. [The appropriateness of the threshold levels for reentry operations will be addressed below.] As would be expected, there will be certain differences in the specific methodology for estimating risk for reentry operations compared to launch operations. These differences appear to be minor because the "end product" (i.e., the distribution of consequences and likelihoods described in Figure 2) are basically the same. For example, the types and significance of failure modes are different and may require, in part, different modelling techniques (e.g., for a ballistic reentry vehicle, the aerodynamic stability may need to be modelled in detail because of its affect on landing dispersion) to produce the estimated risk levels.

Appropriateness of Overall Schema:

The current statutory requirements for launch operations have achieved the previously stated goals through a combination of requirements. The basic requirement for establishing a level of financial responsibility, coupled with a rational approach to establishing the appropriate level of protection (i.e., the use of MPL), is aimed at protecting the launch participants and the government against losses that might result from licensed launch activities. Since licensed reentry operations also place people and property at risk it is appropriate to impose a minimum level of financial responsibility on those choosing to provide licensed reentry operations. The appropriateness of utilizing the MPL methodology as a basis for the government establishment of required insurance was discussed in previous paragraphs. In summary MPL is merely a characterization of a risk based approach for establishing insurance requirements with the alternative being a non-risk based approach such as maximum insurance available at a reasonable cost or no insurance requirement which clearly appear to have been rejected in principal by Congress. In fact, the selection of the MPL threshold probabilities (or what constitutes "probable") can cause the results to range, in essence, from "maximum possible" to zero insurance requirements and the exposure to the launch participants to vary accordingly.

The setting of a statutory ceiling on the maximum insurance required by the provider of launch services, coupled with the alternative limitation of maximum available insurance at a reasonable price aims at imposing financial responsibility requirements upon industry that are not onerous and within which industry can comfortably operate to provide access to space. It is reasonable and appropriate to apply the same basic concept to reentry operations if it is deemed that such operations are important to the Nation and would not likely be performed in the absence of the statutory ceilings. The concept of government providing "so-called" indemnification for losses that may occur in excess of the required

insurance level (less than or equal to the lessor of maximum available insurance at reasonable prices and the statutory limitation of $100 million for government property losses and $500 million for third-party damage) places a limit on industry liability and acts to contain risk perceptions. In the case of third-party damage, a further statutory constraint is placed that re-establishes industry risk above $1.5 billion above the required level. This provision theoretically states that industry risk is unbounded while government risk is limited. But the unboundedness occurs with such a small probability that it is not onerous to industry; yet government exposure is limited. The relationship between insurance payout and government and industry uninsured liability exposure is illustrated in Figures 3 and 4 for government property and third-party liability, respectively.

Appropriateness of Specific Selected Threshold Probabilities:

Threshold probability represents the probability that loss or damage will exceed a specified level. As noted above, the threshold probability is a quantitative measure selected by DOT and defines the likelihood that the insurance requirements will not be sufficient to cover all the losses. Under such "improbable" circumstances, the government might be expected to cover the third-party losses in excess of the insurance amounts required. Should the government not appropriate the funds in this case, excess losses would have to be recovered from the launch participants liable for the losses. Should the government not appropriate the funds and the losses exceed the financial ability of the liable launch participants to cover such excess losses, the public might not recover the losses in excess of the insurance requirements.

From the general public's (third-party) perspective, the higher the imposed insurance amounts (i.e., the lower the threshold probability), the more likely all losses will be covered. Also, from the government's perspective, the higher the imposed insurance amounts, the less likely the government will be asked to pay for losses (for third-party claims or losses to government property). From the launch participant's perspective, higher insurance requirements increase the cost of operation and high losses (in excess of insurance and without so-called indemnification) can mean "betting the company" on the operations.

There does not, at this time, appear to be any rationale that would clearly indicate that the risk levels should be dependent on the type of particular space operation: launches or reentries. Variations in exposures and risks between different launch operations or between launches and reentry operations that may occur still would result in the same "improbability" that losses from claims would not be covered.

