



**FEDERAL AVIATION
ADMINISTRATION**

Report to Congress:

FAA's Development of an Updated Maximum Probable
Loss Method

**U.S. Commercial Space Launch Competitiveness Act (CSLCA),
Public Law 114-90, Section 102**

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I. Background

a. Congressional Reporting Requirement

Section 102(b) of the U.S. Commercial Space Launch Competitiveness Act of 2015 directs the Secretary of Transportation,¹ in consultation with the commercial space sector and insurance providers to:

- 1) Evaluate the methodology used to calculate the maximum probable loss from claims under section 50914 of Title 51, United States Code, and, if necessary, develop a plan to update that methodology;
- 2) In evaluating or developing a plan under paragraph (1)—
 - i. Ensure that the Federal Government is not exposed to greater costs than intended and that launch companies are not required to purchase more insurance coverage than necessary; and
 - ii. Consider the impact of the cost to both the industry and the Government of implementing an updated methodology; and
- 3) Submit the evaluation, and any plan, to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives.

This report fulfills this requirement.

b. GAO Report

In July 2012, the U.S. Government Accountability Office (GAO) issued a report entitled “Commercial Space Launches – FAA Should Update How It Assesses Federal Liability Risk.”² The report addressed, among other things, the Federal Government’s potential costs for indemnification (discussed later in this report). While preparing the report, the Federal Aviation Administration (FAA) worked closely with the GAO to explain its method for calculating MPL, the accuracy of which directly affects the probability that the government will incur cost.

In its report, the GAO recommended the following:

To better ensure the accuracy of FAA’s determination of the amount of insurance coverage required for an FAA commercial space launch license, we recommend that the Secretary of Transportation direct the Associate Administrator for Commercial Space Transportation to review and periodically reassess FAA’s maximum probable loss methodology—including assessing the reasonableness of the assumptions used. For these reviews, the Associate Administrator should consider using external experts such as

¹ By delegation, the FAA is responsible for determining the maximum probable loss from claims under 51 U.S.C. § 50914. 49 CFR 1.83(b).

² GAO, *Commercial Space Launches: FAA Should Update How It Assesses Federal Liability Risk*, GAO-12-899 (Washington, D.C.: July 30, 2012).

*risk modelers, document the outcomes, and adjust the methodology, as appropriate, considering the costs.*³

The FAA concurred with the recommendation to review and periodically reassess its process. In fact, the FAA had already begun research to update the MPL process in 2003. This is discussed further below. The FAA also concurred with the use of external experts, if budget allows.

c. Maximum Probable Loss

The maximum probable loss (MPL) is the greatest dollar amount of loss for bodily injury or property damage that is reasonably expected to result from a launch or reentry. The MPL process is part of a risk-sharing arrangement established by Congress between the commercial space transportation industry and the Federal Government to enable the industry to compete on the world market and to protect the interests of the United States.

Since 2003, the FAA has been proactive in evaluating its MPL method and has made considerable progress updating it. In April 2015, the FAA stopped using its “overlay method,” in use since the early 1990’s, and began using a more technically valid “risk profile” method to calculate financial responsibility requirements. A valid MPL method is necessary to strike a consistent balance between the direct cost on licensees and permittees, in the form of insurance premiums, and a financial liability on the United States, in the form of indemnification and treaty obligations.⁴

This report describes the risk profile method and the work done by the FAA to develop and mature the method. The key statutory and regulatory requirements related to MPL are discussed in the appendix to this report.

II. FAA’s Development of an Updated MPL Method

a. Historical Method

In the early 1990s, the Department of Transportation’s Office of Commercial Space Transportation developed an “overlay method” to calculate third-party casualties and property damage for MPL purposes. Note that “casualties” include both fatalities and serious injuries. This process continued to be used after the office’s transfer to the FAA in 1995. Using this method, the FAA estimated the size of the area where people without shelter would become casualties due to the inert debris field that would result in the event of vehicle breakup. The population density of areas exposed to launch or reentry hazards were factored into a calculation to produce the number of probable casualties due to debris impact. From the casualty amount,

³ GAO-12-899, p. 25-26.

⁴ Of primary interest is the Convention on International Liability for Damages Caused by Space Objects. Under Article II, a launching State is absolutely liable to pay compensation for damage caused by its space object on the surface of the earth or to aircraft in flight.

the FAA then calculated additional casualties from secondary effects such as fires and collapsed buildings using a factor of 1.5 in the launch area. The total number of casualties was then given a value of \$3 million each. The FAA estimated third-party property damage by multiplying the cost of casualties by 0.5.

