13 May 2016

Supplementary Submission to Space Activities Act Review[1]

In this supplementary submission, we examine the risk that the government assumes under the existing Space Activities Act insurance/financial requirements rules in relation to overseas launches and compare it with the additional risk assumed if the insurance/financial requirements were waived for a particular Overseas Launch Certificate (OLC) holder under the Act.

The Space Activities Act requires the holders of permits for overseas launches to obtain insurance for the lesser of A$750M or the Maximum Probable Loss (MPL).[2] As stated in our main submission, the Australian Government's liability under international law is protected by an indemnity from the holder of an Overseas Launch Certificate only to the level of the MPL and only during the liability period defined in the Act.[3] One way of looking at this is that under the current regime Australian satellite operators have the benefit of an insurance policy with an 'excess' of A$750M or the MPL, whichever is the lesser.

Further to our main submission, we argue that:

1. The maximum additional risk that the government assumes by waiving or capping the liability is very small and far outweighed by the economic benefit derived from the activity;
2. As a result, in appropriate cases the insurance requirement should be greatly reduced or even eliminated altogether, provided the risk is tolerable; and alternatively:
3. The OLC application procedure, including the MPL calculations, if retained, should be greatly simplified in order to improve the implementation of the regulatory regime, especially in the case of small satellite operators.

Risk and Liability Calculations

The 2009 publication *Introduction to The Australian Space Safety Regime*[4] deals with the risk thresholds. It recommends using the 'As Low As Reasonably Practicable' (ALARP) principle where upper and lower risk thresholds are defined. The upper threshold defines the level above which risk is no longer acceptable, while the lower threshold defines residual or negligible risk. The lower level represents a risk that is 'low enough to be regarded as residual and not in need of further reduction'. The Australian Launch Safety Standards specify a lower level of risk is 10^{-7}. Risks above this lower level enter into the MPL calculations.

---

[1] The SIAA gratefully acknowledges the work of Dr Elias Aboutanios of the School of Electrical Engineering and Telecommunications, University of New South Wales in the preparation of this Supplementary Submission.

[2] Section 48(3) Space Activities Act.

[3] Section 47 Space Activities Act.

[4] *Introduction to the Australian Space Safety Regime* Version 2.2, The Space Licensing and Safety Office Department of Innovation, Industry, Science and Research, Canberra, 18 May 2009, p. 17.

The MPL calculations are used to calculate the total insurance or direct financial responsibility required of an applicant for an OLC.

The liability of the OLC holder, which we denote by L, is given by

$$L = \min(MPL, \$750\text{M}).$$

In the case of an accident, the Australian Government is liable to pay compensation for damage in excess of the insured amount, capped at A$3 billion in the case of Australian nationals.[5] Although this is not a hard limit to the government's liability in international law, it represents a very high estimate of the government's potential total liability for any individual claim under the Liability Convention or under domestic law and can be safely adopted as an upper limit for the purposes of our calculations.[6] Thus, for the purposes of this submission we have assumed that the government's liability can be expressed in a range of 0 to a maximum of A$3 billion.

Expected Additional Liability

Suppose that, instead of requiring an MPL calculation for each mission, the liability of an applicant for an OLC is capped at an amount $\mathrm{C} < \$750\text{M}$. In that case, the government picks up an additional liability

$$L_g = 750 - C.$$

The goal is then to calculate the expected additional liability to the government in the case that K missions are authorised in a year. We make the following assumptions:

1. Shared missions constitute a single launch since a single accident covers both (i.e. when two Australian payloads ride on the same rocket, the Australian Government's liability is a single liability for the launch and not for each payload). Thus we consider only independent missions. [7]
2. The probability of a launch accident is *p* (Note that the probability that is relevant here is that of a launch accident that has a non-negligible likelihood of causing third party damage. This is discussed in more detail below.)
3. The launches are independent events, meaning that an accident at a particular launch does not influence the likelihood of an accident at another launch.

