Space Activities Regulations 2001 2001 No. 186

EXPLANATORY STATEMENT

Statutory Rules 2001 No. 186

Issued by the Authority of the Minister for Industry, Science and Resources

Space Activities Act 1998

Space Activities Regulations 2001

Part One – general background and overview

The Government has been working to create a competitive environment for space launch activities, and in late 1998 enacted the *Space Activities Act 1998*. The Act established a legal basis for licensing commercial space launch facilities in Australia and licensing overseas launch activities undertaken by Australian nationals. The Act also provides for recovery operations, investigation procedures in the event of an accident and the payment of fees in respect of licences and permits. Further, the Act ensures that the Commonwealth meets its obligations under United Nations conventions on space matters, particularly those relating to liability and registration of space objects, by passing its obligations onto the commercial parties or requiring the provision of appropriate information.

In developing the licensing regime, the Commonwealth was keen to ensure that it both protect public health and safety and the environment, while at the same time ensuring that it was not so onerous as to act as a disincentive to the establishment of a viable space launch industry in Australia.

General outline of Australia's space regulatory regime

Under the Act, a person who wishes to construct and operate a space launch facility on Australian territory requires a space licence. In granting or transferring a space licence the Minister for Industry, Science and Resources must be satisfied that the applicant is competent to construct and operate a launch facility, has an adequate environmental management plan in place, has demonstrated that the probability of the launch activities causing harm to public health and safety is as low as reasonably possible, and that the proposed facility does not compromise national security or Australia's international or foreign policy obligations. Once granted a space licence, holders require a launch permit for each launch or for a series of similar launches from the facility.

The Act also provides for:

- an overseas launch certificate, which is required by Australian nationals with an ownership interest in a space object to be launched outside Australia;

- an authorisation of return of an overseas launched space object, which is required when a space object is to be returned to Australia; and

- an exemption certificate, which exempts a person from the need to obtain a space licence, a launch permit or an authorisation to return an overseas launch space object. It is expected that these will only be issued in exceptional circumstances, and where a strong case has been presented by the applicant.

Fees are payable in respect of each of these instruments and are calculated to recover the costs incurred by the Commonwealth to assess the application, provide the instrument and support the Launch Safety Officer in monitoring launch activities.

The Act defines arrangements for liability to third parties for damage caused by space objects, requires permit holders to meet insurance or financial requirements to offset this liability, and caps the insurance that is required to be held. The Act also provides for a Register of Space Objects by requesting all appropriate data from holders of instruments.

Provision is made for the delegation of the powers of the Minister to another person, for review of a number of decisions by the Minister by the Administrative Appeals Tribunal and for civil penalties for breaching a number of the provisions of the Act.

The Act provides for a Launch Safety Officer to supervise the launch activities at the launch facility and to act on the authority of the Minister to ensure the safety of launch activities. The Act further provides for investigations into the circumstances surrounding any accidents or incidents, including the appointment of an investigator by the Minister. The investigator is empowered to investigate, invite assistance, gather information, and must report on the investigation to the Minister. The Act also provides for a range of offences in relation to investigations, allows the Launch Safety Officer to take custody of a space object for the purposes of an investigation, facilitates suspension of the permit under which the launch was authorised, and prohibits the disclosure of safety records furnished in the course of an investigation.

Two documents are incorporated by reference in the Regulations and set out the technical standards and methods with which applicants must comply. These documents, as set out below, have the same legal status as the Regulations.

- The Flight Safety Code (the Code) sets out the launch safety standards with which applicants, and subsequently, operators of space launch facilities must comply when planning and executing space launch activities. The Code was developed to reflect Australian conditions by experts in the field and sets out safety standards which ensure the risk to the public arising from space operations is as low as reasonably possible. The Code includes a Risk Hazard Analysis Methodology, standards for designated and protected assets, drop zones and landing sites, and additional protection against the risks posed by new launch vehicles and new launch operations.

The safety standards imposed by the Flight Safety Code require that each individual be exposed to a maximum risk of no greater than 1 in 10 million per launch of sustaining an injury requiring hospital care or causing death. The maximum combined risk to the general public per launch can be no greater than 1 in 10 thousand.

- The Maximum Probable Loss (MPL) Methodology sets out the method to be used by applicants in calculating the minimum insurance levels required for licensed launch activities. The methodology specifies the required approach to risk based hazard analysis of events which are sufficiently likely to occur such that insurance is required to cover their consequences. The MPL is focused on events which may cause injury to people or property, or have environmental consequences, and includes calculations to reflect consequential and economic losses.

Australia's international obligations in space

Australia is a signatory to five United Nations conventions which impose a number of obligations on the Commonwealth. These are:

- the Convention on International Liability for Damage Caused by Space Objects (the Liability Convention);

- the Convention on Registration of Objects Launched into Outer Space (the Registration Convention);

- the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies;

- the Agreement Governing the Activities of States on the Moon and other Celestial Bodies; and

- the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space.

The Liability Convention specifies that each launching State shall be liable to pay compensation for all harm or damage to foreign third parties caused by a space object that is launched from its territory or by space objects owned by Australian nationals launched from another country. Under the Act, the Commonwealth passes this liability onto the commercial parties by requiring holders of launch permits and overseas launch certificates to have adequate insurance coverage or to demonstrate financial responsibility for launch activities.

Authority to make Regulations

Section 110 of *Space Activities Act 1998* (the Act) provides that the Governor-General may make regulations for the purposes of the Act.

The purpose of the Regulations is to bring the space licensing and safety regime outlined in the Act into full and effective operation. The Regulations set out:

- the information and documents required to be submitted in support of applications for authorisations under the Act to satisfy the Minister that all criteria set out in the Act have been satisfied, and detail extra criteria which must be satisfied and additional conditions which will apply to each authority (Parts 1 - 6 of the Regulations);

- the insurance or financial obligations on the licensee regarding liability for damage to persons or property in the event of an accident, methods to calculate the minimum insurance required or to otherwise demonstrate financial capacity to meet any liabilities (Part 7 of the Regulations);

- the functions of the Launch Safety Officer, including an extensive list of persons to be notified of an impending launch, and procedures for giving and complying with directions (Part 8 of the Regulations);

- the fees to be paid by the applicant with each application for a licence, permit or certificate (Part 9 of the Regulations);

- the fees and allowances for persons assisting the investigator or appearing as a witness before the investigator (Part 10 of the Regulations); and

•	the powers conferred under the Regulations which the Minister may delegate and the decisions or directions which may be reviewed by the Administrative Appeals Tribunal (Part 11 of the Regulations).

The Regulations were developed following extensive consultations between the Commonwealth Government, State and Territory Governments, the space industry and other affected industries, legal, insurance and technical experts and affected local communities. The Regulations will facilitate the full implementation of the space activities regulatory regime.

An outline of the Regulations is set out in Attachment 1.

Detailed explanation of each of the Regulations appears in Attachment 2.

EXPLANATORY STATEMENT

Attachment 1

OUTLINE OF SPACE ACTIVITIES REGULATIONS 2001

Part 3 of the *Space Activities Act 1998* (the Act) triggers regulations which are in respect of the licensing of certain space activities, and comprise several divisions and parts.

• Part 1 of the Regulations (regulations 1.01 to 1.03) deals with preliminary matters.

• Part 3 of the Regulations (regulations 3.01 to 3.12) discusses the grant or transfer of a launch permit, which is required before a launch can take place from Australia. The Regulations specify an additional criterion about which the Minister must be satisfied before granting a launch permit, set out additional conditions which will apply to a launch permit, outline the form of application for the grant or transfer of a launch permit, and describe the supporting documentation to be provided to satisfy the Minister that all criteria set out in the Act and Regulations have been met. The additional criterion set out in the Regulations addresses the need for an adequate environmental plan. Additional conditions that are attached to a launch permit include maintenance of and compliance with a number of plans and the Flight Safety Code, confirmation of all launch and return details, the need to meet the costs of any accident investigation, and the need to record actions taken in response to directions given by the Launch Safety Officer. The documentation to be provided includes details about the proposed launch and payload, details of any return, details of personnel to be responsible for or involved in the launch, a hazard analysis of the proposed launch or return along with an independent verification of the hazard analysis, details of any recovery, confirmation that the space object does not contain a weapon of mass destruction, a program management plan, a technology security plan, an environmental plan or relevant approvals, a flight safety plan, and an insurance compliance plan. The Flight Safety Code is a document incorporated by reference into the Regulations and will be published by the Department in June 2001. •	Part 4 of the Regulations (regulations 4.01 to 4.07) discusses the grant or transfer of an overseas launch certificate, which is required by Australians procuring the launch of a space object in which they have an ownership interest from a launch facility outside Australia. The Regulations specify an additional criterion on which the Minister must be satisfied before granting an overseas launch certificate, specify conditions which will apply to an overseas launch certificate, outline the form of application for the grant or transfer of an overseas launch certificate and describe supporting documentation to be provided to satisfy the Minister that all criteria set out in the Act and Regulations have been met. The additional criterion set out in the Regulations addresses the need to ensure that the space object does not contain a weapon of mass destruction. The required documentation includes details of the launch and payload, a description of the applicant's organisational structure and key personnel directly connected with the launch, details of previous launches from the facility and using the type of launch vehicle, details of contractual arrangements, evidence to demonstrate that the launch is unlikely to cause substantial harm to public health or safety or damage to property, and confirmation that the space object does not contain nuclear weapons.

- Part 5 of the Regulations (regulation 5.01) provides for the authorisation of the return of overseas-launched space objects to Australian territory. The Regulation specifies an additional criterion about which the Minister must be satisfied before authorising the return of overseas-launched space objects. The additional criterion requires the applicant to have an adequate environmental plan, or other relevant environmental approvals. Requests for supporting documentation will be included in administrative guidelines, as the Act does not make provision for Regulations.

- Part 6 of the Regulations (regulation 6.01) sets out the matters to which the Minister must have regard in deciding whether to exempt a person from the requirement to obtain a space licence, launch permit or overseas launch certificate. Such matters include whether the activity is an emergency situation, might cause substantial harm to public health and safety or damage to property, or might expose the Commonwealth to liability for damage. Requests for supporting documentation will be included in administrative guidelines, as the Act does not make provision for Regulations.

- Part 7 of the Regulations (regulation 7.01 to 7.03) sets out the insurance and financial requirements for launch permits, overseas launch certificates and Section 43 (of the Act) authorisations. There are two ways of satisfying these requirements, either through the demonstration of direct financial responsibility (separately identified for individuals and subsidiary companies), or through the satisfaction of insurance requirements, where the minimum insurance must equal the amount calculated using the Maximum Probable Loss Methodology. A different method for minimum insurance requirements for overseas launch certificates is also set out in this part. The Maximum Probable Loss Methodology is a document incorporated by reference in the Regulations and will be published by the Department in June 2001.

- Part 8 of the Regulations (regulations 8.01 to 8.03) addresses the functions of the Launch Safety Officer. The Regulations describe arrangements for the Launch Safety Officer to give notice to the local community and all relevant Commonwealth, State/Territory, local, emergency management and international authorities of an impending launch. The Regulations also set out procedures for giving and complying with directions, and outline penalties for permit holders who do not comply with directions given by the Launch Safety Officer.

- Part 9 of the Regulations (regulations 9.01 to 9.06) sets out details of the fees payable for each of the authorities issued under the Act, and the timetable for such payments.

- Part 10 of the Regulations (regulations 10.01 to 10.03) addresses the investigation of accidents, and describes the fees and allowances to be paid to people who assist the investigator, or are a witness for an investigation.

- Part 11 of the Regulations (regulations 11.01 and 11.02) provides for certain powers of the Minister to be delegated and for certain matters to be reviewed by the Administrative Appeals Tribunal.

EXPLANATORY STATEMENT

Attachment 2

<u>DETAILED EXPLANATION OF EACH OF THE REGULATIONS</u>

Space Activities Act 1998

Space Activities Regulations 2001

Section 110 of *Space Activities Act 1998* (the Act) provides that the Governor-General may make regulations for the purposes of the Act.

Part 1 Preliminary

Name of Regulations

Regulation 1.01 specifies the name of the Regulations as the *Space Activities Regulations 2001*.

1.02 Commencement

Regulation 1.02 specifies that the *Space Activities Regulations 2001* will commence on gazettal.

1.03 Definitions

Regulation 1.03 sets out the meanings of specific terms used within the Regulations.

Part 2 Space licences

Division 2.1 General

2.01 Definitions for this Part

Regulation 2.01 sets out the meanings of specific terms used within Part 2 of the Regulations. A number of technical terms are used in the definition of 'ground system', however these have a clear, well understood meaning in the engineering and space sectors.

Division 2.2 Criteria for launch facility

Criteria for launch facility

Regulation 2.02 specifies, for the purposes of paragraph 18 (f) of the Act, an additional criterion in respect of which the Minister must be satisfied prior to the grant of a space licence. The additional criterion has the effect of requiring that the launch facility be as effective and safe for its intended purpose as is reasonably possible. The additional criterion is intended to assist in the safe operation of the launch facility and strengthen the protection provided to the local community and to assets of major economic significance.

Division 2.3 Criteria for kind of launch vehicle

2.03 Criteria for kind of launch vehicle

Regulation 2.03 specifies, for the purposes of paragraph 18 (g) of the Act, an additional criterion in respect of which the Minister must be satisfied prior to the grant of a space licence. The additional criterion has the effect of requiring that the launch vehicle be as effective and safe for its intended purpose as is reasonably possible. The additional criterion is intended to assist in the safe operation of the launch vehicle and strengthen the protection provided to the local community and to assets of major economic significance.

Division 2.4 Space licence conditions

2.04 Standard space licence conditions

Regulation 2.04 prescribes, for the purposes of paragraph 20 (c) of the Act, additional conditions that will apply to each space licence. As a space licence is granted for a period of 20 years, the conditions set out in this regulation are intended to keep the Minister informed of relevant changes to the holder's operations and personnel, and maintain protection of public health and safety. The conditions also ensure that construction and operation of the facility, and subsequent launch activities, are undertaken in a manner which is consistent with the arrangements set out in the documents provided in support of an application, and upon which provision of a space licence was based. As some matters will be finalised following the provision of a space licence, the regulation requires that relevant approvals, evidence and information be provided once received. Finally, the conditions provide for the Minister to direct the revision to a number of plans.

Subregulation 2.04 (1) sets out the meanings of specific terms used within regulation 2.04.