Although this method was simple and produced conservative MPL values that limited Government liability, the MPL results did not necessarily align well with the actual risks of a launch. In addition, the overlay method did not work well for launches of small launch vehicles in remote areas, or for reentries.

b. Development of the Risk Profile Method

In 2003, the FAA tasked ACTA, Inc.⁵ to review the MPL method in use at the time to investigate more rigorous approaches. Of particular importance to the FAA was to make use of, and be consistent with, risk analyses that are conducted under a license. As funds allowed, the FAA funded further studies through 2012.⁶

The focus of this work was to research and develop approaches to calculating MPL with a risk profile. A risk profile is a way of predicting the consequences of extreme events, which, unlike a risk analysis, is the focus of an MPL calculation.⁷ The challenges developing the approach included:

- Developing a model for clustering people,
- Developing an approach for estimating damage and repair of property, and
- Developing computer models that produce an accurate risk profile without taking an inordinate amount of computer time.

This early work demonstrated the feasibility of the using a risk profile method for MPL calculations, and began the development of analytical tools to realize the approach. The FAA sponsored two workshops during this period to discuss methods and test results.

In August 2014, the FAA tasked ACTA to complete implementation of the risk profile method for computing MPL. The task included:

- Validating code,
- Writing and evaluating procedures for risk profile computation,
- Defining methods for obtaining population data in the immediate vicinity of the launch site,

⁵ Initial tasks were funded through a contract with ITT Industries.

⁶ Reports documenting the work include:

- 1) Development of Rigorous Methods to Compute Maximum Probable Loss, May 2005.
- 2) FY05 Activity on the Development of Maximum Probable Loss Models, December 2005.
- 3) Development of Quantitative Methods to Compute Maximum Probable Loss, December 2006.
- 4) Computing Maximum Probable Loss in RRAT: Examples and Improvements, December 2012.

⁷ A licensee must quantify the collective risk to the public in terms of the average number of casualties. This measure of risk gives no indication of the potential for extreme loss.

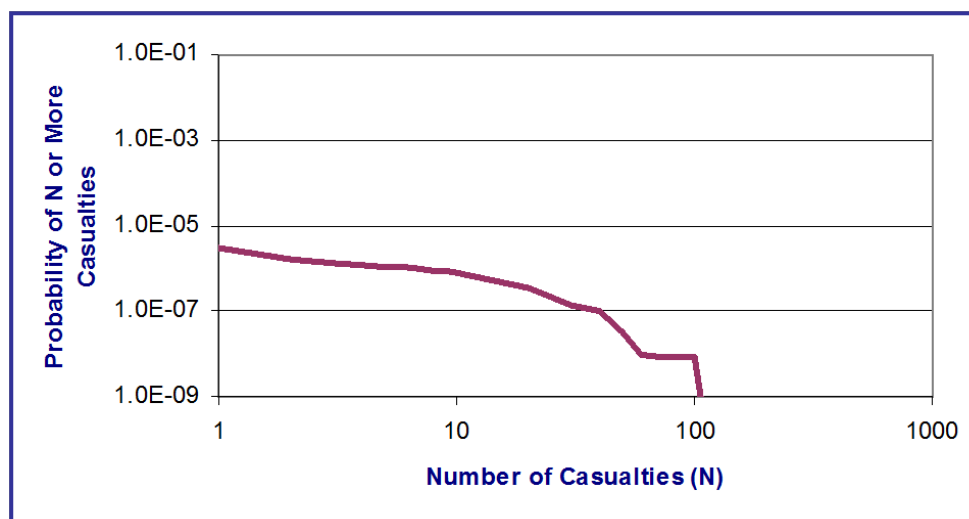
- Defining optimal population resolution, and
- Recommending new data requirements.

This last task, completed in January 2016, matured the risk profile method so that it could be used for routine MPL analyses. The risk profile method is now the FAA's standard process for calculating MPL, and has fully replaced the overlay method.

c. Description of the Risk Profile Method

The FAA develops a risk profile for debris impacts⁸ from a launch or reentry using physics based computer simulations of many accident scenarios. Thousands of discrete accident scenarios are simulated that cover all foreseeable accident scenarios for each and every failure time and vehicle response mode.⁹ Each accident scenario produces a predicted set of debris impacts or explosions. The computer model predicts the precise impact location of each fragment and the consequence of whether a fragment impacts on or near a person or structure, and stores the discrete number of resulting casualties for each scenario. An MPL analysis must model each accident scenario as a discrete event with discrete results, e.g. no casualties, exactly one casualty, two casualties, etc. Each accident scenario also has a quantitative probability of occurrence.