For launch operations, threshold probabilities of 10^{-5} and 10^{-7} are utilized for establishing financial responsibility requirements for government property and third-party losses, respectively. This implies that threshold levels for financial responsibility requirements would be insufficient to cover 100 percent of losses with a likelihood on the order of 10^{-5} for government property and 10^{-7} for third-parties. The implication is that if the level of required insurance is set equal to the maximum probable loss and the MPL is determined based upon the threshold probability, there is a 10^{-5} chance that the U.S. government will be required to absorb losses above this required insurance level for government property. Similarly, there is a 10^{-7} chance that the U.S. government will be called upon to

cover third-party losses (in excess of the MPL) per launch. Both theory[51] and practice[52] have indicated that the choice of threshold probabilities is very conservative. These values are consistent with the design/operation safety goals based upon established ELV launch practices at government ranges where every effort is made to keep the probability of any accident of significant nature (e.g., potential for loss of life or loss of highly valued property) below 10^{-5} to 10^{-6}.[52] This means that when looking at the likelihoods of incurring significant losses (and consequently the likelihood that losses exceed significant values), such likelihoods are lower than the probabilities reflected by the range safety goals. In other words, reasonably large losses will not occur because of safety considerations with likelihoods in excess of these probability levels.

Appropriateness of Specific Levels of Government Indemnification:

With respect to reentry activities as with launches, the appropriateness of specific levels of so-called government indemnification must be judged in part by the levels of maximum probable loss, the flexibility desired in the setting of financial responsibility requirements in terms of the relationship of MPL to the level of government indemnification, and the need for providing indemnification to accomplish national objectives.

One question might be whether the characteristics of reentry operations are such that they do or should present different potential levels of so-called indemnification compared to launch operations. The lower the maximum probable loss dollar value, the greater the potential (not probable) amount of indemnification or losses bourn by the government. This may be, for example, the difference between the MPL value and the maximum *possible* loss. However, just as in launch operations where the exposures and risks vary from situation to situation, one can expect the same to be the case for reentry activities. In launch operations MPL amounts have varied from $1 million to $80 million for government property and from approximately $10 million to $215 million for third-parties. While the MPL values do vary, it is important to remember that the likelihood of the losses exceeding the stated value are roughly the same - the threshold probability.

In looking at the potential for future reentry operations it is difficult to estimate the range of MPL values. Future reentry operations will likely involve vehicles larger than COMET, some vehicles may have fuels on board and they will fly over populated areas (e.g., single-stage-to-orbit vehicles). Therefore, it is not unreasonable to expect the same type of variance in values depending on the specific scenarios. One way to compare the possible MPL values between launch operations and reentry operations is to look at a few of the scenarios that could affect the levels of risk and the MPL values. The likely upper limits on MPL for each of the potential damage outcomes from reentry operations as indicated in Figure 6 may be estimated for each of the following impact scenarios. It must be cautioned that this is not an attempt to develop the details of the MPL computational procedures but an attempt to identify the possible upper bounds of MPL so as to ascertain the appropriateness of the existing statutory requirements. Scenarios to be considered are the recovery system:

- ♦ colliding with manned orbiting systems (considered as third-party property and third-parties),

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[51] Starr, C., "Benefit-Cost Studies in Sociotechnical Systems," Perspectives on Benefit-Risk Decision Making, National Academy of Engineering, 1972.

[52] Hazard Analysis of Commercial Space Transportation (Volumes 1, 2, and 3), prepared by Transportation Systems Center for DOT"s Office of Commercial Space Transportation, May 1988.

- colliding with another spacecraft (considered as third-party property),
- producing orbital debris,
- impacting airborne aircraft,
- causing third-party damage on landing (casualty and property), and
- causing government property damage on the reentry range.

Similar to launch operations, it is assumed that there will exist good coordination between orbiting assets such as the space station and the space shuttle with respect to reentry operations. This combined with the extremely low probability (less than 10^{-6}) of an uncontrolled reentry causing an impact with these assets makes this an extremely unlikely event (beyond the 10^{-5} and 10^{-7} thresholds). It is further assumed that as a last resort, the space station and the space shuttle will have some maneuvering capability for collision avoidance which should make even an uncontrolled reentry (which is the same problem ultimately to be faced with all orbiting objects above the shuttle and space station altitudes) impact an extremely unlikely event. Similar risks are posed by launch operations and the uncontrolled reentry of upper stages. At this time for reentry operations (controlled or uncontrolled), there is no reason to expect that these risks will be significantly different. However, if such an event should take place during an uncontrolled reentry, the maximum third-party casualty loss could be on the order of $30 million and the property loss could be measured in terms of billions of dollars. This magnitude of property loss can not be covered by the existing capacity of the insurance industry; in fact it is so large that insurance coverage should not be considered and indemnification would come into play. While the upper bound of $100 million for government property might be increased, there is no hard rationale for the number for reentry operations being different from that for launch operations as they present the same basic risk levels.