Subregulation 2.04 (2) sets out the extra conditions that are to apply to the space licence, in addition to those specified in section 20 of the Act. The conditions set out in the regulation require the holder of the space licence to:

- comply with the plans provided in support of the application including the program management plan, the flight test plan, the technology security plan, the emergency plan, and an environmental plan, as required under regulation 2.06;

- provide copies of all approvals obtained, following provision of the space licence, as identified in the outstanding acquittals plan;

- amend, to keep in an up-to-date condition, any plans approved by the Minister in support of the application;

- provide copies of any amended plans to the Minister;

- revise certain plans according to any direction given by the Minister;

- provide details of a range of personnel within the applicant's organisation and/or who will work at the facility or in conjunction with a launch; and

- maintain a personnel record for each employee or deemed employee or person who performs services for the applicant, for a period of 7 years.

Subregulation 2.04 (3) specifies the circumstances under which a flight test plan will be required, where a launch vehicle is of a new kind and no launch vehicles of that kind have been flight tested, or where the launch vehicle has undergone a major modification.

Subregulation 2.04 (4) specifies the types of modifications which may be considered major modifications to a launch vehicle for the purposes of subregulation (3).

Subregulation 2.04 (5) specifies which individuals may be considered employees or deemed employees for the purposes of providing details under paragraph (2) (j).

Subregulation 2.04 (6) provides for the Minister to give the holder of a space licence a written direction to revise any of the following plans: the program management plan; the flight test plan; the technology security plan; and the environmental plan.

Division 2.5 Applications for grant of space licences

2.05 Applications for space licences (Act s 23)

Regulation 2.05 specifies, for the purposes of section 23 of the Act, that an application for a space licence must be made in accordance with Division 2.5 of the Regulations.

2.06 Form of application

Regulation 2.06 sets out the way in which an application for a space licence must be made, the information which must be included in the application, and the details of documents that must be submitted in support of an application.

Subregulation 2.06 (1) specifies that the application must:

- be in writing and include contact details and information on the corporation;

- provide general details of the proposed launch facility and when it is proposed to commence operations;

- specify the kind of launch vehicle proposed to be used;

- give details of the dates of any proposed test flights;

- provide details of the key contact person within the applicant's organisation able to deal with all matters in relation to the application. After hours contact details are required to facilitate the continuous assessment of the application and immediate resolution of urgent matters; and

- provide the documents required under paragraph 2.06 (1) (h).

Subregulation 2.06 (2) specifies that the application and the accompanying documents must be lodged with the Department of Industry, Science and Resources.

Subregulation 2.06 (3) specifies that the documents must be provided in English and, if translated into English, must be accompanied by a certificate of verification by an accredited translator. Accredited translator is defined in regulation 1.03.

Subregulation 2.06 (4) sets out the documents and plans that are required to be submitted by applicants in support of their application under paragraph 2.06 (1) (h). These include:

- documents providing details of the applicant's organisational structure, financial standing, and key personnel connected with the operation of the launch facility and launch vehicles;

- a program management plan;

- design and engineering plans for the facility;

- a flight test plan (if required, see subregulation 2.06 (6));

- a technology security plan;
- an emergency plan and any required approvals in relation to the emergency plan;
- environmental approvals and an environmental plan if required (see regulation 2.17);
- documents relating to the launch vehicle proposed to be used at the facility; and
- an outstanding acquittals plan.

Subregulation 2.06 (5) specifies that a flight test plan (where required) may be part of a program management plan or a separate document. This is intended to provide the applicant with some flexibility in the preparation of its material.

Subregulation 2.06 (6) specifies the circumstances under which a flight test plan is required.

Subregulation 2.06 (7) specifies the types of modification which may be considered major modifications to a launch vehicle.

Subregulation 2.06 (8) defines a technical recognition agreement for the purpose of the regulation. Such an agreement is currently under negotiation with the Government of Russia.

Division 2.6 Applications for transfer of space licences

Applications for transfer of space licences (Act s 23)

Regulation 2.07 specifies, for the purposes of section 23 of the Act, that an application for transfer of a space licence must be made in accordance with Division 2.6 of the Regulations.

Form of application

Regulation 2.08 sets out the way in which an application for the transfer of a space licence must be made, the information which must be included in the application, and the details of documents that must be submitted in support of an application. Whilst it is similar to the requirements set out in regulation 2.06 the major difference lies in the requirement for the applicant to provide reference numbers of the existing (transferor's) space licence, and the need for the application to be signed by both the transferor and transferee. Regulation 2.08 further provides that the applicant need not provide certain plans if they propose to use the plans previously approved in the grant of the original space licence, and they provide a written statement to that effect.

Division 2.7 Documents relevant to conditions and applications under this Part

Regulations under this Division describe the expected contents of documents required to be provided in support of an application for a space licence. They are intended to provide considerable detail to guide applicants in the preparation of material, information and documents.

2.09 Definitions for this Division

Regulation 2.09 sets out the meaning of terms used in Division 2.7 of the Regulations.

2.10 Applicant's organisational structure and financial standing

Regulation 2.10 sets out the information to be provided in respect of the applicant's organisational structure, financial standing and details of key personnel, which will be used to satisfy the Minister about criteria specified in paragraphs 18 (a), 18 (c) and 18 (e) of the Act, that the applicant is competent to operate a launch facility and launch vehicles of that kind, has sufficient funding to build and operate the proposed launch facility, and that there are no circumstances related to the applicant or their employees which represent a threat to Australia's national security, foreign policy or international obligations. Subregulation (2) specifies personnel about whom relevant information is required.

2.11 Program management plan for launch facility and launch vehicles

Regulation 2.11 sets out the information to be provided in the program management plan and addresses the applicant's approach to, and practices and procedures for, managing and operating the launch facility, including quality assurance, maintaining documents, and maintenance and servicing of the launch facility and launch vehicles. The information set out in the plan will be used to satisfy the Minister about criteria specified in paragraphs 18 (a) and 18 (d) of the Act, that is, the competency of the applicant to operate a launch facility and launch vehicles of that kind, and that the probability of the construction and operation of the launch facility causing substantial harm to public health or public safety or causing substantial damage to property is sufficiently low. The program management plan also requires the applicant to describe the arrangements to be put in place to ensure that the risk to third parties is as low as reasonably possible and to ensure that they satisfy the launch safety standards set out in the Flight Safety Code. This regulation also provides for the applicant to submit any additional information to build on the safety case associated with proposed space launch activities.

2.12 Flight test plan for conducting test flights

Regulation 2.12 specifies the information to be provided in the flight test plan, where a test flight (or test flight program) is to be conducted. The information set out in the plan is intended to satisfy the Minister about criteria specified in paragraphs 18 (a) and 18 (d) of the Act addressing the competency of the applicant and their employees to operate a launch facility and launch vehicles of that kind, and that the probability of the construction and operation of the launch facility causing substantial harm to public health or public safety or causing substantial damage to property is sufficiently low. It will also address the additional criterion specified for launch vehicles (under regulation 2.02), that the launch vehicle be expected to be reasonably safe for its intended purpose. This regulation has the effect that vehicles with these kinds of modifications are required to be flight tested to confirm the safety of their operation.

2.13 Technology security plan for launch facility and launch vehicles

Regulation 2.13 specifies the information to be provided in the technology security plan, including a description of the applicant's arrangements for safeguarding technology of the launch facility and relevant launch vehicles. The plan should also satisfy Australia's obligations under any relevant international agreements such as subsidiary agreements under the Inter-Government Agreement with Russia. The information set out in the plan is intended to satisfy the Minister about criteria specified in paragraph 18 (e) of the Act, that is, that the proposed activities do not represent a threat to Australia's national security, foreign policy or international obligations.

2.14 Emergency plan for launch facility and launch vehicles

Regulation 2.14 specifies the information to be provided in the emergency plan. The information set out in the plan is intended to satisfy the Minister about criteria specified in paragraphs 18 (a) and 18 (d) of the Act, that is, the competency of the applicant to operate a launch facility and launch vehicles, and that the probability of the construction and operation of the launch facility causing substantial harm to public health or public safety or causing substantial damage to property is sufficiently low.

The emergency plan must:

- identify potential emergency situations in relation to the operation of the facility and launch activities;

- describe actions to respond to these identified emergencies;

- identify authorities to be notified in the event of an emergency situation and describe co-ordination arrangements with emergency authorities;

- detail evacuation procedures;

- detail exercises to test the plan, for reviewing the plan, and reporting on the review to the Minister;

- describe procedures for identifying and locating wreckage (if any); and

- describe how the applicant proposes to meet any other legal obligations in respect of emergencies.

The plan needs to address emergencies that take place on or near the facility. "Near the facility" is determined as the radius of risk from an on-pad explosion. The radius of risk is established using the Risk Hazard Analysis Methodology set out in the Flight Safety Code. The broad focus of the emergency plan is intended to ensure that the people who are close to the facility are adequately protected in the event of an emergency.

2.15 Documents relating to the kind of launch vehicles

Regulation 2.15 specifies the material to be provided relating to the kind of launch vehicles proposed to be used at the facility. In particular, it seeks technical information about the launch vehicles, including technical specifications, details of manufacturers and their quality assurance arrangements, and qualification, acceptance and verification programs. The information is intended to satisfy the Minister about criteria specified in paragraph 18 (d) of the Act, that is, the probability of the construction and operation of the launch facility causing substantial harm to public health or public safety or causing substantial damage to property is sufficiently low. It will also serve to satisfy the new criterion set out in regulation 2.02, that is, that the vehicle is expected to be reasonably safe for its intended purpose. These documents are only required if a technical recognition agreement between Australia and the country manufacturing the vehicle is not in place. It is expected that this material will otherwise be provided under the auspices of such an agreement.

2.16 Outstanding acquittals plan

Regulation 2.16 specifies that the applicant provide a list of all approvals and authorities required under other Commonwealth, State or Territory legislation or local government requirements, and the strategy for obtaining the required approvals (including timing). The information set out in the plan is intended to satisfy the Minister about criteria specified in paragraph 18 (a) of the Act, that is, that the applicant is competent to operate a launch facility and launch vehicle. In seeking this material, the Commonwealth does not seek to duplicate the requirements of other Governments, but rather to recognise their requirements and approvals processes.

Division 2.8 Miscellaneous

2.17 Arrangements and procedures for environmental plan for launch facility

Regulation 2.17 specifies the information required in an environmental plan and must include the applicant's arrangements for:

- monitoring and mitigating any adverse effects of the construction or operation of the facility on the environment and for implementing the plan;

- reporting on the on the implementation of and reviewing the plan; and

- ensuring all environmental requirements under Australian law for protection of the environment are met.

The information in the plan is intended to satisfy the Minister about paragraph 18 (b) of the Act, that is, that the launch facility is constructed and operated in accordance with an environmental plan that has been approved by the Minister.

Regulation 2.17 will only apply where an environmental plan in relation to the construction and operation of the launch facility has been approved under another Australian law. Where such approvals have been granted and an environmental plan prepared, these approvals and plans will be used to satisfy the Minister about paragraph 18 (d) of the Act.

Part 3 Launch permits

Division 3.1 Criteria for launch permits

3.01 Criteria for launch permits

Regulation 3.01 prescribes, for the purposes of paragraph 26 (3) (h) of the Act, an additional criterion that the Minister must be satisfied about prior to grant of a launch permit. Subregulation 3.01 (2) specifies that the applicant must have an adequate environmental plan for conducting the launch or launches and any connected return. The environmental plan provided with a space licence covers the operation of the facility and the vehicle, however, matters relevant to the launch are to be addressed in the launch permit. This additional, new criterion thus fills a gap in the Act.

Division 3.2 Launch permit conditions

3.02 Standard launch permit conditions

Regulation 3.02 prescribes, for the purposes of paragraph 28 (1) (b) of the Act, other conditions that will apply to each launch permit. These conditions are in addition to those specified in section 29 of the Act and are as follows:

- meet all costs and expenses for an investigation into any accident or incident;

- respond to, and record their response to, directions given by the Launch Safety Officer, provide a copy of the record to the Minister, and retain the record for 7 years;

- prior to a launch, provide confirmation of launch details to the Minister;

- provide additional information to the Minister following a launch as required under Australia's international obligations and the Flight Safety Code;

- ensure the launch is conducted in accordance with the program management plan, technology security plan and flight safety plan approved by the Minister;

- ensure that each launch conforms to requirements of Australian environmental law;

- amend the plans so that they remain up-to-date; and

- provide copies of amendments to plans to the Minister, so that the Minister remains informed.

Subregulation 3.02 (2) specifies that the Minister may give directions to the holder requiring the revision of specified plans.

Division 3.3 Applications for grant of launch permits

Applications for grant of launch permits (Act s 32)

Regulation 3.03 specifies, for the purposes of section 32 of the Act, that an application for a launch permit must be made in accordance with Division 3.3 of the Regulations.

Form of application

Regulation 3.04 sets out the way in which an application for a launch permit must be made, the information which must be included in the application, and the details of documents that must be submitted in support of an application.

Subregulation 3.04 (1) specifies that the application must:

- be in writing and include contact details and information on the corporation;

- provide details of the date and time of the proposed launch;

- provide details of each payload to be carried, including proposed orbit and details of sensors attached to the payload (this information is required to satisfy national security concerns);

- provide details of the nominated trajectory of each space object to be launched;

- provide information required under the United Nations Registration Convention;

- provide details of the place of return of the space object (if applicable);

- provide details of the key contact person within the applicant's organisation able to deal with all matters in relation to the application. After hours contact details are required to facilitate the continuous assessment of the application and immediate resolution of urgent matters;

- provide information required by the Flight Safety Code; and

- provide documents as required under paragraph 3.04 (1) (l).

Subregulation 3.04 (2) specifies that the application and the accompanying documents must be lodged with the Department of Industry, Science and Resources.

Subregulation 3.04 (3) specifies that the documents must be provided in English and, if translated into English, must be accompanied by a certificate of verification by an accredited translator. Accredited translator is defined in Regulation 1.03.

Subregulation 3.04 (4) sets out the documents to be submitted by applicants in support of their application under paragraph 3.04 (1) (l). These include:

- evidence that the applicant is a corporation. This evidence is being sought in order to assist in the confirmation that the applicant is a foreign corporation or a trading or financial corporation formed within the limits of the Commonwealth as is required by paragraph 26 (3) (b) of the Act;

- details of the qualifications and experience of each person who will be responsible for specified key functions in relation to the proposed launch or connected return;

- a hazard analysis of the proposed launch and any connected return, carried out as described in the Risk Hazard Analysis Methodology of the Flight Safety Code, or by an alternative methodology agreed with the Minister, and in the second case, a written statement of verification by an independent third party;

- a statement of procedures in relation to the return of a space object, and of technical parameters related to the return;

- a statutory declaration by the CEO of the applicant confirming that the space object(s) does not contain a nuclear weapon or weapon of mass destruction;

- a program management plan for the launch;

- a technology security plan;

- if no other agency (Commonwealth, State/Territory or local) requires an environmental plan, an environmental plan containing the information set out in regulation 3.12 and an assessment of its adequacy prepared by an independent third party;

- a flight safety plan;

- any document specified in the Flight Safety Code which is required to be lodged with an application; and

- a written statement indicating whether the applicant proposes to satisfy the insurance requirements under paragraph 47 (2) (a) of the Act and an insurance compliance plan, or to show direct financial responsibility for the launch as described under paragraph 47 (2) (b) of the Act.