The predicted results of all foreseeable accident scenarios are accumulated into a histogram that provides the probability of exactly one casualty, exactly two casualties, etc. Based on this histogram, the risk profile is computed as the complementary cumulative distribution. The outcome is a plot that shows the probability of a given number of casualties or more versus the number of casualties, as shown in the example below.¹⁰

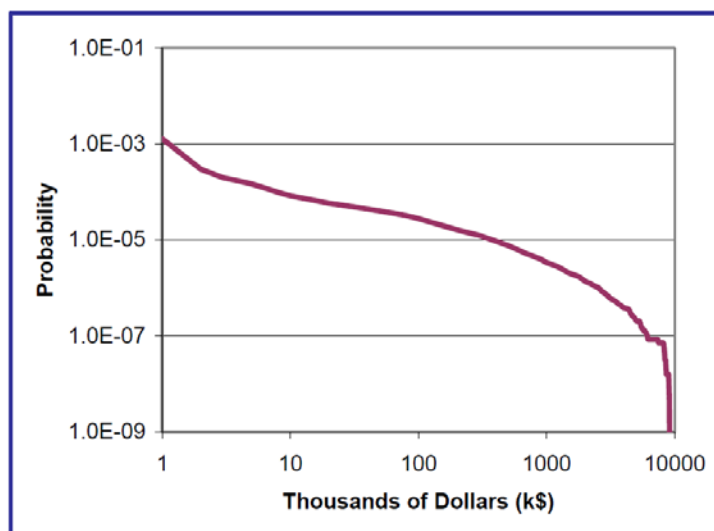


⁸ Due to safety requirements for launch and reentry, distant focusing of blast overpressure and toxic hazards are not generally considered in MPL analyses.

⁹ A vehicle response mode relates to a vehicle's behavior after a failure.

¹⁰ The area under the risk profile plot equals the Expected Casualty. Thus, the risk profile method provides MPL values that are directly related to the public risk assessment.

Through a structure hazard histogram, a similar plot is developed to estimate property damage, as shown in the example below. The ability to model property damage is limited to generic structure types, such as typical residential and commercial buildings. Damage to specialized property such as launch and reentry-unique facilities on a launch or reentry site is estimated, if necessary, on a case-by-case basis.



The risk profile method provides a valid technical basis, consistent with Congress's original direction that MPL determinations "will be made on the basis of the launch vehicle size and type, launch trajectory, payload, and other relevant factors."¹¹ It also properly balances costs to the industry and the Government. Although the risk profile method requires more data from an applicant than the overlay method, the information is similar to the type of information required by the FAA for a risk analysis, so the added burden on an applicant is minimal.¹² Similarly, although the risk profile method requires more of an FAA analyst's time than the overlay method, the work done by the FAA on risk analysis provides much of the foundation for an MPL analysis, minimizing the added burden.

d. Tools

The FAA primarily uses two tools to calculate MPL values using the risk profile method, the Range Risk Analysis Tool (RRAT) and Risk Estimator Sub-orbital and Orbital Launch Vehicle and Entry (RESOLVE).

¹¹ Senate Report 100-593, Commercial Space Launch Act Amendments of 1988, P.L. 100-657, p. 9.

¹² Data required for a risk analysis includes the predicted behaviors of a failing vehicle, probabilities of each scenario, a description of the debris created, the numbers and locations of people at risk, and the vulnerability models for people in the open and in various structures. Additional information required for MPL is primarily related to property, such as building structure and contents.

RRAT is a comprehensive high fidelity risk analysis software program currently used by the U.S. Air Force, Army, Navy, National Aeronautics and Space Administration (NASA), and the FAA to evaluate public risks for launch and reentry operations. It simulates thousands of vehicle failure scenarios to estimate risk, taking into consideration behaviors of a failing vehicle, failure scenario probabilities, inert and explosive debris created by a failure, debris impact dispersions, the numbers and locations of people at risk, and vulnerability models for people in the open and in various structures. As noted above, RRAT had to be modified to better address the consequences of extreme events and property damage.

RESOLVE is a medium fidelity tool developed by the FAA in-house that can compute MPL values using the risk profile method. The tool was originally developed in 2006 to estimate risk from amateur rockets launches, and was gradually improved to estimate the risk from launch and reentry vehicle operations. It has less capability than RRAT, but is useful for MPL calculations that do not require high fidelity, such as for overflight regions, sparsely populated launch areas, and reentry. RESOLVE significantly reduces the time required to conduct such analyses.