---

[5] See Section 69 of the Space Activities Act

[6] We note that the Cosmos 954 accident in 1978 resulted in a negotiated settlement between the USSR and Canada of C$3 million, about 0.1% of the postulated ceiling amount. Similar incidents not resulting in compensation payments are described by Prof Steven Freeland in the UNSW Law Journal at http://www.austlii.edu.au/au/journals/UNSWLJ/2001/31.html

[7] Note that once the payloads are injected into orbit, they become multiple missions and the Australian Government is liable for each separately. However, we ignore this separation for two reasons: firstly, the bulk of the MPL calculations come from expected damage on Earth or in the air where human lives are possibly involved, and secondly the liability regime in space is not absolute but fault-based. Therefore, although there are accidents in space, the ability to prove fault on the part of one of the parties is a major practical constraint. For instance, in the recent collision between Cosmos-2252 and Iridium-33 the Liability Convention was not invoked because it was felt that conflicting information leading up to the collision, coupled with the lack of tracking data for that region of Earth orbit, gave neither party sufficient evidence to meet the fault standard set by the Liability Convention - see http://www.thespacereview.com/article/2023/1

Accident Probability

While the historical failure rate of all space launches is of the order of 10%, this statistic is not relevant to the MPL. Launch activities on Australian soil may have implications for Australian residents and property under Australian law, but when these activities are carried out overseas, only failures that have the potential of causing third party damage as defined in the space treaties would be relevant to the MPL calculations. Generally, launch failures include all launches that do not get the payloads to their intended orbits. These may include failures at the launch pad, in flight and at the orbit injection phase. Many of these failures do not enter into or have negligible bearing on the MPL calculations. Launchpad failures, for instance, would not result in any Australian liability under the space treaties since the damage would be suffered by a launching state. Failure at the orbit injection phase may simply result in the satellite being in an incorrect orbit and no third party damage would be involved. Also liability in that case is not absolute but fault-based.[8] While all of these events would be considered failures, they clearly do not have any appreciable probability of causing third party damage on Earth or to aircraft in flight. Also, according to general practice overseas launches tend to be carried out seaward and away from population centres and high value assets, and rockets have mechanisms (such as the self-destruct mode) in order to prevent significant deviations from the nominal path and reduce the risks of damage.[9] Consequently, when surveying historical failures, only those that either resulted or had the potential to result in third party damage should be considered. These are a much smaller proportion and their likelihood is indeed very small relative to the total historical launch failure rate.

Calculation of the Expected Additional Liability (EAL)

The problem under consideration is a combinatorial one: the expected liability, that is the amount that the government can expect to pay out in a year, is obtained by summing up the liabilities of all scenarios comprising the possible combinations of accidents. A scenario is essentially the proportion of accidents out of the total number of missions. To illustrate this, suppose we have N=4 missions. Then there are 4 possible scenarios. One of those is that where all 4 missions succeed. This scenario has only one possibility, namely that the 4 missions are successful. Another scenario is one where one out of the four missions fails. This scenario involves 4 possibilities where in the first possibility mission 1 fails and missions 2 to 4 are successful. The second possibility is the one where the mission 2 fails while missions 1, 3 and 4 succeed, and so on. One can enumerate all N scenarios, and all combinations of each scenario. We can see now that each scenario is characterised by the parameter set $\{\mathrm{N}, \lambda, \mathrm{Q}\}$, where N is the number of combinations of launch accidents giving rise to the scenario, λ is the probability of the scenario occurring (that is the likelihood that a combination of launch accidents taking place), and Q is the total liability incurred for the scenario.

The trivial scenario is clearly that no accident takes place, in which case the Government's actual liability is 0. The probability of this scenario is given by $(1-p)^K$. The first non-trivial scenario

[8] As previously noted, historical experience suggests that there is a lower likelihood of claims arising out of incidents occurring in space.

[9] Even when looking at a new rocket, such as the Cyclone 4, as part of the MPL calculations of the QB50 mission, the probability of failure was found to be no more than 9 in 1000 and most failure modes were extremely unlikely to cause third party damage (so the actual probability of third party damage was much lower still). This is a much lower probability than 1. In any case, it would indeed be surprising if a government regulator allowed a launch to go ahead where the likelihood of significant loss of life were higher than 1 in 1000.

consists of only one mission failing and the remainder succeeding. In this case, the number of possible combinations is K, the probability of the launch failure is p and the additional cost that is incurred is L_g. The expected cost of the first scenario is then $Kp(1-p)^{K-1}L_g$.