Division 3.4 Applications for transfer of launch permits

Applications for transfer of launch permits (Act s 32)

Regulation 3.05 specifies, for the purposes of section 32 of the Act, that an application for transfer of a launch permit must be made in accordance with Division 3.4 of the Regulations.

Form of application

Regulation 3.06 sets out the way in which an application for the transfer of a launch permit must be made, the information which must be included in the application, and the details of documents that must be submitted in support of an application. Whilst it is similar to the requirements set out in regulation 3.04, regulation 3.06 requires the applicant to provide reference numbers of the existing (transferor's) launch permit and of the transferee's space licence, and that the application must be signed by both the transferor and transferee. Regulation 3.06 further provides that the applicant need not provide certain plans if they propose to use the plans previously approved in the grant of the original launch permit, and they provide a written statement to that effect. Similarly, certain plans need not be provided if the details of the payload remain the same as in the original launch permit.

Division 3.5 Documents relevant to conditions and applications under this Part

Definitions for this Division

Regulation 3.07 sets out the meanings of specific terms used within Division 3.5 of the Regulations.

Program management plan for launches

Regulation 3.08 sets out the information to be provided in the program management plan for launches. The information in the plan is intended to satisfy the Minister about criteria specified in paragraphs 26 (3) (c) and 26 (3) (e) of the Act, that is, that the applicant is competent to carry out the proposed launch or return, and that the probability of the launch causing substantial harm to public health or public safety or causing substantial damage to property is sufficiently low. The program management plan required in this regulation differs from that for a space licence (regulation 2.11) in that it is in respect of the payload and the proposed launch rather than the facility and launch vehicle. Thus the two program management plans are complimentary.

The program management plan for launches must include:

- details of the applicant's approach to, and practices and procedures for, conducting the launch and connected return, including key technical procedures such as ignition sequence, countdown and vehicle arming and disarming. The process set out here relates to arrangements leading up to the launch of the vehicle and uses terminology which is widely used in, and readily understood by, the space industry;

- arrangements for reporting on the launch;

- ensuring launch related personnel are properly prepared for the launch, aware of their duties or functions in relation to the launch and of arrangements for responding to problems during the launch, and for testing the vehicles concerned, including identifying anomalies and failures;

- identification of hazardous ground operations associated with the launch, the applicants procedures to manage those operations;

- details of communication arrangements for the launch; and

- details of any change to the payload and the impact of such a change on the operation of the vehicle. Launch vehicles are designed to accommodate payloads or combinations of payloads of a particular size and weight. Where such dynamics might change there could be an impact on the operation of the launch vehicle. Thus details of these matters are required to ensure the continued safety of the proposed launch.

Technology security plan for launches

Regulation 3.09 specifies the information to be included in the technology security plan, including a description of the applicant's arrangements to safeguard any technology to be used in conducting the launch or return and any related activities, and to ensure that Australia's obligations under any relevant international agreements are satisfied. Matters to be addressed include preventing unauthorised people from having access to the technology and integrating the vehicle with the payload. The information set out in the plan is intended to satisfy the Minister under criteria specified in paragraph 26 (3) (g) of the Act, that is, that the launch proposed by the applicant does not represent a threat to Australia's national security, foreign policy or international obligations. It will also ensure that Australia meets its obligations arising from bilateral and multilateral agreements.

Flight safety plan for launches

Regulation 3.10 sets out the information required to be provided in the flight safety plan for launches. The information in the plan is intended to satisfy the Minister about criterion specified in paragraph 26 (3) (e) of the Act, that is, that the probability of the launch causing substantial harm to public health or public safety or causing substantial damage to property is sufficiently low.

The information supplied by the applicant must:

- demonstrate that the proposed launch and/or return will be conducted in accordance with the launch safety standards in the Flight Safety Code;

- detail arrangements to ensure compliance with the launch safety standards;

- detail the assumptions and data used in the hazard analysis for the launch and any connected return;

- detail arrangements for reporting to the Minister any changes in the parameters noted above or to arrangements for carrying out the launch and any connected return; and

- detail arrangements for reporting, following a launch, compliance with the launch safety standards set out in the Flight Safety Code and the assumptions and data previously provided.

The flight safety plan is a key aspect of the demonstration of the safety of the launch and, as such, has clear links to the Flight Safety Code.

Insurance Compliance Plan

Regulation 3.11 specifies the information required in the insurance compliance plan. The applicant must provide details of the proposed insurer, the party taking out the insurance, of all items and risks to be covered by the insured amount and a certificate from the insurer verifying their financial capacity to provide the specified insurance. The latter will be used to provide certainty that the insurer has the capacity to meet any liabilities arising out of a possible accident or incident. It will thus ensure, as far as possible, that all damage and loss to Australian nationals and foreign third parties will be met.

The information in the plan is intended to satisfy the Minister about the criterion specified in paragraph 26 (3) (d) of the Act, that the insurance/financial requirements of Division 7 of the Act will be satisfied.

Division 3.6 Miscellaneous

Arrangements and procedures for environmental plan for launches

Regulation 3.12 sets out the information required in an environmental plan. The environmental plan must include the applicant's arrangements for:

- managing the environmental impacts of each launch and return and for implementing the plan;

- reporting on the implementation of, and review of the plan; and

- ensuring all environmental requirements under Australian law are met.

The information in the plan is intended to satisfy the Minister about the additional criterion specified in subregulation 3.01 (2), that is, that the applicant has an adequate environmental plan for conducting the launch(es) and any connected return.

Regulation 3.12 will only apply where an environmental plan in relation to the construction and operation of the launch facility has been approved under another Australian law. Where such approvals have been granted and an environmental plan prepared, these approvals and plans will be used to satisfy the Minister about paragraph 18 (d) of the Act.

Part 4 Overseas launch certificates

An overseas launch certificate is required by Australian nationals with an ownership interest in a space object to be launched outside Australia, and facilitates the management of Australia's potential liability under the Liability Convention for any damage caused by such payloads.

Division 4.1 Criteria for overseas launch certificates

4.01 Criteria for overseas launch certificates

Regulation 4.01 prescribes, for the purposes of paragraph 35 (2) (d) of the Act, an additional criterion that must be satisfied before the Minister may grant an overseas launch certificate. Subregulation 4.01 (2) has the effect that no part of a space object or objects, in respect of which an applicant has an ownership interest, may contain a nuclear weapon or a weapon of mass destruction. This additional criterion is consistent with the criterion that applies to launches of payloads from Australia, authorised under a launch permit. The criterion also enables the Commonwealth to manage Australia's potential liability under the Liability Convention for damage caused by such weapons where they are launched by Australian nationals.

Division 4.2 Applications for grant of overseas launch certificates

Regulation 4.02 Applications for grant of overseas launch certificates (Act s 39)

Regulation 4.02 specifies, for the purposes of section 39 of the Act, that an application for the grant of an overseas launch certificate must be made in accordance with Division 4.2 of the Regulations.

Regulation 4.03 Form of application

Regulation 4.03 sets out matters that must be addressed in the application for an overseas launch certificate and the information that the applicant must provide in support of their application.

Subregulation 4.03 (1) specifies that the application must:

- be in writing and include contact details and personal identification information or, if the applicant is incorporated, information on the corporation;

- identify the launch facility, the location of the facility and the date when the facility commenced operations or is proposed to commence operations;

- for single launches, provide the date and time of the proposed launch, or if that information is not available at the time of the application, the period, which is to be no greater than 6 months, of the proposed launch. The provision of a window for the proposed launch or launches provides the flexibility for applicants to seek an overseas launch certificate at an early stage and in the absence of confirmation of the launch date. It also recognises that there is some movement in launch dates to accommodate the complexities and subsequent delays in manufacturing satellites;

- for a series of launches, provide the period, which is to be no greater than 6 months, of the proposed launches. The provision of a window for the proposed launch or launches provides the flexibility for applicants to seek an overseas launch certificate at an early stage and in the absence of confirmation of the launch date. It also recognises that there is some movement in launch dates to accommodate the complexities and subsequent delays in manufacturing satellites;

- specify the launch vehicle or vehicles on which the payload is proposed to be launched;

- specify each payload to be carried in which the applicant has an ownership interest;

- provide details of the proposed final orbit (if any) of each payload;

- provide details of all nominated trajectories or range of trajectories of each space object;

- include, in relation to each payload in respect of which the applicant has an ownership interest, information required under the Registration Convention;

- where a particular space object is proposed to be returned, specify the place or area for the return;

- provide details of the key contact within the applicant's organisation who is able to deal with all matters in relation to the application to facilitate the assessment of the application. After hours contacts are required in the event that urgent matters need to be addressed; and

- provide the documents as required under paragraph 4.03 (1) (k).

Subregulation 4.03 (2) specifies that the application and the accompanying documents must be lodged with the Department of Industry, Science and Resources.

Subregulation 4.03 (3) specifies that the documents must be provided in English and if translated into English must be accompanied by a certificate of verification by a suitably accredited translator. Accredited translator is defined in regulation 1.03.

Subregulation 4.03 (4) specifies the documents that are required under paragraph 4.03 (1) (k) as follows:

- all publicly available information about launches, or attempted launches, at the launch facility of launch vehicles of the kind proposed to be covered by the overseas launch certificate for the previous 5 years. This will assist the Minister in forming a view about the criterion set out in paragraph 35 (2) (b) of the Act, that is that the probability of the launch or launches causing substantial harm to public health or safety or causing substantial damage to property is sufficiently low;

- documentation relating to the applicant's organisational structure and the persons who would have duties and functions connected with the proposed launch or launches;

- a statement that sets out the details relating to any contractual arrangements between the applicant and any other persons directly connected with the launch or launches;

- enough information about the launch or launches to enable the Minister to make an informed decision as to the probability of the launch or launches causing substantial harm to public health or safety or causing substantial damage to property;

- in relation to each space object that is proposed to be launched, a statutory declaration that the space object in which the applicant has an ownership interest is not and does not contain a nuclear weapon or a weapon of mass destruction should be completed by the applicant, or if the applicant is incorporated by or under the law of the Commonwealth or of a State or Territory, by the person performing the duties of the chief executive officer in the applicant's organisation; and

- if any part of the space object contains fissionable material, a copy written approval from the Minister.

Division 4.3 Applications for transfer of overseas launch certificates

4.04 Applications for transfer of overseas launch certificates (Act s 39)

As provided in section 39 of the Act, regulation 4.04 specifies that an application for the transfer of an overseas launch certificate must be made in accordance with Division 4.3 of the Regulations.

4.05 Form of application

Regulation 4.05 sets out the matters that must be addressed in the application for a transfer of an overseas launch certificate and the information that the applicant must provide in support of their application. Regulation 4.05 includes requirements that are similar to the requirements set out in Regulation 4.03. The main differences between the application for a transfer and the application for a grant of a licence are that the application for a transfer:

- is not required to provide certain information if the information is the same as that most recently provided to the Minister and the transferee provides a written statement to that effect;

- must state the reference number of the overseas launch certificate that the transferee is seeking to obtain; and

- must be signed by both the proposed transferor and transferee.

Division 4.4 Documents relevant to applications under this Part

4.06 Definitions for this Division

Regulation 4.06 sets out the meanings of specific terms used in Division 4.4 of the Regulations.

4.07 Applicant's organisational structure

Regulation 4.07 sets out the information to be provided in respect of the applicant's organisational structure and details of key personnel directly connected to the launch, that must be provided with an application for grant of an overseas launch certificate and with an application for transfer of an overseas launch certificate. This material is required to satisfy the Minister about paragraph 35 (2) (c) of the Act, that is, that the proposed launch activity does not compromise Australia's national security or foreign policy or international obligations.

Part 5 Authorisation of return of overseas-launched space objects

5.01 Other criteria for authorising returns of overseas-launched space objects

Regulation 5.01 specifies an additional criterion to which the Minister must have regard when authorising the return of an overseas-launched space object, that is, that the person seeking to carry out the return must have all necessary environmental approvals, and an adequate environmental plan for the return or returns. This criterion is in addition to those matters set out in paragraph 43 (3) of the Act. This regulation limits details of information to be provided to those directly connected with the launch and payload. As such, it does not require information about broader personnel employed by the company.

Part 6 Exemption certificates

Paragraph 46 (2) of the Act provides that the Regulations may set out additional matters to which the Minister must have regard when deciding whether to issue an Exemption Certificate.

6.01 Matters to which the Minister must have regard

Regulation 6.01 sets out such matters as being:

- whether the exemption is to deal with an emergency situation, which will often be time-critical;

- the probability of the launch activity causing substantial harm to people or property. This requirement is consistent with criterion set out in the space licence, launch permit and the overseas launch certificate. It goes to the core of the safety of the proposed activity; and

- the probability of the Commonwealth being exposed to liability, under the Liability Convention or otherwise under international law, for damage caused by the conduct. Other approvals under the Act require insurance to be taken in respect of such liabilities or otherwise demonstrate financial capacity to fund such liabilities.

Part 7 Insurance/financial requirements

7.01 Direct financial responsibility

Regulation 7.01 prescribes, for the purposes of paragraph 47 (2) (b) of the Act, financial requirements that must be satisfied in order for the holder of a launch permit, overseas launch certificate or section 43 authorisation to show direct financial responsibility for a launch or return. The Regulation only applies to holders that are seeking to show direct financial responsibility for the launch or return. A holder is only required to show direct financial responsibility for the launch or return if the holder does not hold the amount of insurance required under subsection 48 (3) of the Act in respect of the launch or return.

Subregulation 7.01 (1) applies to the holder of a launch permit, an overseas launch certificate or a section 43 authorisation unless the holder is incorporated by or under a law of the Commonwealth or of a State or Territory and is a subsidiary of, or under the direction or financial control of, another body having legal personality - in which case subregulation 7.01 (3) applies.

Subregulation 7.01 (2) requires the holder to provide evidence that the holder has sufficient net assets to pay compensation for all damage caused to third parties by the launch or return. The subregulation also allows the holder to provide any other evidence that shows that the holder can meet the potential liability. To assist the Minister to form a view as to whether or not the holder is able to show direct financial responsibility for the launch or return, the subregulation requires the holder to provide any information requested by the Minister for the purpose of showing that the holder is able to pay compensation for all damage caused to third parties.