In July 2015, the FAA contracted with NASA to conduct a validation and verification of the RESOLVE software tool. This process required the FAA to formalize a requirements document, user's guide, and configuration management plan for the software, and to conduct unit and end-to-end testing of the software. NASA issued its final report in August 2016.

e. Cost of Casualty

In addition to developing the risk profile method, the FAA has reassessed the dollar value assigned to a casualty. The FAA has used a value of \$3 million as the cost of a casualty in its MPL calculations since the first issued license in 1988.¹³ In the fall of 2015, the FAA contracted with the Science and Technology Policy Institute (STPI) to reassess the cost of a casualty and recommend to the FAA a new value.

The inherent challenges of the study were that there have been no third party casualties from a launch or reentry, and available data from analogous transportation modes such as aviation are difficult to obtain due to the data's proprietary nature. In addition, transportation accidents yield a wide range of third party claims, so no reasonable value for the cost of a casualty can cover all space transportation accident scenarios.¹⁴ Nonetheless, STPI's research suggested that the FAA should adjust its cost of casualty value upward, to approximately double its current value.

The FAA is currently reviewing the study. Any change to the cost of a casualty would only be made through a process that provides notice to the public and an opportunity for comment.

¹³ At the time, jury awards for transportation fatalities were often in the neighborhood of \$1 million, but the Office chose \$3 million for the cost of a casualty for conservatism.

¹⁴ Creating a distribution of casualty payouts would have been the ideal method for estimating the cost of a casualty and modelling the effects of injuries and other factors. Unfortunately, STPI was unable to access any database that would provide such an outcome.

Note that the U.S. Department of Transportation (DOT) annually identifies the Value of a Statistical Life to be used for DOT analyses assessing the benefits of preventing fatalities.¹⁵ This value, \$9.6M for 2016, is not directly applicable to MPL analyses because it is based on “the additional cost that individuals would be willing to bear for improvements in safety ... that, in the aggregate, reduce the expected number of fatalities by one.”¹⁶ An MPL analysis addresses the potential liability of parties involved in launch or reentry services from claims by third parties for death or bodily injury, which is different from an individual's willingness to pay for improved safety.

III. Conclusion

The FAA has made significant improvements to the calculation of MPL. Replacing the overlay method with the risk profile method has greatly improved the validity of the MPL process. Due to the dynamic nature of the commercial space transportation industry, the FAA will continually work with industry to examine emerging industry developments and may make refinements in its MPL method in the future as a result. Any refinements will support the FAA's goal of ensuring that the Federal Government is not exposed to greater costs than intended and that launch companies are not required to purchase more insurance coverage than necessary.

¹⁵ The DOT also establishes policies for assigning comparable values to prevention of injuries.

¹⁶ U.S. Department of Transportation, " Revised Departmental Guidance 2016: Treatment of the Value of Preventing Fatalities and Injuries in Preparing Economic Analyses," August 2016.

Appendix

Key Concepts in Statutory and Regulatory Requirements

a. Statutory Requirements

Statutory requirements for financial responsibility for launch and reentry are in 51 U.S.C. § 50914. The statute sets up a three-tiered approach as follows:

1) Tier 1: MPL-Based Financial Responsibility Requirements

When a launch or reentry license or permit is issued, a licensee or permittee must obtain liability insurance or demonstrate financial responsibility¹⁷ in amounts to compensate for the MPL from claims by –

- A third party for death, bodily injury, or property damage or loss resulting from an activity carried out under the license or permit; and
- The United States Government against a person for damage or loss to Government property¹⁸ resulting from an activity carried out under the license or permit.

A licensee or permittee is not required to obtain insurance of more than \$500M for third-party liability, or \$100M for government property. Nor must a licensee or permittee obtain insurance of more than the maximum liability insurance available on the world market at reasonable cost.

An insurance policy must protect the following parties to the extent of their potential liability for involvement in launch or reentry services:

- The Government.
- Executive agencies and personnel, contractors, and subcontractors of the Government.
- Contractors, subcontractors, and customers of the licensee or permittee.
- Contractors and subcontractors of the customer.
- Space flight participants (until September 30, 2025).

2) Tier 2: Government Indemnification

Subject to congressional appropriation, the Federal government indemnifies the launch or reentry operator for claims above the insured amount up to \$1.5 billion, adjusted for

¹⁷ A licensee or permittee can use other means besides insurance to demonstrate financial responsibility, such as placing money in escrow. For simplicity, this report will refer to insurance.