Impacting airborne aircraft is an extremely unlikely event if it is assumed that air traffic/launch coordination will be maintained as is currently accomplished for launch operations. If the reentry vehicle system does not attempt a reentry then it will eventually reenter as other satellites in an uncontrollable fashion. The only difference between this vehicle and other satellites is that at least a part of the reentry vehicle is designed to survive reentry. This however is outside of the licensed reentry considerations.

It is assumed that appropriate safety and design considerations of the recovery system will result in similar probabilities as Expendable Launch Vehicles of producing orbital debris (e.g., explosion during flight) during the conduct of reentry operations. The consequences of orbital debris remaining in orbit cannot easily be judged because of the uncertainty associated with knowledge of the overall debris environment and its effect on long term operations and the implications of adding slightly to the overall debris situation. It is anticipated that the likelihood of causing orbital debris will be similar to that of other satellites and upper stages of launch vehicles. The major difference may be with respect to pieces surviving reentry. The consequences of this are likely to be less than the damage caused by an errant reentry vehicle (discussed in a following paragraph).

An upper limit to government property damage (within the threshold probability) caused by the recovery system may be estimated if it is assumed that the recovery system impacts government property on the ground. The likelihood of this is only significant if the landing site is located on government property, in which case it is not unreasonable to assume that the same level of protection would be afforded to facilities as is afforded during launch activities. In the past (e.g., the NASA Shuttle and the proposed landing of

COMET at the Utah Test and Training Range[53]), such sites have had the designated landing areas appropriately removed from high cost facilities. In launching, it is noteworthy that the launch complex itself is often a high cost facility which is exposed during launch. Overall, the risks do not appear to be all that different. It may be that some reusable vehicle designs might fly over facilities just as, in some case, launch vehicles do on ascent. If the complete building were to be destroyed, the damage would be the cost of replacing the building. Thus the maximum level of damage to government facilities is the cost of the most expensive facility on the reentry range. This cost is expected to be well under the $100 million indemnification level set for launch operations since it is unlikely that a reentry range would be selected that contains costly property that is placed at risk.

An important area is the level of damage may be caused to third-parties. Conventional expendable launch vehicles currently have MPL amounts up to approximately $215 million. In the future, the size and makeup of reentry vehicles can be very similar to some of the present day launch vehicles. Such reentry operations, just as for launch operations, will presumably only be approved if it can be demonstrated that the risks are within some acceptable level. Such a public health and safety policy are likely to have the same effect on limiting the MPL third-party amounts as was described for launch operations (see Section 4). If there were extremely high MPL values (e.g., greater than $500 million for third-parties), that could reflect conditions that exceed adequate safety limits.

Thus, indications are that there are no obvious reasons for using MPL ceilings different from those used for launches ($100 million for government property and $500 million for third-party damage) for reentry operations. In both cases, launches and reentry operations, there is the potential for wide variations in MPL amounts for different missions yet the overall exposure of the government and launch participants from losses in excess of the MPL values are roughly the same. The same, obviously, holds for the so-called indemnification.

6. Summary

The use of a risk based approach to setting financial responsibility requirements for reentry operations was examined and probability thresholds, the bases of any risk based approach, were discussed. It was noted that the selection of extreme threshold probabilities causes the requirements model to revert to either no requirements (i.e., where the threshold value is set very high) or to requirements based on maximum possible requirements (i.e., where the threshold value is set very low). Regardless of the issues of indemnification, it would appear that the Congress when passing the 1988 amendments to the Commercial Space Launch Act embraced the concept of a risk based approach rather than some type of fixed insurance requirement (e.g., maximum possible at a reasonable cost).

The existing statutory ceilings on third-party liability and government property insurance requirements for launch activities have been examined and an assessment completed of the appropriateness of these established ceilings for licensed reentry operations. This included an assessment of report language associated with Congressional actions relating to financial responsibility requirements for licensed commercial launches, and the

[53] It should be noted that as of this date, COMET has been renamed METEOR and the proposed landing site has been moved to the Atlantic Ocean.

status of the insurance industry and the availability of coverage at a reasonable cost. In addition, the methodologies for setting financial responsibility requirements for commercial launch operations were examined and an assessment completed of their appropriateness for application to licensed reentry operations.

The following is a summary of the pertinent findings with respect to congressional intent, the availability of insurance coverage at reasonable prices, and the appropriateness for use in the setting of financial responsibility requirements for reentry operations of the overall schema, MPL methodology, specific selected threshold probabilities, and specific levels of government indemnification that are currently in place for licensed commercial launch operations.