Subregulation 7.01 (3) applies where the holder of a launch permit, overseas launch certificate or section 43 authorisati1on is a company that is incorporated by or under a law of the Commonwealth or of a State or Territory and is a subsidiary of, or under the direction or financial control of another body having legal personality (the "other body"). The subregulation provides the holder with various options for showing direct financial responsibility for the launch or return. The holder may show evidence that it has sufficient net assets to pay compensation for all damage caused to third parties by the launch or return or may provide any other form of evidence of it's ability to pay such compensation. Alternatively, the holder may provide evidence that the holder and the other body have sufficient combined net assets to pay compensation for all damage caused to third parties by the launch or return. The subregulation also allows the holder to provide any other evidence that shows that the holder and the other body have the combined ability to pay such compensation. The holder may also provide evidence that the other body has sufficient net assets to pay compensation for all damage caused to third parties by the launch or return or any other evidence of the other body's ability to pay the compensation.

Where the holder seeks to show evidence of its own ability to pay the compensation under subregulation 7.01 (3), the holder will be required to provide any information requested by the Minister for the purpose of showing that the holder is able to pay compensation for all damage caused to third parties. Where the holder seeks to provide evidence of the other body's ability to pay (all or part) of the potential liability under subregulation 7.01 (3), the holder will be required to provide a guarantee from the other body, in respect of that part of the holder's obligations that the other body will be funding.

7.02 Maximum probable loss

Regulation 7.02 prescribes, for the purposes of paragraph 48 (3) (a) of the Act, the method to be used to determine the amount of maximum probable loss that may be incurred in respect of damage to third parties caused by a launch or return. The method to be used to determine the maximum probable loss for a launch or return requires adding the value of damage that may be incurred in respect of third party casualty losses, third party property losses, losses arising from environmental damage and loss of economic use. The meaning of each of these losses, and the method for calculating each type of loss will be set out in a document entitled Maximum Probable Loss Methodology and published by the Minister. Once the applicant has determined the maximum probable loss, the Act requires the applicant to take out insurance for that amount, as a minimum.

7.03 Different method of determining minimum amount of total insurance

Regulation 7.03 prescribes, for the purposes of paragraph 48 (3) (b) of the Act, the method to be used to determine the minimum amount of total insurance that may be obtained in respect of a launch authorised by an overseas launch certificate. The regulation does not apply in respect of a launch or return authorised by a launch permit or a return authorised under section 43 of the Act.

In order for a launch to be insured for the minimum amount of total insurance, an insurance analyst must be jointly appointed by the holder and the Minister. Regulation 7.03 requires the insurance analyst to be an insurer or actuary who is professionally qualified to assess the amount of liability that the Commonwealth might incur under the Liability Convention or otherwise under international law for any damage to third parties caused by the launch. The minimum amount of total insurance required will be the amount of liability that the insurance analyst assesses the Commonwealth might incur.

Part 8 Launch Safety Officer

8.01 Functions of Launch Safety Officer - notice of launches

Subregulation 8.01 (1) specifies, for the purposes of paragraph 51 (a) of the Act, that notice of a launch must be given as described in this regulation.

Subregulation 8.01 (2) provides that notice of a launch must be given by the Launch Safety Officer between 10 and 2 days prior to the launch to the people and authorities listed in subregulations (3) and (4), and to any community located within a 50km radius of the launch facility, via publication in all local newspapers and broadcast on all local radio stations serving the community. The 50 km limit for notifications was set on the basis that outside this area it can be expected that a large proportion of the launch vehicle's fuel load will have been expended and the vehicle will have left the atmosphere.

Subregulations 8.01 (3) and (4) specify a range of Commonwealth and State and Territory agencies, local government and emergency management and co-ordination authorities, air and space authorities and operators of ground-based public transport facilities to whom notice of a launch must be given.

Subregulation 8.01 (5) specifies an additional notification of an impending launch to be given by the Launch Safety Officer between 12 and 1 hours prior to a launch, to any community located within a 50km radius of the launch facility, via broadcast on all local radio stations serving the community. This is intended to provide confirmation of notification previously given in accordance with subregulation 8.01 (2).

8.02 Procedure for giving directions

Regulation 8.02 makes provision for the Launch Safety Officer to give directions according to the process set out in the Regulations and as provided for under paragraph 54 (1) (a) of the Act. It specifies that the Launch Safety officer for the facility must record each direction given under authority of the Act, and provide a copy of the direction to the Minister within 10 working days. This regulation is intended to enhance the accountability of the Launch Safety Officer and to ensure that the Minister has the capacity to closely scrutinise any directions given.

8.03 Procedure for complying with directions

Regulation 8.03 requires the person given a direction by the Launch Safety Officer to follow the procedures described, as provided for under paragraph 54 (1) (b) of the Act. It also specifies that the person to whom a direction is given by the Launch Safety Officer must, as soon as is practicable, record the action taken (or proposed to be taken) in response to the direction and provide a copy of the direction and the record to the holder of the space licence. This regulation ensures that person to whom the direction is given is held accountable for the response to that direction.

Part 9 Fees

Section 59 of the Act provides for the Regulations to set out fees for licences, certificates and permits issued under the Act. The space licensing regulator, the Space Licensing and Safety Office (SLASO) is required by Government to recover the costs it incurs in assessing applications for authorities under the Act. The fee structure detailed in these regulations was calculated by having regard to projected operating costs for the SLASO and projected demand for the SLASO services. Operating costs for the purposes of the calculation included assessment and review of applications (including contracted specialist services), processing application and authorities, managing the licensing regime, and monitoring the safety of launch activities by the Launch Safety Officer.

Regulations 9.02 - 9.05 each specify that the fee referred to is the price of taxable supply within the meaning of the GST Act.

9.01 Definitions

Regulation 9.01 sets out the meaning of terms used in Part 9 of the Regulations.

9.02 Fees in respect of launches authorised by launch permits

Regulation 9.02 sets the fee for a launch permit at $44,000, and at $11,000 for each subsequent launch in a series of launches, as provided for under subsection 59 (1) of the Act. The regulation further provides that the holder must pay the fee within 30 days following the grant of the permit, and for a series of launches, within 30 days of each subsequent authorised launch. The fee is payable in respect of both the grant and transfer of a launch permit.

9.03 Fees in respect of applications for overseas launch certificates

As provided under subsection 59 (2) of the Act, regulation 9.03 specifies the fee for an overseas launch certificate is $11,000, and is payable in respect of both the grant and transfer of the overseas launch certificate. The applicant must pay the fee at the time of application.

9.04 Fees in respect of applications for space licences

As provided under subsection 59 (3) of the Act, regulation 9.04 specifies the fee for a space licence is $300,000. The fee is in respect of both the grant and transfer of a space licence. The applicant may pay the fee at the time of application, or by instalment, with the first payment of $150,000 due at the time of application and the second payment of $150,000 within four months of submission of the application.

9.05 Fees in respect of applications for exemption certificates

As provided under subsection 59 (4) of the Act, regulation 9.05 specifies the fee for an exemption certificate is $11,000. This fee must be paid at the time of application.

9.06 Non-payment of fees

Regulation 9.06 specifies that the recovery of any unpaid or overdue fees may be through the courts.

Part 10 Investigation of accidents

Where dollar values are set in regulations 10.01 - 10.03, these have been based on those paid by the Administrative Appeals Tribunal, as detailed in Schedule 2 to Administrative Appeals Tribunal Regulations 1976.

10.01 Fees for persons assisting Investigator

Regulation 10.01 prescribes, for the purposes of subsection 90 (2) of the Act, the method of determining the fees that are to be paid to a person who is invited to assist an Investigator to perform the Investigator’s functions under Division 2 of Part 7 of the Act. The regulation is intended to ensure that a person who assists an Investigator is renumerated on the basis of his or her skills, knowledge and experience, taking into account the market value of the assistant’s particular expertise, and standard employment practices. The ability to compensate assistants on the basis of the market value of their expertise will, in turn, enable Investigators to engage a team of people who have the right mix of skills and expertise to properly investigate an accident or incident.

Subregulation 10.01 (1) sets out the method for calculating the fees payable to a person who is invited to assist an Investigator.

Paragraph 10.01 (1) (a) provides for a person, who has been invited to assist on the basis of his or her occupation and who is normally remunerated by wages or salary for practising his or her occupation, to be paid an amount that is equal to the daily rate of the person’s remuneration multiplied by the number of days of assistance provided. The method for determining the daily rate of the person’s remuneration is set out in subregulation 10.01 (2). The daily rate includes a component for superannuation and any annual allowances that are paid in addition to the person’s wages or salary.

Paragraph 10.01 (1) (b) provides for a person, who has been invited to assist on the basis of his or her occupation and who is normally remunerated by fees for practising his or her occupation, to be paid fees that equal the average hourly rate of fees charged by that person multiplied by the number of hours of assistance provided. The person's average hourly rate will be the average hourly rate charged by the person for the three previous services provided by that person in return for fees. The three previous services provided by the person must be comparable in nature to the assistance being given to the Investigator.

Paragraph 10.01 (1) (c) provides for remuneration of people who have not been invited to assist an Investigator on the basis of their occupation at a rate of $95 per day for each day on which they provide assistance. The value represents the lower limit set for witnesses by the Administrative Appeals Tribunal.

10.02 Allowances for persons assisting Investigator

Regulation 10.02 prescribes, for the purposes of subsection 90 (2) of the Act, how allowances for expenses that are to be paid to a person who is invited to assist an Investigator to perform the Investigator's functions under Division 2 of Part 7 of the Act will be determined. The regulation is intended to ensure that people who assist an Investigator receive appropriate reimbursement for the expenses they incur in the course of providing assistance.

Allowances for a person who has been invited to assist because of his or her occupation, and who is normally remunerated by wages or salary for practising his or her occupation, will be paid in accordance with the allowances that the person is entitled to in the course of performing his or her occupation.

Allowances for a person who has not been engaged on the basis of their occupation, will be paid in cases where the person is required to be absent overnight from his or her usual place of residence. A reasonable amount, as determined by the Investigator, will be paid for transport, meals and accommodation. This approach reflects that adopted by the Administrative Appeals Tribunal.

10.03 Fees and allowances for persons attending before Investigator

Regulation 10.03 prescribes, for the purposes of subsection 91 (7) of the Act, how fees and allowances for expenses that are to be paid to a person who attends before an Investigator will be determined. The intention of the regulation is to ensure that, when a person is required to attend before an Investigator o answer questions in relation to an investigation, the person is fairly compensated for the time he or she is required to spend in attendance.

Subregulation 10.03 (1) provides for payment of a person who is required to attend before an Investigator because of the person's professional, scientific or other special skill or knowledge. The subregulation is intended to allow for the payment of appropriate expenses to people who are required to attend before an Investigator as "expert witnesses" for the purposes of answering questions in relation to an investigation. Where such a person is normally remunerated by wages, salary or fees for practising his or her occupation, the person will be paid an amount that equals the wages, salary or fees that the person has lost as a result of being required to attend before the Investigator. Payment in cases where the person does not receive wages, salary or fees in the practice of his or her occupation will be an amount between $95 and $475 per day, as determined by the Investigator. The range of values is the same as that set for 'professional' witnesses not remunerated by wages, salary or fees by the Administrative Appeals Tribunal.

Subregulation 10.03 (2) applies to a person who is required to attend before an Investigator for reasons other than the person's professional, scientific or other special skill or knowledge. Such a person might be a witness to an accident or incident and might be required to attend before an Investigator to provide non-expert evidence in relation to what he or she witnessed. Where such a person is normally remunerated by wages, salary or fees for practising his or her occupation, the person will be paid an amount that equals the wages, salary or fees that the person has lost as a result of being required to attend before the Investigator. Payment in cases where the person does not receive wages, salary or fees in the practice of his or her occupation will be an amount between $54 and $89 per day, as determined by the Investigator. The range of values is the same as that set for 'non-professional' witnesses by the Administrative Appeals Tribunal.

Subregulation 10.03 (3) provides that, where a person is required to be absent overnight from his or her usual place of residence in order to attend before the Investigator, the person will be paid a reasonable amount, as determined by the Investigator, for transport, meals and accommodation. This approach reflects that adopted by the Administrative Appeals Tribunal.

Part 11 Miscellaneous

Delegation by Minister

Regulation 11.01 specifies that the Minister may delegate certain powers under the Regulations to the Director of the Space Licensing and Safety Office (SLASO), as provided for under section 104 of the Act. The SLASO is the body located within the Department of Industry, Science and Resources which will undertake the assessment of all applications and supporting documentation for licences, permits and certificates issued under the Act. It will make recommendations to the Minister about a range of matters, as appropriate.

The powers which can be delegated to the Director of the SLASO under regulation 11.01 are:

- as provided for under subparagraph 3.04 (4) (c) (i), for the purposes of considering an application for the grant of a launch permit, approving a person to carry out a hazard analysis according to the Risk Hazard Analysis Methodology in the Flight Safety Code;

- as provided for under subparagraph 3.04 (4) (c) (ii), for the purposes of considering an application for the grant of a launch permit, approving an alternative methodology to the Risk Hazard Analysis Methodology set out in the Flight Safety Code;

- as provided for under subparagraph 3.04 (4) (e) (ii), for the purposes of considering an application for the grant of a launch permit, approving a person to provide a written statement verifying the hazard analysis, prepared using an approved alternative methodology, meets the launch safety standards set out in the Flight Safety Code;

- as provided for under paragraph 3.04 (4) (j), for the purposes of considering an application for the grant of a launch permit, approving a person to provide a written statement confirming that, where launches are conducted according to the flight safety plan, such launches can satisfy the launch safety standards set out in the Flight Safety Code;

- as provided for under subparagraph 3.06 (4) (c) (i), for the purposes of considering an application for the transfer of a launch permit, approving a person to carry out a hazard analysis according to the Risk Hazard Analysis Methodology in the Flight Safety Code;

- as provided for under subparagraph 3.06 (4) (c) (ii), for the purposes of considering an application for the transfer of a launch permit, approving an alternative methodology to the Risk Hazard Analysis Methodology set out in the Flight Safety Code;

- as provided for under subparagraph 3.06 (4) (e) (ii), for the purposes of considering an application for the transfer of a launch permit, approving a person to provide a written statement verifying the hazard analysis, prepared using an approved alternative methodology, meets the launch safety standards set out in the Flight Safety Code;

• as provided for under paragraph 3.06 (4) (i), for the purposes of considering an application for the transfer of a launch permit, approving a person to provide a written statement confirming that, where launches are conducted according to the flight safety plan, such launches can satisfy the launch safety standards set out in the Flight Safety Code; and

• as provided for under paragraph 7.02 (1) (e), for the purposes of Maximum Probable Loss, approving a person to provide a written confirmation that the values obtained in paragraphs 7.02 (1) (a) to (d) have been worked out in accordance with the Maximum Probable Loss Methodology.