¹⁸ This provision is for Federal Government property, not State and Municipal property. As stated in Senate Report 100-593, accompanying the Commercial Space Launch Act Amendments of 1988, “the facilities that are being utilized by commercial launch operators are critical to the national security of the United States. They should, therefore, be protected as fully as possible to ensure that damage to them, which results from commercial launch operations, is compensated by insurance.” Senate Report 100-593, p. 5536.

inflation from January 1989 (approximately \$3 billion as of 2016¹⁹). Indemnification is not available to permittees. Unless it is extended, the indemnification provision expires on September 30, 2025.

3) Tier 3: Above Indemnification and MPL-Based Insurance

Financial responsibility reverts to the licensee, or legally liable party.

This three-tiered approach generally relieves the commercial space transportation industry of the financial risk of potentially catastrophic liability associated with launch and reentry vehicles. It also allays any concerns about lack of insurance capacity, and allows the U.S. industry to compete effectively against foreign launch services providers whose governments offer indemnification to customers and other participants.²⁰

b. Regulatory Requirements

The FAA's financial responsibility regulations, found in 14 CFR part 440, implement and expand upon the statutory requirements. These include defining thresholds for MPL, distinct phases of launch, coverage of government personnel, and coverage of Government property.

1) Thresholds

The MPL is the greatest dollar amount of loss that is reasonably expected to result from a launch or reentry. The regulations define what is reasonable by establishing probability thresholds:

- Losses to third parties that are reasonably expected to result from a licensed or permitted activity are those that have a probability of occurrence of no less than one in ten million.
- Losses to Government property and Government personnel involved in licensed or permitted activities that are reasonably expected to result from licensed or permitted activities are those that have a probability of occurrence of no less than one in one hundred thousand.

Stated another way, for any launch or reentry, there should only be a 1 in 10,000,000 chance that claims from third parties would exceed the MPL value, and a 1 in 100,000 chance that claims from the Government for Government property loss would exceed the MPL value. This report will refer to these as 10^{-7} and 10^{-5} thresholds, respectively. The difference in thresholds reflects the government's acceptance of greater risk in supporting launch and reentry activities than that accepted by the uninvolved public.

¹⁹ Determined using the Consumer Price Index.

²⁰ Parties involved in launch or reentry services also enter into no fault, no subrogation reciprocal or cross-waivers of claims under which each participant accepts its own risk of property damage or loss and agrees to be responsible for injury, damage or loss suffered by its employees.

2) Phases of Launch

The regulations recognize two distinct phases of launch - pre-flight and flight. The consequences of an accident and hence the MPL can be significantly different for these two phases. For this reason, the FAA normally imposes different financial responsibility requirements for each phase.

For reentry, the FAA does not determine separate MPL values for flight and post-flight operations because post-flight operations are generally brief.

3) Government Personnel

For purposes of MPL, the regulations treat U.S. Government personnel and the personnel of contractors and subcontractors working for the Government, in support of licensed or permitted activities, as third parties.²¹ On Federal launch ranges, these personnel typically include government personnel and government contractor personnel that support the licensed or permitted operator, as well as FAA inspectors. On non-Federal launch or reentry sites, these personnel typically include only FAA inspectors. Government customer personnel may also be exposed to launch or reentry hazards and are also treated as third parties.

4) Government Property²²

Location of Government Property

Government facilities covered by Government property insurance are limited to those facilities on or adjacent to the Federal launch range from which the launch or reentry take place, including downrange tracking facilities. Government property off-range is treated as third-party property.

Transient Government Property

The FAA considers only fixed property in its MPL calculation for government property. Fixed property refers to facilities that are immovable and to equipment that is intended to be left in place. The FAA does not consider transient property in its MPL calculation for government property. Transient property includes launch vehicles and payloads.²³ Note, however, that despite transient property not being included in the MPL calculation, if Government transient property is damaged due to a launch or reentry mishap, the Government can claim the loss under the licensee's Government property insurance.

²¹ The reason for this treatment is to avoid violation of the Anti-Deficiency Act (P.L. 97-258) which prohibits the Government from agreeing to assume an unfunded contingent liability absent specific statutory authority to do so. 63 FR 45592, 45597 (Aug. 26, 1998).

²² The FAA articulated the policies in this section in preamble language, not regulatory text.

²³ Such property is not considered in the MPL calculation because the Government presumably has the option of not moving the property into a risk area or of moving the property away, and thus removing it from any possible harm due to the licensed activity.

Property Valuation

The value given to Government property is its current replacement value, that is, the value necessary to return the facility to its intended and currently functioning purpose. Losses due to the interruption of range operations are not included in MPL values.