- **Congressional Intent**

  The methodology for setting financial responsibility requirements for commercial launch activities was developed to protect launch participants from maximum probable loss due to claims by third-parties and government property exposed to potential damage or loss during commercial launch activities. The goals were to protect the launch participants and government against losses that might occur from the launch activities, establish conditions that make it very unlikely that the government would be called upon to augment the financial requirements imposed by the government upon industry, and to impose financial responsibility requirements upon industry that were not onerous and within which industry could comfortably operate.

  These goals were achieved through the passage of legislation that specified that the setting of insurance requirements would be based upon the computation of maximum probable loss, (MPL) (the maximum magnitude of loss such that there is less than a specified probability, referred to as the threshold probability, of losses exceeding the amount), and that financial responsibility would be set based on the MPL amount but less than the lesser of the maximum available insurance at reasonable prices and a specified statutory limit ($100 million for government property damage and $500 million for third-party losses). The government would waive its property losses above the dollar amount set for financial responsibility. The government would also assume, if appropriations were authorized, responsibility for third-party losses above the dollar amount set for financial responsibility but limited to $1.5 billion above this level.

  Legislation also affected the allocation of risks through interparty waiver of claims provisions under which each party (launch participants and the government) to each such waiver agrees to be responsible for any property damage or loss it sustains or for any personal injury to, death of, or property damage or loss sustained by its own employees resulting from activities carried out under the license to the extent that claims exceed the required amount of insurance or demonstration of financial responsibility.

- **Availability of Insurance at Reasonable Prices**

  It appears that sufficient capacity to insure launches for third-party liability damages is available up to, and possibly exceeding, the statutory ceiling of $500 million. Rates are on the order of 1 percent or less of coverage. Specifically for reentry operations, approximately the same amount of capacity, or slightly less ($300 million to $400 million) appears to be available at a cost of less than 1 percent of coverage.

- **Overall Schema: Appropriateness for Licensed Reentry Operations**

  Assuming that the same basic goals apply for reentry operations as apply for the setting of financial responsibility for launch operations, the overall schema (i.e., the use of MPL combined with considerations of the availability of insurance at reasonable prices and the statutory limits) developed for the setting of financial responsibility for launch operations is, in general, appropriate for the setting of financial responsibility for reentry operations. Indemnification was judged to be important to ensure that there would continue to be a commercial space transportation industry in the U.S. Assured access to space was deemed to be extremely important; important enough to single out the industry to qualify for the so-called indemnification provisions of the Act. If such concern extends to future space transportation systems and concepts, including vehicles that will routinely reenter such as single-stage-to-orbit and reusable vehicles, then the prior concerns with respect to access to space are warranted.

- **MPL Methodology: Appropriateness for Licensed Reentry Operations**

  The Maximum Probable Loss (MPL) Methodology is based upon a standard risk analysis framework. Risk analysis is the technical process and procedures for identifying, characterizing, quantifying and evaluating hazards. The analysis of risk consists of a qualitative step of hazard identification, characterization and ranking, and a quantitative risk evaluation entailing estimation of the occurrence probabilities and the consequences of hazardous events, including catastrophic events. The specific tools used vary depending on the unique circumstances of the mission at hand. The main goals of risk management are to prevent the occurrence of accidents by reducing the probability of their occurrence (e.g., practice risk avoidance), to reduce or otherwise mitigate the impacts of uncontrollable accidents (e.g., prepare and adopt emergency responses) and to transfer risk (e.g., via insurance coverage and the establishment of financial responsibility requirements).

  For reentry operations, specific safety criteria can be adopted and implemented during the payload determination approval process (i.e., approval will not be granted unless it is demonstrated that the criteria can be met). These criteria are aimed at reducing the probability of government property and third-party loss to acceptable levels; for example, not creating additional risks to the population higher than the normal background risks (10^{-6} per year).

  The MPL risk based methodology that is currently employed for the setting of financial responsibility associated with launch operations is appropriate for use in setting financial responsibility for reentry operations. The methodology aims to establish the maximum loss that is expected to occur at the specified threshold probability levels. As would be expected, there will be certain differences in the specific methodology for estimating risk for reentry operations compared to launch operations. These differences appear to be minor because the "end product" (i.e., the distribution of consequences and likelihoods described in Figure 2) are basically the same. For example, the types and significance of failure modes are different and may require, in part, different modelling techniques (e.g., for a ballistic reentry vehicle, the aerodynamic stability may need to be modelled in detail because of its affect on landing dispersion) to produce the estimated risk levels. These differences are minor and can be accounted for in the detailed implementation of the MPL methodology.