11.02 AAT review of decisions

Regulation 11.02 allows for review by the Administrative Appeals Tribunal of certain directions that may be given by the Minister under the Regulations and of certain decisions that may be made by an Investigator under the Regulations.

Review by the Administrative Appeals Tribunal may be sought in respect of a written direction given by the Minister to a holder of a space licence concerning the contents or revision of any of the plans referred to in subregulation 2.04 (6), that is, the program management plan, the flight test plan, the technology security plan and/or the environmental plan. Review by the Administrative Appeals Tribunal may also be sought in respect of a written direction given by the Minister to a holder of a launch permit about the contents or revision of any of the plans referred to in subregulation 3.02 (2), that is, the program management plan, the technology security plan, flight safety plan and/or the environmental plan.

Review by the Administrative Appeals Tribunal may be sought in respect of decisions by an Investigator concerning the allowances that are paid under paragraph 10.02 (b) to a person assisting an Investigator, the fees that are paid under paragraph 10.03 (1) (b) to a person who attends before an Investigator, the fees that are paid under paragraph 10.03 (2) (b) to a person who attends before an Investigator and the allowances that are paid under subregulation 10.03 (3) to a person who is required to attend before an Investigator.

Space Activities Regulations 2001

REGULATION IMPACT STATEMENT

ID No. 1009

Contents:

BACKGROUND

Australia offers a range of competitive advantages as a site for commercial space launch facilities. For example, it

- is located in the Asia-Pacific region, with close proximity to the equator, making it ideal for geostationary launches an important sector of the international launch market);

- has extensive low population land areas in which to site and operate launch facilities, limiting the likelihood of threat to public health and safety;

- has a relatively mild and benign climate which allows for year–round launch activities;

- has a well developed and sophisticated infrastructure, including telecommunications and transport facilities;

- has a stable economic and political environment;

- has a well educated, adaptable and technically proficient workforce;

- has respected non-proliferation credentials that facilitate access to critical technologies; and

- has expertise in general services to the space industry including financial, insurance, legal and consultancy services.

The Government has been working to create a competitive environment for space launch activities, including by enacting the *Space Activities Act 1998*. The Act establishes a legal basis for licensing commercial space launch facilities in Australia and licensing overseas launch activities by Australian nationals. The Act also provides for recovery operations, investigation procedures in the event of an accident and the payment of fees in respect of licences and permits. Further, the Act ensures that the Commonwealth meets its obligations under United Nations conventions on space activities, particularly those relating to liability and registration of space objects, by passing its obligations onto the commercial parties or requiring the provision of appropriate information.

In developing the licensing regime, the Commonwealth was keen to ensure that it both protect public health and safety and the environment, while at the same time ensuring that it was not so onerous as to act as a disincentive to the establishment of a viable space launch industry in Australia.

General outline of Australia's space regulatory regime

Under the Act, a person who wishes to construct and operate a commercial launch facility on Australian territory requires a space licence. In granting or transferring a space licence, the Minister for Industry, Science and Resources must be satisfied that the applicant is competent to operate a launch facility, has completed an environment management plan, that the probability of substantial harm to public health and safety is as low as reasonably possible, and that the proposed facility does not compromise national security or Australia's international or foreign policy obligations. Once granted a space licence, holders require a launch permit for each single launch or for a series of similar launches from their facility.

Applicants for a space licence are required to submit considerable information to satisfy the Minister about the matters set out above. The details of this material are set out in the *Space Activities Regulations 2001*. Underpinning this material is the requirement that applicants demonstrate that the facility and vehicle are safe for their intended purpose.

Other authorisations provided for under the Act include:

- an overseas launch certificate, required by Australian nationals with an ownership interest in a space object to be launched outside Australia;

- an authorisation of return of an overseas launched space object, required when a space object is to be returned to Australia; and

- an exemption certificate, exempting a person from the need to obtain a space licence, a launch permit or an Authorisation to return an Overseas Launch Space Object. It is expected that these will only be issued in exceptional circumstances, and where a strong case has been presented by the applicant.

Fees are payable in respect of applications for each of these instruments and are calculated on the basis of recovery of costs incurred by the Commonwealth in operating the regulatory regime.

The Act defines arrangements relating to liability to third parties for damage caused by space objects, requires permit holders to meet insurance or financial requirements against this liability, and caps the level of insurance required to be taken out. The Act also provides for a register of space objects by requesting all appropriate data from holders of instruments, thus meeting another key international obligation.

Provision is made for the delegation of the powers of the Minister under the Act to another person, review of a number of decisions by the Minister by the Administrative Appeals Tribunal and civil penalties (that is, fines) for breaching a number of the provisions of the Act.

The Act provides for a Launch Safety Officer to supervise the launch of vehicles on the site and to act on the authority of the Minister to ensure the safety of launch activities. The Act further provides for investigations into the circumstances surrounding any accidents or incidents, including the appointment of an investigator by the Minister. The investigator is empowered to investigate, invite assistance, gather information, and must report on the investigation to the Minister. The Act also provides for a range of offences in relation to investigations, provides for custody of a space object in relation to an investigation, suspension of the permit under which the launch was authorised in certain cases, and prohibits the disclosure of safety records furnished in the course of an investigation in civil circumstances.

Australia's international obligations in space

Australia is a signatory to following five United Nations conventions which impose a number of obligations on the Commonwealth:

- the Convention on International Liability for Damage Caused by Space Objects;

- the Convention on Registration of Objects Launched into Outer Space;

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

- the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies; and

- the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space.

The Liability Convention specifies that each launching State shall be liable to pay compensation for all harm or damage to foreign third parties caused by a space object that is launched from its territory or by space objects owned by Australian nationals launched from another country. Under the Act, the Commonwealth passes this liability onto the commercial parties by requiring launch permit holders to have adequate insurance coverage or to demonstrate financial responsibility for

launch activities, and by requiring overseas launch certificate holders to have insurance coverage up to an appropriate level.

Development of regulations to accompany the *Space Activities Act 1998*

The Government has established the Space Licensing and Safety Office (SLASO) to license space launch activities under the Act. The SLASO will receive and assess applications for authorisations under the Act, will advise the Minister on whether licenses and permits should be granted and will monitor launch activities. The SLASO staff will include a Launch Safety Officer and other personnel with appropriate expertise in technical matters, such as launch activities, launch site operations and safety matters. Consistent with Commonwealth requirements, the SLASO will recover the costs incurred in assessing applications for authorities and for monitoring of launch activity by the Launch Safety Officer from fees collected from applicants. As the fees are paid in respect of the assessment of an application, they are not refundable in the event an application is unsuccessful.

The Act was drafted on the basis that regulations would provide the details required to bring the space licensing and safety regime into effective operation. Parts 2, 3, 4, 7 and 8 of the Act provide triggers for regulations to expand and clarify the requirements of the Act (Attachment 1 to this statement provides a complete list of triggers for regulations under the Act).

Development of the regulations commenced shortly after the Act was passed by the Parliament, with the release in mid 1999 of a public discussion paper seeking comment on policy issues associated with the detail of the licensing regime. This document also set the foundation for the regulations. Following wide consultation with the space industry, the research community, other business groups, the community and State and Commonwealth Governments and authorities, drafting instructions for the regulations were developed. The drafting instructions were released to all interested parties for consideration and further consultations were held in June 2000. These discussions focused on the practical application of the regulatory regime.

Separate consultations were held on occupational health and safety issues with relevant State government authorities in 2000, on flight safety and other technical issues (in particular in respect of the Flight Safety Code) with State Governments and others affected parties in December 2000, March and June 2001, and with relevant Commonwealth Government agencies on a range of environmental, operational and national security issues over the period 1999 to 2001.

Following advice on a wide range of legal matters raised during the course of the consultations and preparation of the regulations, an exposure draft of the *Space Activities Regulations 2001* was released for comment in March 2001. Interested parties were consulted and the major issues raised at those consultations are detailed later in this statement.

The Department has sought to address all matters raised during this extensive round of consultations. Some have been accommodated through revisions to the proposed regulations while others require amendment to the Act (planned for late 2001). The development of supporting documents, such as the Flight Safety Code, also addresses a range of industry and community concerns. In addition, the proposed regulations will be supported by guidelines for industry, providing further explanatory material.

The development of Australia's space launch industry

Since the Act was passed, potential space launch proponents have been moving forward with the development of their proposals to establish commercial space launch facilities in Australia. Spaceports are major facilities requiring substantial planning and investment, and a number of these proponents were granted major project facilitation status by the Minister for Industry, Science and Resources. Others in the Australian space industry, such as scientific, educational and research

groups have moved forward with their projects to develop and launch small experimental payloads and rockets.

The Department has maintained close contact with the industry and, in late 2000, a number of groups indicated their intentions to apply for authorisations under the Act. The industry sought details of the proposed operation of the licensing process, and guidance about the nature and expected content of their applications and supporting documents.

An application for an exemption certificate was received in February 2001, an application for an overseas launch certificate was received in May 2001, and at least 2 commercial launch proponents have advised the Department of Industry, Science and Resources of their intention to submit applications for space licences from June 2001. In addition, a number of educational and scientific groups have launches of test rockets or satellites planned for late 2001 and early 2002 and will require permits or certificates under the Act. We note, however, that planned amendments to the Act will introduce a new certificate into the existing licensing regime to better cater to this type of launch activity.

The process of developing the regulations has proven to be both complex and lengthy, given:

- the few international models for regulation of the space launch industry from which experience and precedents could be drawn;

- Australia's limited experience with the emerging space industry;

- the need for highly technical documentation and assessments in respect of applications under the Act to minimise the risks to public health and safety from launch activities;

- the need to ensure that the interests of the affected local communities and other major industry sectors (in particular the petroleum industry) are protected;

- the need to find a balance between industry development and documentation to satisfy the Minister for Industry, Science and Resources about criteria set out in the Act; and

- recognition of the lengthy planning and investment phases for the space launch industry.

The development process for the regulations has also played a role in minimising negative public perceptions about the nature of space launch activities. The process has culminated in the development of the proposed *Space Activities Regulations 2001*, which are the subject of the remainder of this document.

PROBLEM

The key issue is how best to ensure an operationally effective space licensing and safety regime, as provided for under the Act. The space launch industry presents inherent risks to public health and safety, the consequences of which are potentially catastrophic. Keeping those risks to public health and safety, and to public and national assets to an acceptably low level is the responsibility of the Commonwealth Government.

Addressing these issues in an appropriately rigorous and transparent manner requires regulations to be made by executive government and cannot be resolved in the marketplace.

Implications of the absence of regulations for the operation of the space licensing and safety regime.

Operation of the *Space Activities Act 1998*

The Act currently exists in the absence of regulations, however, in anticipation of applications being received under the Act (as outlined above), the Department sought advice from the Australian Government Solicitor (AGS) on the scope of the operation of the Act in the absence of regulations. The AGS advised that the regime described by the Act can operate only to a limited extent, with the Minister able to grant certain authorisations provided for by the Act.

The limitation to granting these authorisations lies in the inability of applicants to satisfy provisions relating to the insurance and financial requirements of the Act in the absence of regulations.

The key purpose of the insurance/financial provisions is to transfer the Commonwealth's liability to pay compensation for harm of damage to foreign third parties to holders of the relevant authorisations under the Act. This liability is, however, limited and reverts to the Commonwealth where damage is above the insured amount.

The insurance requirements are described in section 48 of Act, and specify that determining the extent of insurance required will be through the method(s) set out in regulations. In the absence of regulations, and therefore a methodology, the Australian Government Solicitor advises that the amount of insurance to be taken out by the applicant cannot be determined. The alternative, demonstrating direct financial responsibility under section 47 (2) (b), similarly cannot be satisfied since the method applicants must use to demonstrate such responsibility is also required to be set out in regulations. Thus the authorisations in the Act which require satisfaction of the insurance/financial requirements as a pre-condition cannot be granted in the absence of regulations.

Other key areas of the regulatory regime which will not effectively operate in the absence of regulations include:

- Cost recovery - As noted above, the Government expects to recover the costs incurred in assessing applications for authorisations under the Act and monitoring launch activities from applicants. However, without regulations it will not be possible for the Government to charge fees to applicants to recover costs since the level of fees to be charged are required to be set out in regulations;

- Assistants to an investigator - an investigator appointed to investigate an accident will be unable to pay fees and allowances to any assistants, for example rocket engineers or personnel with expertise in launches and vehicles, and medical or legal professionals, since such fees and allowances are to be determined in regulations;

- No limit to liability - Sections 69 and 74 of the Act limit liability to pay compensation for damage caused by a licensed space object to the insured amount, as calculated using the Maximum Probable Loss Methodology. However, without regulations setting out the method to determine the insured amount, these limits to liability will not apply. In this case the holders of launch certificates would be liable to pay compensation for all damage to Australians and foreign nationals caused by the launch or return of a licensed space object.

In summary, the Department has been advised that:

- in the absence of regulations enabling applicants to satisfy insurance/financial requirements under the Act:

- it will be possible for the Minister to grant a space licence;

- it will not be possible for the Minister to grant a launch permit, an overseas launch certificate, nor authorise the return of an overseas launched space object; and

- there will be no limit on the liability incurred by responsible parties under sections 69 and 74 of the Act;

- it will not be possible for the Government to charge fees for the assessment of applications, or for inspection of the Register of Space Objects; and

- in the case of an investigation, the investigator could not pay assistants.

Impact on industry

Whilst it is expected that the Minister will be able to grant a space licence, the holder would not derive any significant benefit since the Minister cannot grant launch permits, and thus launches would not be possible.

Similarly, Australia's telecommunications carriers could not be granted an overseas launch certificate, thereby preventing them from commissioning the launch of satellites by overseas launch providers. The Australian space research and educational launch sector would also be prevented from launching test or research rockets either in Australia or overseas, depriving them of the opportunity to piggy-back on existing payloads at low or no cost.

The absence of regulations will also generate considerable uncertainty for operators of commercial space launch facilities as they would not be provided with the clear, concise framework and the details of documents needed to meet it's obligations under the *Space Activities Act 1998*. Without inclusion of the appropriate information in their initial application, applicants may be subject to lengthy turnaround times, ongoing requests for information and excessive paperwork in respect of those applications. This may result in the loss of commercial opportunities and thus impact on the industry's competitiveness in the international marketplace. The industry would also be forced to operate in an environment of uncertainty. Legal disputes may arise over any failure to be granted an authority, since it would be difficult to objectively demonstrate that identical standards had been applied to applications from different organisations.

The absence of regulations may also require the development of a space industry code of conduct, or other similar industry-based regulatory approach, upon which the safety regime would rely. This approach is unacceptable given the potential risks to the health and safety of the general community.

OBJECTIVES

a) What are the objectives of Government action?