The second non-trivial scenario involves the failure of any two of the K missions. Thus, the number of combinations is $\binom{K}{2}$, the probability of occurrence is $p^2(1-p)^{K-2}$ and the total additional financial burden is $2L_g$.

In general, for a scenario involving k failures, the number of combinations is $\binom{K}{k}$, the probability is $p^k(1-p)^{K-k}$ and the loss is kL_g. Now the expected additional loss (EAL) is obtained by summing the losses from all scenarios corresponding to k ranging from 1 to K:

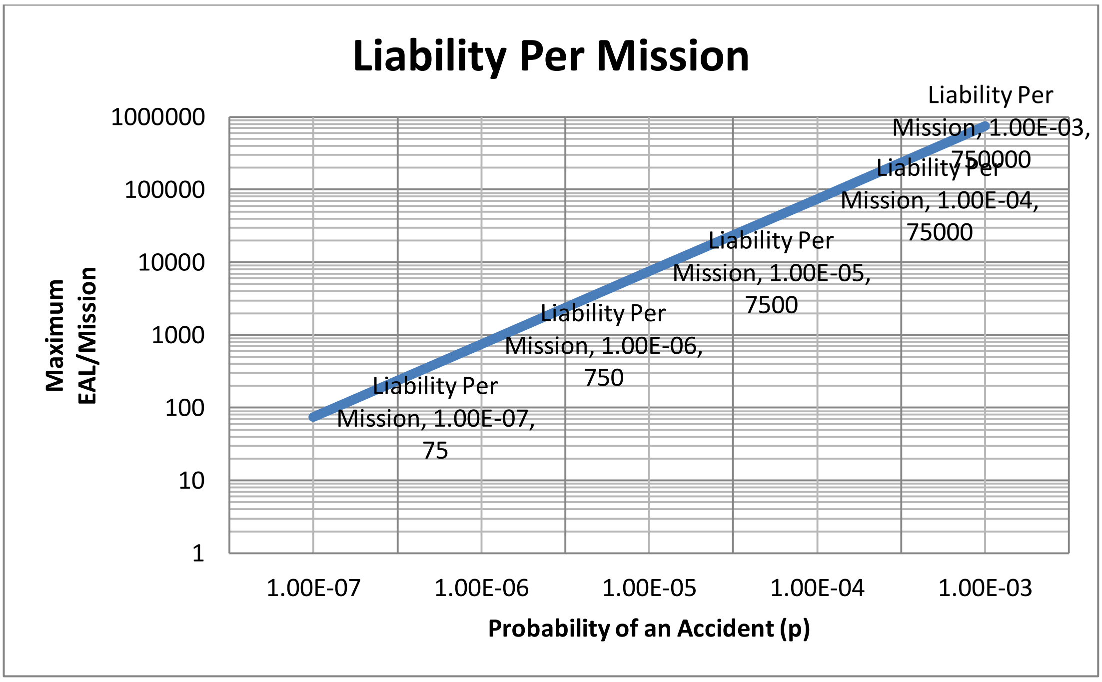
$$EAL = \sum_{k=0}^{K} \binom{K}{k} p^k (1-p)^{K-k} k L_g,$$

which is equivalent to:

$$EAL = L_g \sum_{k=0}^{K} k \binom{K}{k} p^k (1-p)^{K-k}.$$

The outcome of the summation is the expected value of the number of accidents that is calculated from a binomial distribution. This expected value is known to be Kp. Therefore, the $EAL = pKL_g$.

Clearly, the expected cost per mission is equal to pL_g. This is independent of the number of missions and is entirely controllable by the maximum tolerable probability of an accident. For a particular accident probability, the maximum EAL is obtained in the case that the government waives the insurance requirement altogether. The plot below shows the maximum EAL per mission against the probability of an accident. We see that the maximum EAL permission for an accident probability of 1 in 1000 (which is considered to be quite high) is only A$750,000. This is expected since the EAL per mission is the maximum liability multiplied by the probability of an accident.