- **Threshold Probability: Appropriateness for Licensed Reentry Operations**

Threshold probability represents the probability that loss or damage will exceed a specified dollar amount. The threshold probability is a quantitative measure selected by DOT and used to represent the probability of occurrence associated with "unlikely" events, third-party losses and/or degree of damage due to launch activities. The MPL is established at the threshold probability. There does not, at this time, appear to be any rationale that would clearly indicate that the risk levels should be dependent type of particular space operation: launches or reentries. Variations in exposures and risks between different launch operations or between launches and reentry operations that may occur still would result in the same "improbability" that losses from claims would not be covered.

For launch operations, threshold probabilities of 10^{-5} and 10^{-7} are utilized for establishing financial responsibility requirements for government property and third-party losses, respectively. These probability levels were chosen so as to provide coverage for government property and third-parties claims against low probability but high value losses. In part, the selection of the threshold values for launch operations was based on fact that potential losses reflect those that cannot be protected against through the current safety requirements and programs. Generically, such programs focus on eliminating or greatly reducing the likelihood of high consequence events. Significant losses are therefore likely to occur at probability levels that are less than the safety standards are intended to ensure do not occur. For example, if a launch is allowed to take place only if the probability of a casualty is equal to or less than 10^{-6}, then the likelihood of one or more casualties (e.g., significant losses) will be less than 10^{-6} (e.g., 10^{-7}). In one sense, selection of threshold values was basically independent of the type of operations taking place. If safety criteria for public health and safety and safety of property similar to launches are used for reentry operations, it is reasonable to expect the same thresholds to be appropriate. It is reasonable for the public to expect the same level of safety be ensured for reentry operations as it is accustomed to for launches. Thus these threshold values appear also to be appropriate for use when considering reentry operations.

- **Levels of Indemnification: Appropriateness for Licensed Reentry Operations**

The point at which so-called indemnification kicks in can be affected by the MPL value and the statutory ceilings imposed. Such points determine the potential amount of so-called indemnification available to the licensee. The appropriateness of specific levels of government so-called indemnification also must be judged in part by the flexibility desired in the setting of financial responsibility requirements in terms of the relationship of MPL and the level of government indemnification, and the need for providing indemnification to accomplish national objectives. The current statutory levels for launch operations are $100 million for government property and $500 million (with an upper limit of $1.5 billion above the determined level of financial responsibility that the U.S. government may have to indemnify) for third-party claims. Indications are that the current statutory levels for launch operations are likely to be well in excess of the MPL as established for reentry operations. Using these statutory levels for reentry operations could provide significant flexibility for government policy decision. Reentry operations, just as for launch operations, will presumably only be approved if it can be demonstrated that the risks are within some acceptable level. Such a public health and safety policy are likely to have the same effect on limiting the MPL third-party amounts as was described for launch operations. If there were extremely high MPL values (e.g., greater than $500 million for third-parties), that could reflect conditions that exceed adequate safety limits. Thus, indications are that there is no obvious reasons for using MPL ceilings different from those used for launches ($100 million for government property and $500 million for third-party

damage) for reentry operations. In both cases, launches and reentry operations, there is the potential for wide variations in MPL amounts for different missions yet the overall exposure of the government and launch participants from losses in excess of the MPL values are roughly the same. The same, obviously, holds for the so-called indemnification.

7. Recommendations

It is recommended that :

- The same schema (i.e., the use of MPL combined with considerations of the availability of insurance at reasonable prices and the statutory limits) developed for the setting of financial responsibility for launch operations be utilized for the setting of financial responsibility for reentry operations.

- The MPL methodology, in combination with threshold probabilities of 10^{-5} and 10^{-7} for government property and third-party losses, respectively, be utilized for the setting of financial responsibility requirements for reentry operations. In keeping with the desire to have government and third-party imposed risks independent of operations, the threshold probabilities should be the same as those used for establishing MPL for launch operations.

- Statutory ceilings set for launch operations are expected to be considerably in excess of financial requirements established through the use of MPL. Even though these statutory levels could be reduced, it is recommended that they remain the same in order to maintain additional flexibility with respect to the setting of the level of financial responsibility. This is also in keeping with the use of the statutory levels set based upon large launch vehicle operations when considering small launch vehicle operations.