The key objective of Government in making regulations is to bring the space licensing and safety regime outlined in the Act into full and effective operation. Further objectives are to:

- engender confidence in the licensing regime by the Australian public and business community through the rigour of the licensing process and the availability of public data;

- provide an open and transparent licensing regime; and

- facilitate long-term planning by commercial launch proponents on the basis of a stable and predictable regulatory regime.

Achieving these objectives will, in turn, facilitate the achievement of a range of the Government's policy objectives for the space industry including:

- ensuring the protection of public health, safety and property;

- ensuring that Australia's foreign policy, national security and international obligations are met;

- ensuring that any potential damage to the environment is minimised;

- recovering the costs incurred by the Space Licensing and Safety Office in assessing applications for authorities under the Act, and for monitoring launch activities;

- assisting the Australian space launch industry to become established and internationally competitive;

- ensuring that the regulatory framework and assessment processes are efficient and transparent;

- expand education and training opportunities in space related industries; and

- engendering confidence in the international marketplace about the safety of proposed launches from Australia.

However, development of the space industry in Australia will assist the Government to achieve some of its broader goals, such as:

- developing new, high technology industries which create jobs, contribute to GDP and create flow-on opportunities for local communities, manufacturing and support organisations;

- facilitating regional development;

- facilitating new tourism opportunities; and

- building on existing research, development and scientific capabilities.

b) Is there a regulation/policy currently in place? Who administers it?

The *Space Activities Act 1998* provides the legislative basis for the development of regulations. The Act is administered by the Department of Industry, Science and Resources.

OPTIONS

Develop explicit Government regulations to accompany the *Space Activities Act 1998*.

Explicit government regulation refers to primary or subordinate legislation and has three main characteristics: it attempts to change behaviour of groups or individuals by detailing how regulated entities should act; it generally relies on government inspectors and/or monitoring to detect non-compliance; and it imposes punitive sanctions if the regulations are not complied with. This approach establishes clear and standardised rules and can be successful for addressing well-defined and stable problems.

Explicit government regulation also offers a high level of certainty, industry-wide coverage, and greater effectiveness compared to other forms of regulation because of the availability of legal sanctions. This form of regulation is subject to scrutiny through the parliamentary process.

For the legal reasons outlined in the Problem section above, explicit government regulations are required to fully implement the Government's regulatory regime for space activities. Other types of regulatory options, such as self regulation or industry codes of practice, are not appropriate due to the potential risk to public health and safety presented by the space launch industry, the requirement for uniform application of standards across the industry, and the need for legal sanctions where specified standards are not met.

Regulations in respect of the *Space Activities Act 1998* should enable the full implementation of the regulatory regime established under the Act, and should include methods referred to in the Act. The regulations would also provide legally supported guidance to applicants regarding the type of documents which are required to be provided in support of applications for authorisations under the Act.

Providing this clear guidance will serve to minimise requests for additional information and assessment times, thus reducing compliance costs for business. It is also preferable that the contents of documents required by the regulations not place excessive burdens on business, but rather seek information similar to that required for good industry practice.

Explicit regulations will ensure that all companies involved in the Australian space launch industry are aware of their legal obligations concerning the disclosure of information, safety practices and liability. The regulations will thus assist the competitiveness of the Australian industry by ensuring a high level of objective safety standards.

The breadth of subject matter covered in the Act requires that regulations be both detailed and comprehensive. Two documents will be incorporated by reference in the regulations and will set out technical standards and methods that must be complied with. This material will have the same legal status as the regulations.

- The Flight Safety Code (the Code) sets out the launch safety standards with which applicants and operators of space launch facilities must comply when planning and executing space launch activities. The Code was developed to reflect Australian conditions by experts in the field and sets out safety standards which ensure the risk to the public arising from space operations are as low as possible. The Code includes a Risk Hazard Analysis Methodology, standards for designated assets, drop zones and landing sites, and additional protection against the risks posed by new launch vehicles and new launch operations.

The safety standards imposed by the Flight Safety Code require that each individual be exposed to a maximum risk of no greater than 1 in 10 million per launch of sustaining an injury requiring hospital care or causing death. The maximum combined risk to the general public per launch can be no greater than 1 in 10 thousand.

- The Maximum Probable Loss Methodology, which sets out the method to be used by applicants in calculating the minimum insurance levels in respect of licensed launch activities. The methodology specifies the required approach to risk based hazard analysis of events which are sufficiently likely to occur such that insurance (or equivalent) is required to cover their consequences. The MPL is focused on events which may cause injury to people or property, or have environmental consequences.

The probability that losses resulting from an accident would exceed the value calculated using the MPL methodology is no higher than 1 in 10 million.

There are two approaches to explicit regulation which could usefully be applied to the space industry.

Option 1 - Regulation by performance-based standards

This type of regulation sets performance benchmarks and allows companies to determine the most appropriate operational methods to meet those benchmarks. The proposed *Space Activities Regulations 2001* regulates through performance-based standards in two ways:

1) Documentary requirements: The proposed regulations describe, at a broad level, the content of documents required to accompany an application for an authority under the Act. This will facilitate consistency in assessment of all applications against the criteria set out in the Act.

Applicants will be able to structure the contents of these documents to suit their circumstances and operations, whilst still meeting the standards prescribed in the regulations. The documents provided by applicants should also draw on material already prepared for their internal purposes or for compliance with other State, Territory or Commonwealth legislation.

For example, section 18 (b) of the Act requires that the Minister be satisfied that an adequate environmental plan has been made. The proposed regulations specify a requirement for an environmental management plan. Applicants may also have to comply with State, Territory and Commonwealth environment legislation, and to prepare environmental management plan(s) for this purpose. The proposed regulations adopt a performance based standards approach which provides some flexibility for the Minister to consider plans prepared in accordance with these other legislative requirements, rather than requiring a separate environmental management plan to be prepared.

2) Technical requirements: while setting general standards, such as the launch vehicle must reasonably expected to be safe and effective for its intended purpose, the proposed performance-based regulations offer flexibility to applicants about the most appropriate methods or procedures to demonstrate that the launch vehicle meets the standard. There are, however, a small number of regulations which refer to specific technical requirements in respect of protecting public health and safety. For example, the Flight Safety Code sets out the launch safety standards which must be met for each launch. While the method of calculation of the risk of casualties is highly prescriptive, and the standard is not negotiable, applicants can adjust operational approaches (such as planned trajectories) to increase the safety margins within their operations, and ensure they meet the launch safety standards. In addition, an alternative risk hazard analysis methodology can be agreed between the Minister and the launch proponent.

Further, the SLASO is required by Government to recover the costs it incurs in assessing applications for authorities under the Act. The proposed fee structure was calculated having regard to projected operating costs for the SLASO and projected demand for the SLASO services. Operating costs for the purposes of the calculation included assessment and review of applications (including contracted specialist services), processing application and authorities, managing the licensing regime, and monitoring the safety of launch activities by the Launch Safety Officer. As application fees are paid in respect of the assessment of an application, and, with the exception of a launch permit, they are not refundable in the event an application is unsuccessful. The proposed application fees are:

$300,000 for a space licence;

$44,000 for a launch permit (and $11,000 for each subsequent launch of a series);

$11,000 for an overseas launch certificate; and

$11,000 for an exemption certificate.

Option 2 Prescriptive Regulation

Prescriptive regulations set out in exhaustive detail each specified performance standard to be met. Prescriptive regulations might include, for example detailed technical specifications for each system for each rocket type, the requirements for specific fuel storage, delivery and monitoring systems and for the large number of other systems required to safely operate a space launch facility. Developing such a system would be extremely difficult and costly for industry, while monitoring such a prescriptive system would be highly onerous for Government.

The ongoing costs would also be high for industry, both in terms of compliance and direct regulatory charges, since the regulator will operate on a cost recovery basis. In addition, technology security agreements with other governments and launch vehicle providers may limit the availability of the detailed technical specifications which would be required to document compliance with a highly prescriptive regime, particularly with regard to sensitive technology. Amendments to the regulations would be required to accommodate advances in technology. Thus, such an approach is likely to stifle innovation and the adoption of rapidly developing technology, a hallmark of the space industry.

IMPACT ANALYSIS (COSTS AND BENEFITS) OF EACH OPTION

Impact group identification:

Groups affected by regulations pursuant to the *Space Activities Act 1998* include:

Consumers:

- Australian and international companies wishing to purchase launch services from the space launch industry in Australia, including telecommunications, information technology, environment and navigational organisations.

Business:

- The space industry - companies and consortia proposing to establish and operate commercial space launch facilities in Australia; companies involved with the import of rockets (at this stage from Russia and United States) and the payloads; local industry which supplies technology, expertise, management services, hardware and software, maintenance of the facility, and other expertise specifically related to the construction and operation of launch facilities; research organisations and universities with a focus in space development, companies seeking permits for overseas launch/return activities; consultants preparing material to accompany applications (technical and large insurance providers);

- The petroleum industry, in particular those operating within the vicinity of, or close to, the flight paths of the proposed launch facilities on Christmas Island, and the Australian Petroleum Production and Exploration Association (APPEA);

- Other businesses or industries affected by the operations of launch facilities or by launches; and

- Local or small business operating in the vicinity of proposed launch facilities.

Government:

- Commonwealth agencies which are required to contribute to the assessment of applications under the Act, such as the Department of Foreign Affairs and Trade, the Department of Defence and the Attorney-General's Department;

- Commonwealth Departments with whose requirements launch proponents must comply, such as the Civil Aviation Safety Authority, the Australian Communications Authority and the Australian Safety Authority;

- State and Territory Governments and their agencies which will be involved in considering various operational approvals under their relevant legislation, including those agencies responsible for issuing permits for the transport and handling of hazardous goods, and those agencies responsible for the provision of emergency services; and

- Local governments who have a role in issuing building, planning and occupancy approvals and licences.

Community:

- Community groups located close to proposed facility locations of Christmas Island and Woomera; and

- The general public.

Option 1 - Regulation by performance based standards

Costs and Benefits to Consumers

Costs to consumers include:

- No specific costs to consumers could be identified.

Benefits to consumers include:

- Reduction in costs of launch services due to highly competitive local presence in the international market (in comparison with costs under a prescriptive regime); and

• Confidence in the rigorous safety regime, seeking to minimise the risk of failure of the launch vehicle.

Costs and Benefits to Business

Costs to space industry include:

• Liability for accidents and incidents is shifted from Commonwealth to industry (in contrast to most other countries, and thus imposes costs on operators);

• Costs for the operation of the regulator borne by the industry (the fees schedule is set out above); and

• Costs of non-compliance, that is, penalties under the Act, and suspension or revocation of the space licence, launch permit or overseas launch certificate.

Benefits to space industry include:

• Flexibility in approaches to meet safety and other criteria set out in the Act by providing for procedures and methods which are most appropriate to the applicant and their facility;

• Costs of compliance minimised through capacity to adapt documentation required for applications from normal operating documentation, and the regulator recognising approvals issued under other Commonwealth, State and local government legislation and rules;

• Increased competitiveness of Australian operators in the international marketplace due to clarity of government process, and enhanced perceptions of a safe operating environment;

• Facilitates rapid adoption of new technology in the industry; and

• Confidence of other industry sectors that their interests are appropriately protected.

Costs and Benefits to Government

Costs and Benefits to Government

Costs to Government include:

• Industry perception that the Government's regulatory requirements are onerous, particularly relating to the transfer of liability obligations, which is not a feature of the regulatory regimes of other countries, and the volume of documentation required in support of an application for a licence or permit.

Benefits to Government include:

• Economic returns to Australia expected through the establishment of a viable space launch industry;

• Streamlined licensing system minimises costs of operating the licensing regime;

• Minimisation of administrative costs associated with the ongoing monitoring of appropriateness of regulations, given they are flexible and will not be substantially affected by advances in technology;

- Minimisation of regulatory costs as they are recovered from the industry;

- Effective transfer of liability to the industry; and

- This proposed regulatory approach minimises duplication between Commonwealth and State requirements.

Costs and Benefits to the Community

Costs to community include:

- While minimising the risk, the stringent flight safety standards can not really eliminate the risk to the public from launch activities.

The benefits to community include:

- Minimisation of indirect cost through taxation to pay for the government assessment of applications and monitoring of the regulatory regime;

- Economic returns to Australia expected through the establishment of a viable space launch industry (including lower taxes, increased employment and increased GDP); and

- Benefits to the local and regional communities through increased employment and economic opportunities, particularly during the construction phase.

In summary, the performance based standards approach proposed under option 1 offers:

- In comparison to no regulations, increased safety to the public through implementation of the safety standards embodied in the Flight Safety Code, and increased costs to the industry and government, balanced by a clear regulatory framework which is designed to facilitate industry development.

- In comparison to a prescriptive approach, at least equal safety standards, decreased costs to industry and government, a less onerous regulatory burden on operators, and greater flexibility to accommodate advances in technology.

Option 2 Prescriptive Regulation

<u>Costs and Benefits to Consumers</u>

Costs to consumers include:

- Higher cost of compliance to launch providers (compared to option 1 or no formal regulatory regime) passed on to consumers as increased costs of launch services; and

- Increased costs of launch services due to limited capacity by launch providers to adopt new technology due to highly prescriptive approach. The previous regulatory approach in the USA was highly prescriptive and was found to impede the development of new technology and increase costs to industry. The USA has now moved to a more flexible approach.

The benefits to consumers include:

- No benefits are foreseen from this approach.

Costs and Benefits to Industry

Costs to space industry include:

- Liability for accidents and incidents is shifted from Commonwealth to industry (in contrast to most other countries, and thus imposes costs on operators);

- High cost of compliance through limited capacity to adapt documentation required for applications from normal operating documentation, and the need to prepare additional detailed documentation solely for regulatory purposes;

- Increased costs of operation of the regulator borne by the industry (higher than in Option 1 due to greater monitoring costs);

- Lengthened processing/approvals times as a result of requirements for extreme levels of verification;

- Inflexible legislative requirements reduce operational flexibility and capacity to rapidly adopt new technology;

- Single, specified approach to system design and performance to meet criteria in the Act until regulations are amended to recognise each advance in technology; and

- Reduced international competitiveness due to increased operational costs and prevention of rapid adoption of new technology in the industry and higher charges for launch services.

Benefits to industry include:

- No benefits are foreseen from this approach.

<u>Costs and Benefits to Government</u>

Costs to Government include:

- High resource cost in the ongoing monitoring of regulations for relevance to industry operations;

- High resource implications of ongoing amendment of the regulations to reflect the changing technology of the industry;

- Viability of Australian space launch industry at risk due to decreased international competitiveness. Also at risk are economic returns such as employment, revenue and GDP opportunities, and potential returns on the Government's expenditure on industry facilitation; and

- Industries concern that the Government's regulatory requirements are highly onerous, in particular, the transfer of liability obligations to industry, which is not a feature of the regulatory regimes of other countries.