For a particular accident probability, the total EAL is given by the EAL per mission multiplied by the number of independent missions, where the independence is taken to mean that the missions are using different launches. Therefore, an increase in missions would lead to the government assuming greater risk[10]. As nanosatellites aim to reduce launch costs by sharing rocket launches, this would mitigate the independent missions effect by allowing multiple Australian missions to share a single launch. Thus, the increased liability that could result from a growth in the number of missions could be easily mitigated by facilitating or even encouraging payloads to share rocket flights[11]. This approach fits the 'new space' business model in which many satellites share flight costs. Furthermore, the increase in space missions that may result from easing the legal and insurance requirements would greatly contribute to Australia capturing a bigger share of the global space economy.

It should be noted that while our calculations are based on an upper MPL limit of A$750 million, the experience in the United States (which uses a similar methodology for the calculation of the MPL) is that for all launcher types the actual MPL calculation produces a figure that is considerably less than this amount. According to FAA data in the US, the average in-flight MPL for third party risks for all commercial launchers currently licensed by the FAA is US$103 million.[12] If this maximum MPL is applied to our analysis, the EAL range is significantly smaller.[13]

Conclusion

Our analysis shows that using the acceptable accident probability methodology outlined above, the Expected Additional Liability (EAL) per mission that would be assumed by the Australian Government by waiving the insurance/financial requirement, for acceptable accident probabilities (i.e. where the probability is less than 1 in 1,000) is quite low - somewhere in the range of A$75 to A$750,000 as shown in the above chart, and a significantly lower upper exposure if actual MPL calculations are taken into account.[14]

This is in further support of our main submission in which we argue for the removal or amelioration in certain circumstances of the insurance/financial requirement for overseas launch certificates. As stated previously, Australian satellite owners seeking to launch their payloads overseas face a regulatory burden that can be disproportionate to the size and cost of their projects and/or that duplicate approvals and indemnity arrangements that are also required in the country of launch.

---

[10] It is unlikely, however, that we will see the missions numbering in the thousands or even hundreds in the near future. In a 2015 presentation titled "Small Satellite Market Observations", 158 small satellites are reported to have been launched globally in 2014. The global forecast for launches in 2020 is around 400. For details see the report at the link: http://www.spaceworksforecasts.com/docs/SpaceWorks_Small_Satellite_Market_Observations_2015.pdf

[11] A separate but important issue that needs to be tackled globally is that of space debris. Increasingly affordable access to space will lead to an increase in missions, albeit to low orbits. Therefore, it is imperative that a global approach is developed for ensuring the proliferation of small satellites does not lead to a space debris crisis.

[12] See https://www.faa.gov/about/office_org/headquarters_offices/ast/launch_license/mpl_values/media/MPLApril2015.pdf

[13] If the average MPL for US missions is US$103M, equivalent to about A$140M, the practical EAL for an accident probability ranging from 10^{-7} to 10^{-3} is between A$14 and A$1.4M. Using the tolerable upper limit of 10^{-4}, the EAL is A$140,000.

[14] See footnote 13.

Changes to the Act and the Regulations can improve this situation:-

(a) by leaving the licensing of the overseas launch to the country of launch where the government is satisfied that it will be properly indemnified and all launch safety issues have been adequately addressed; or

(b) by waiving the insurance/financial requirement for the liability periods under the Act in carefully defined situations and only insisting on indemnification where the public good and other considerations set out above are outweighed by the importance of protecting the public purse.

According to Goldman Sachs, the addressable opportunity for aerospace and defence companies in the satellite manufacturing, launch and operations sector in 2016 will be of the order of US$60 billion.[15] Capturing even a 1% share of that market would result in a US$600 million injection into the Australian economy. This far outweighs the tangible demonstration of government support implicit in assuming the EAL in appropriate cases, as outlined in this submission.

[15] http://www.goldmansachs.com/our-thinking/pages/macroeconomic-insights-folder/what-if-i-told-you/report.pdf