Benefits to Government include:

- Provides basis to satisfy the community about risk to safety posed by space launch activities;

- Effective transfer of liability to the industry; and

- Economic returns to Australia are expected through the establishment of a space launch industry.

<u>Costs and Benefits to Community</u>

Costs to the community include:

- Costs of supporting the regulatory process will be high since prescriptive standards will require ongoing updating to reflect technology advance (that is, amendment to the regulations through parliamentary process); and

- While minimising the risk, the stringent flight safety standards can not eliminate all risk

The benefits to the community include:

- Possibly increased community confidence in a highly prescriptive licensing regime

In summary, the prescriptive regulatory approach explored under option 2 offers:

- In comparison to no regulations, increased safety to the public through implementation of the launch safety standards embodied in the Flight Safety Code, increased costs to the industry and government and a clear regulatory framework which imposes a high level of technical control over launch operators which can be expected to limit (if not forestall) industry development.

- In comparison to a performance based standards approach (option 1), identical safety standards, increased costs to the industry and government and a clear regulatory framework which imposes a high level of technical control over launch operators and can be expected to limit (if not forestall) industry development.

CONSULTATION

a) Consultation process

Consultations which occurred prior to the release of the exposure draft are described in the background section of this document. The exposure draft of the Space Activities Regulations was

released in March 2001. Interested parties were consulted, and the major issues raised at those consultations are detailed below. Where practicable, the Department sought to address the issues raised by revising the proposed regulations. A number of matters were raised which can only be addressed through amendments to the Act, planned for late 2001.

b) Who are the main affected parties?

Up to four launch facilities have been under consideration for development in Australia. Of these, one is located at Christmas Island and three at Woomera in South Australia. In addition to the impact groups (consumer, business and government) identified above, the following groups were consulted:

<u>Government</u>

- In addition to the Commonwealth agencies identified above under impact groups, discussions were held with the Department of Prime Minister and Cabinet, Environment Australia, the Australian Communications Authority, the Australian Customs Service, the National Occupational Health and Safety Commission, and the Bureau of Air Safety Investigations;

- A Working Group on national security, which comprises some of the Commonwealth agencies identified above, was convened to discuss their information requirements to facilitate the assessment of foreign policy and national security implications of applications for authorities under the Act, and to develop a process to consider such applications;

- The State and Territory Governments, in particular those in Western Australia, South Australia and Queensland, where launch facilities are or have been proposed;

- The local governments of Christmas Island, Gladstone and Woomera;

- International Governments in relation to liability issues under the United Nations conventions on space activities;

- Governments of the USA and Russia regarding bilateral agreements in respect of technology to be used at the proposed space launch facilities, and protection of the security of that technology; and

- The Department has also received extensive advice from the Office of Legislative Drafting, the Attorney Generals Department, the Australian Government Solicitor, ISR Legal Section, and ISR Cabinet Liaison.

Business:

- Space industry technical consultants; and

- Experts in insurance, financial, legal and environmental matters.

Community:

- Representatives of local communities in Woomera, Gladstone and Christmas Island; and

- Environmental groups.

c) What are the views of the consulted parties?

Following consultations on the Issues Paper, there was general agreement by all parties that regulations to accompany the Act were necessary to effectively implement the safety and licensing regime provided for by the Act.

Participants were supportive of the need for the licensing regime, but considered that the regime should not render the emerging Australian industry uncompetitive relative to other participants in

the global market. They also expressed a desire for clear guidance in terms of the information they would be required to provide when applying for an authority. The overarching view of industry was that they required certainty and confidence that the rules would not change over time. Such confidence would, in turn, flow to investors and potential customers, and contribute to the viability of the emerging Australian commercial space industry.

The industry was also persuasive in its argument that the regulations offer some flexibility, for example in the contents of the documents applicants will provide with an application for a licence or permit, to facilitate the rapid take-up of new technologies. This is especially significant given the technical nature of the industry, the continual emergence of new technologies and improvements to existing vehicles, strong competitiveness amongst launch proponents and the time associated with changes to government regulation.

Industry was appreciative of the extensive consultations being held and provided a range of useful suggestions which will assist the practical operation of the regulations. They were also satisfied with the content of the drafting instructions, and subsequently, the exposure draft of the regulations. Key issues raised in the consultations on the exposure draft are detailed below.

Key Issues raised in consultations on the exposure draft:

1. Approval by the Minister of plans submitted in support of applications for permits and licences

The regulatory regime requires applicants for a space licence and a launch permit to provide a range of plans addressing operational, security and safety matters with their application for a licence or permit under the Act. In the exposure draft of the regulations, these plans, if acceptable, were proposed to become 'approved plans' (that is, approved by the Minister for the purposes of the Act) and holders of the relevant permit would be required to comply with these approved plans.

Industry, other Commonwealth agencies, and local and State or Territory Governments sought clarification of the term 'approved' in relation to these plans. In particular, they sought clarification of the term relative to other approvals of the same or similar plans required under other Commonwealth Acts, or the legislation of other jurisdictions (for example, with respect to environment or building approvals).

The broader issue underlying these concerns relates to the interaction of the *Space Activities Act 1998* with other pieces of Commonwealth and State Legislation. The Act is not intended to override other legislation, rather it works alongside relevant Acts and in some cases, such as environmental approvals, draws on approvals given under other legislative instruments. To this end, Section 105 of the Act is clear that the Act is intended to operate alongside other Commonwealth legislative instruments. The drafters of both the Act and the proposed regulations were careful to ensure that the operation of the space regulatory regime would not nullify any requirements of State, Territory or local government.

Nevertheless, allaying these concerns was important to ensure confidence in the operation of the regime. The Department thus amended the exposure draft to remove reference to 'approved (by the Minister)' in respect of those plans which may be approved under other legislative instruments, in particular, for Emergency and Environment plans. In addition, the guidelines to accompany the proposed regulations will include an extensive listing of other legislative requirements which may need to be satisfied by the applicant.

2. Environmental Approvals

Early on in the process of developing regulations to accompany the *Space Activities Act 1998,* clarification was sought by the space industry about Commonwealth environmental obligations

under *Environment Protection (Impact of Proposals) Act 1974* (EPIP Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Some launch projects were designated under the old EPIP Act while others will be designated under the new EPBC Act.

Proponents of projects already designated under the EPIP Act were concerned that they not be required to go through another environmental assessment and approvals process under the EPBC Act simply due to the Space Activities Regulations.

To address these concerns, the Department sought legal advice about the scope of application of the EPBC Act, the obligations it imposes and levels of environmental assessment. The Department also sought a comparison of key aspects of the old and new legislation, particularly as they relate to approvals, powers of Ministers and levels of assessment. In addition, the Department held extensive discussions with Environment Australia. As a result, the proposed regulations accommodate both the old and new environmental legislation, without imposing additional obligations. The Regulator will recognise environment approvals and accept an environmental plan approved under either Commonwealth environment Act or State/Territory environment legislation.

3. Details on construction workers.

The exposure draft of the regulations required that applicants for a space licence provide details of the working and residential history of all employees, including those on site at a launch facility during its construction, those who will work on site at the facility once it is operational, and those engaged during launch operations. The industry expressed concerns that provision of this information in respect of individuals involved in the construction of the facility is both onerous and unnecessary.

These provisions were to contribute to an assessment of the national security and foreign policy implications of the proposed space launch facility, consistent with the Act. However, given that construction of a launch facility is similar to that of any other major industrial facility and that the construction process does not involve any sensitive material, the Department accepted industry's position and the draft regulations were revised to omit these requirements for details of personnel involved in the construction of the facility.

4. Information required to accompany an application for a space licence.

In respect of the information required to accompany an application for a space licence, the space industry advised that not all the information requested would be available at the time of application. They sought some flexibility between the degree of detail to be provided at the time of application and that to be provided following the grant of a space licence (as a condition of the space licence). The information and documentation required at the time of application, as detailed in the exposure draft of the regulations, represented the minimum level of detail required to satisfy the Minister that all the criteria specified in the Act had been met prior to grant of a space licence. Thus the department has been unable to accommodate industry's position on this issue, and the required information must be submitted with the space licence application.

We accept, however, that further information will be submitted following the grant of the space licence and the regulations make allowance for this.

A similar concern was expressed in relation to both the launch permit and overseas launch certificate, particularly the availability of trajectories and information required for Article IV of the Registration Convention at the time of application. Accepting that some of these details are not known until just before launch, the Department revised the draft regulations for the launch permit and overseas launch certificate to make provision for a range of trajectories, and to seek only information which is known at the time of application about that part of the space object in which the applicant has an ownership interest.

The need for applicants to provide confirmation of the final trajectory and confirm other details for the Registration Convention has been included as a standard condition of the launch permit in the proposed regulations. A similar requirement will be imposed as a condition on each overseas launch certificate issued, as the Act makes no provision for standard conditions to be applied to overseas launch certificates.

5. Statutory Declaration on Weapons of Mass Destruction

The exposure draft of the regulations required that each director of the applicant company provide a statutory declaration verifying that the relevant space object(s) does not contain a nuclear weapon or weapons of mass destruction. Comments from industry indicated that the requirement to obtain a statutory declaration from each Director was very onerous, particularly where Directors reside overseas. Accordingly, the Department has revised the draft regulations in the launch permit and overseas launch certificate to require such a statutory declaration from only the CEO of the applicant.

6. Overseas Launch Certificates

The exposure draft contained provisions requiring applicants for an overseas launch certificate (OLC) to provide extensive details of the launch history of the launch facility the applicant proposes will launch their payload. This information was requested to satisfy the Minister that the proposed launch poses a sufficiently low risk to public health or safety or of damage to property, and that the launch poses no threat to national security or international obligations. Industry presented a strong case to the Department that the launch provider (an overseas company or Government) was unlikely to make available to the applicant (the payload owner) the level of detail sought, and that they would therefore be unable to provide this information in support of their application. In response, the Department has limited this requirement in the proposed regulations to publicly available information.

Industry also had concerns with regard to the degree of detail required about the applicant's management personnel for the grant of an OLC. These provisions have been revised to focus on personnel employed by the applicant and working in that part of the applicant's organisational structure relevant to the overseas launch.

7. Fees and charges

The space industry is aware that cost recovery will apply to operations of the Space Licensing and Safety Office (SLASO). Industry was generally comfortable with the principle of cost recovery and the proposed fee schedule.

However, the space scientific and research community sought some mitigation of the fees in respect of their launch activities, given that they do not operate on a commercial basis and do not derive revenue from these activities. The argument for a two tiered fees structure to accommodate non-commercial launch activities has merit, however the Act does not make provision for such an arrangement. The Department is considering options to address the concerns of this group of the Australian space industry, such as amending to the Act.

Concerns were also expressed about the uncapped cost of investigations into accidents, which are to be borne by the launch proponent. There is no provision in the Act to limit the cost of investigations through regulation. The Department is currently considering other options to limit the costs of accident investigations, including amending the Act.

8. Documents incorporated by reference to the Regulations

There were separate consultations on the technical documents incorporated by reference into the Regulations.

- The Flight Safety Code. The petroleum industry, in particular, was concerned that the Code afforded sufficient protection to high value assets, such as oil production platforms. The Code has been modified to clarify the launch safety standards which will apply to such facilities.

- The Maximum Probable Loss Methodology was finalised after consultation with the launch proponents, APPEA and the State Governments.

CONCLUSION AND RECOMMENDED OPTION

Regulations pursuant to the *Space Activities Act 1998* will facilitate development of the space launch industry in Australia, while, at the same time, ensuring that a rigorous safety regime is in place to protect safety of the public and provide protection to high value economic assets. Regulations will also provide certainty to industry about the long term regulatory environment. The Commonwealth's liability under international obligations will be substantially transferred onto operators in the space launch industry.

It is intended that the regulations should enhance the competitiveness of the Australian space launch industry by clarifying the requirements of applicants under the Act, and establish a rigorous safety framework, both of which will contribute to international consumer confidence.

Option 1 - Regulation by performance based standards

This option imposes the minimum costs and complexity for both government and industry and thus represents the optimum approach for enhancing the competitiveness of the emerging Australian space launch industry. At the same time, it implements a rigorous safety regime. The proposed *Space Activities Regulations 2001* have been drafted to offer maximum flexibility to industry to supply the information in support of their application and demonstrate they have met (and continue to meet) the rigorous safety standards expected by the Australian public and to which the Commonwealth has committed.

Option 2 Prescriptive Regulation

This option would impose high ongoing implementation and monitoring costs for both industry and government, and will require ongoing regulatory amendments to accommodate technological changes. This option would impede the capacity of the Australian space launch industry to be innovative and to adopt new technology, and would severely limit the industry's competitiveness. In summary, regulations of this type would represent no net benefit to the community in respect of safety standards, yet would pose a risk to the establishment and international competitiveness of this emerging industry.

IMPLEMENTATION AND REVIEW

The proposed *Space Activities Regulations 2001* will be considered by Executive Council in late June and, subject to its agreement, will come into effect in early July. Following tabling in the Federal Parliament, the Regulations will be subject to a disallowance period of 15 sitting days, which will expire in late September. The Regulations will be administered primarily by the SLASO, within the Department of Industry, Science and Resources, and will be supported by guidelines to applicants providing extensive details on the contents of each of the documents required under the Regulations. An internal procedures manual for use by the SLASO is being prepared in concert with the guidelines, and consistent with the proposed regulations. It is expected that some of the powers of the Minister under the Act will be delegated (as provided under Section 104) to the Director of SLASO when a permanent appointment is made.

The Department proposes to review the Regulations approximately 12 months after they come into effect, or as needed following planned amendments to the Act. The SLASO and the Department plans to review the fees schedule approximately two years after implementation.

ATTACHMENT 1

TRIGGERS FOR REGULATIONS PROVIDED FOR BY THE ACT

PART 2

Section 8 - Definition of *liability period*, *responsible party* and *related party*

PART 3

DIVISION 2 - SPACE LICENCE

Section 18 (f) and (g) - allow for the regulations to prescribe any other criteria in relation to the launch facility and launch vehicle.

Section 20 (c) - allow the regulations to specify any other condition under which a space licence may be issued

Section 23 - allows the regulations to describe the process by which the grant or transfer of a space licence may be made

DIVISION 3 - LAUNCH PERMIT

Section 26 (h) - states that the regulations may prescribe any criteria necessary for the Minister to grant a launch permit

Section 28 (1) (b) and (2) - allow the regulations to extend upon the conditions of the launch permit stated in section 29, and, allow the regulations to stipulate the events which may dictate the duration of the launch permit.

Section 32 - the regulations may state the process by which the grant of or a transfer of the launch permit must be made

DIVISION 4 - OVERSEAS LAUNCH CERTIFICATE

Section 35 (2) (d) - Under the Act, the regulations may prescribe any criteria which the Minister will need to consider before granting an overseas launch certificate.

Section 39 - an application for the grant or transfer of an overseas launch certificate must be made in accordance with the regulations.

DIVISION 5 - AUTHORISATION OF RETURN OF OVERSEAS-LAUNCHED SPACE OBJECTS

Section 43 (3) (f) - the regulations may prescribe any other criteria not stated in section 43, which must be satisfied before an authorisation of return can be provided.

DIVISION 6 - EXEMPTION CERTIFICATES

Section 46 (2) - the regulations may set out matters to which the Minister must have regard in deciding whether to issue an exemption certificate.

DIVISION 7 - INSURANCE/FINANCIAL REQUIREMENTS

Section 47 (2) (b) - states that the holder of the launch permit, overseas launch certificate or authorisation of return of overseas-launched space object satisfies the insurance/financial requirements if they have, in accordance with the regulations, shown direct financial responsibility for the launch or return.

Section 48 (3) (a) and (b) - state that the total insurance for each launch or return must be for an amount no less than the maximum probable loss, calculated by the method stipulated in the regulations, or by the method stipulated in the regulations for this particular section.

DIVISION 8 - LAUNCH SAFETY OFFICER

Section 51(a) - the launch safety officer must ensure that notice is given, in accordance with the regulations, of launches conducted at the launch facility

Section 54 (1) - the regulations may prescribe the procedure to be followed by the launch safety officer and any person to whom the launch safety officer gives direction

Section 54 (2) - the regulations may prescribe penalties for contravening the regulations made in section 54 (1).

DIVISION 9 - ADMINISTRATION ETC

Section 59 - Under section 59, the regulations will state the fee relating to the launch authorised by a launch permit, overseas launch certificate, space licence, exemption certificate and inspection, as well as set the amount of the fee or the timing of payment of the fee.

PART 4

DIVISION ONE - SCOPE OF PART

Section 65 - the regulations may make provision to the waiver of some or all of the rights of persons connected with a launch or return, and of their employees, contractors and subcontractors, to seek compensation for damage to which this Part applies.

PART 7

DIVISION 2 - INVESTIGATIONS

Section 90 (2) states that a person who assists the accident/incident Investigator is entitled to be paid fees and expenses, as determined under the regulations.

PART 8

Section 110 - states that the Governor-General may make regulations prescribing matters which are required or permitted by the Act to be prescribed, or, necessary or convenient for carrying out or giving effect to this Act.

ATTACHMENT 2

OUTLINE OF THE PROPOSED *SPACE ACTIVITIES REGULATIONS 2001*

Part 3 of the *Space Activities Act 1998* (the Act) triggers regulations which are in respect of the licensing of certain space activities, and comprise several divisions and parts.

- Part 1 of the proposed regulations (regulations 1.01 to 1.03) deals with preliminary matters.

- Part 2 of the proposed regulations (regulations 2.01 to 2.17) discusses the grant and transfer of a space licence, which is required before a launch facility can commence operation in Australia. The Regulations specify additional criteria about which the Minister must be satisfied before granting a space licence, set out additional conditions which will apply to a space licence, outline the form of application for the grant or transfer of a space licence and describe supporting documentation to be provided to satisfy the Minister that all criteria set out in the Act and regulations have been met. The additional criteria set out in the Regulations address the safety and effectiveness of both the launch site and launch vehicle for their intended purposes. Conditions that attach to a space licence relate to the maintenance of and compliance with a number of plans, and the maintenance and update of personnel records. The required documentation includes information regarding the launch site and launch vehicle(s), documentation relating to the applicant's organisational structure and financial standing, details on each person to work at the facility and on the launch, a program management plan, a flight test plan, a technology security plan, an emergency plan, an environmental plan (and/or relevant environmental approvals), and technical documentation relating to the launch vehicle. A number of these plans or statements must be accompanied by verification by an independent third party.

- Part 3 of the proposed regulations (regulations 3.01 to 3.12) discusses the grant or transfer of a launch permit, which is required before a launch can take place from Australia. The Regulations specify an additional criterion about which the Minister must be satisfied before granting a launch permit, set out additional conditions which will apply to a launch permit, outline the form of application for the grant or transfer of a launch permit, and describe the supporting documentation to be provided to satisfy the Minister that all criteria set out in the Act and regulations have been met. The additional criterion set out in the Regulations addresses the need for an adequate environmental plan. Additional conditions that are attached to a launch permit include maintenance of and compliance with a number of plans and the Flight Safety Code, confirmation of all launch and return details, the need to meet the costs of any accident investigation, and the need to record actions taken in response to directions given by the Launch Safety Officer. The documentation to be provided includes details about the proposed launch and payload, details of any return, details of personnel to be responsible for or involved in the launch, a hazard analysis of the proposed launch or return along with an independent verification of the hazard analysis, details of any recovery, confirmation that the space object does not contain a weapon of mass destruction, a program management plan, a technology security plan, an environmental plan or relevant approvals, a flight safety plan, and an insurance compliance plan. The Flight Safety Code is a document incorporated by reference into the Regulations and will be published by the Department in June 2001.

- Part 4 of the proposed regulations (regulations 4.01 to 4.07) discusses the grant or transfer of an overseas launch certificate, which is required by Australians undertaking an overseas launch or procuring the launch of a space object in which they have an ownership interest from a launch facility outside Australia. The Regulations specify an additional criterion on which the Minister must be satisfied before granting an overseas launch certificate, specify conditions which will apply to an overseas launch certificate, outline the form of application for the grant or transfer of an overseas launch certificate and describe supporting documentation to be provided to satisfy the Minister that all criteria set out in the Act and regulations have been met. The additional criterion set out in the Regulations addresses the need to ensure that the space object does not contain a weapon of mass destruction. The required documentation includes details of the launch and payload, a description of the applicant's organisational structure and key personnel directly connected with the launch, details of previous launches from the facility and using the type of launch vehicle, details of contractual arrangements, evidence to demonstrate that the launch is unlikely to cause substantial harm to public health or safety or damage to property, and confirmation that the space object does not contain a nuclear weapon or a weapon of mass destruction.

- Part 5 of the proposed regulations (regulation 5.01) provides for the authorisation of the return of overseas-launched space objects to Australian territory. The Regulation specifies an additional criterion about which the Minister must be satisfied before authorising the return of overseas-launched space objects. The additional criterion requires the applicant to have an adequate environmental plan, or other relevant environmental approvals. Requests for supporting documentation will be included in administrative guidelines.

- Part 6 of the proposed regulations (regulation 6.01) sets out the matters to which the Minister must have regard in deciding whether to exempt a person from the requirement to obtain a space licence, launch permit or overseas launch certificate. Such matters include whether the activity is an emergency situation, might cause substantial harm to public health and safety or damage to property, or might expose the Commonwealth to liability for damage. Requests for supporting documentation will be included in administrative guidelines.

- Part 7 of the proposed regulations (regulation 7.01 to 7.03) sets out the insurance and financial requirements for launch permits, overseas launch certificates and Section 43 (of the Act) authorisations. The financial requirements may be satisfied in two ways, either through the demonstration of direct financial responsibility (separately identified for individuals and subsidiary companies), or by demonstrating that the minimum required insurance has been taken out. Minimum insurance must be calculated using the Maximum Probable Loss Methodology. A different method for minimum insurance requirements for overseas launch certificates is also set out in this part. The Maximum Probable Loss Methodology is a document incorporated by reference in the Regulations and will be published by the Department in June 2001.

- Part 8 of the proposed regulations (regulations 8.01 to 8.03) addresses the functions of the Launch Safety Officer. The Regulations describe arrangements for the Launch Safety Officer to give notice to the local community and all relevant Commonwealth, State/Territory, local, emergency management and international authorities of an impending launch. The Regulations also set out procedures for giving and complying with directions, and outline penalties for permit holders who do not comply with directions given by the Launch Safety Officer.

- Part 9 of the proposed regulations (regulations 9.01 to 9.06) sets out details of the fees payable for each of the authorities issued under the Act, and the timetable for such payments.

- Part 10 of the proposed regulations (regulations 10.01 to 10.03) addresses the investigation of accidents, and describes the fees and allowances to be paid to people who assist the investigator, or are a witness for an investigation.

- Part 11 of the proposed regulations (regulations 11.01 and 11.02) provides for certain powers of the Minister to be delegated and for certain matters to be reviewed by the Administrative Appeals Tribunal.

Documents Incorporated by Reference

COMMONWEALTH OF AUSTRALIA
SPACE LICENSING AND SAFETY OFFICE

MAXIMUM PROBABLE LOSS METHODOLOGY

Department of Industry,

Science and Resources

18 June, 2001

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ISR - 2001/150**Table of Contents**

I. INTRODUCTION

This document presents a methodology for determining risks and potential consequences due to mishaps that may occur during phases of flight of space vehicles beginning at ignition and ending either on orbit, impact or recovery. Insurance requirements remain in place for the entire flight's liability period and are not phase specific. The methodology here presented is termed the maximum probable loss (MPL) methodology.

Maximum probable loss (MPL) is a risk-based analysis that yields the greatest potential loss, for bodily injuries and property damages, that can reasonably be expected to occur as a result of licensed launch or re-entry activities. MPL measures probabilities, not possibilities, to identify events that are sufficiently probable as to warrant financial responsibility to cover their consequences. Insurance requirements are established at a level that provides financial protection against the consequences of events that are deemed sufficiently probable under the regulations. A probability threshold is used as a quantitative measure to distinguish unlikely events from those which are sufficiently probable to warrant inclusion in the MPL. Loss or damage that has a likelihood of occurring that is equal to or greater than the probability threshold is considered probable. The probability that losses would exceed the MPL is no higher than the probability threshold, which in this study is set at 10^{-7} (1 in 10 million).

While the MPL methodology may be used for any type of loss category, for our purposes, the methodology is focused on risks to third parties, to their persons and their property, and deals with the potential casualties, property damage, loss of use and environmental damage that may result from each phase of flight.

The MPL methodology developed for the Commonwealth of Australia includes indirect, consequential damages, such as the ones that could result from loss-of-supply claims by customers, or ones that could result from a consequential oil spill, or other consequential losses, if the probability that such an accident may happen is within the 10^{-7} probability threshold. This is done because it can reasonably be anticipated that parties suffering consequential losses (loss of business and profits *etc.*) will include the estimated value of these consequential losses in calculating the amount of the insurance claim as well as the amount of damages in any legal claim. Most courts will give recognition to such consequential damages.

The MPL methodology requires the applicant to develop or estimate the debris catalogue and resulting casualty areas for its vehicle at different flight phases and requires the applicant to calculate impact probabilities during different phases of flight. The applicant will develop the debris casualty areas, calculations for probability of impact and casualty expectation in accordance with the "Risk Hazard Analysis" in the current version of the SLASO Flight Safety Code.

One aspect of the MPL methodology is based on a bounding approach, which removes most of the need for substantial mathematical analyses and computations. Experience shows that operating at remote probabilities with minimal empirical data is problematic and often results in conclusions too speculative to justify a rigorous mathematical risk assessment. Similarly, breaking the flight into many discrete phases does not aid the MPL process; in fact, it would needlessly encumber that process. Instead, the MPL methodology looks at gross phases, such as uprange in the launch area and downrange during overflight for expendable launch vehicles.

The bounding approach identifies an area around the planned flight trajectory that will contain all the impacts from debris resulting from any possible mishap, to within the 10^{-7} probability threshold. In other words, the probability of any debris falling outside the identified area is smaller, or more remote, than the 10^{-7} threshold. Within the identified area the MPL methodology determines a monetary value to the estimated casualties, the loss of property, the loss of use, and the environmental damages and clean up costs that are expected. In particular, casualties are assigned a monetary value, which for the current study has been set at 5,000,000 A$ per person. The property damages that may result from the impact of the vehicle or its debris are characterized as a percentage of the value of the estimated casualties. For the current study, the percentage has been set at 50 percent. Loss of use is estimated using the gross domestic product per capita and the estimated number of casualties. Finally, in the bounding approach, environmental damages and clean-up costs are estimated as 100,000 A$.

In addition to the bounding approach, if there is a particular high-valued third-party asset individually facing an impact probability at or within the 10^{-7} threshold, the MPL methodology calls for an accurate engineering evaluation of the likely property losses due to impact, plus the resulting loss of use, environmental damage and cleanup costs associated with the high-valued facility, including consequential losses. A high-value asset is one for which the MPL values for property damage, loss of use and environmental damage and clean-up calculated using the gross bounding approach described above would be inappropriate.

The property loss, loss of use and environmental damage and clean up MPL values will be the higher of the values obtained using the gross bounding approach and the high-value facility assessment.

The MPL methodology here presented is not dependent on the specific characteristics of the launch or re-entry site or approach corridors. It is dependent only on the risks posed to people and property within the probability threshold area. Thus, whether launching from Woomera, Christmas Island, Gladstone or elsewhere, this methodology may be used. The risk to the public, which is based on the development of probability threshold areas for launch, re-entry and recovery vehicles, includes the fact that SLASO will impose a phased reliability assessment approach for permit applicants, assigning only low vehicle reliability values initially, followed by higher reliability values as flight data support over the course of time.

The MPL methodology requires the permit applicant to develop the break-up model, the debris catalogue and resulting Casualty Areas (CA) for its vehicle at different flight phases and requires the applicant to develop probability of impact contours during different phases of flight.

II. METHODOLOGY

The steps comprised in the generalized MPL process are described in this section and presented graphically in Figure 1. The complete MPL process can be thought of as being a two-phase process. During the first phase the applicant needs to gather all the relevant information to develop the MPL evaluation, while during the second phase the applicant integrates all the information and then develops the MPL recommendations.

Intermediate MPL recommendations are made separately for third-party losses for each phase of flight. Even when the determination is made that the risk to the public, during any given phase, is beyond the accepted probability threshold, the applicant will want to so state to avoid the appearance of having skipped or overlooked an aspect of the analysis.

The final MPL recommendation will be the highest values obtained for all the phases of flight considered.

(a) Phase One: Gather information

(b) Phase Two: MPL recommendations

Figure 1: MPL process flow chart

PHASE ONE

Step 1: Complete preparatory risk analysis by developing the vehicle break-up model, the lethal debris area, the Casualty Area, and the impact probability threshold contours for uprange, downrange, re-entry and recovery as appropriate. Impact probability threshold contours

define areas that that will contain all the impacts from debris resulting from any possible mishap, to within the 10^{-7} probability threshold. In other words, the probability of any debris falling outside the identified area is smaller, or more remote, than the 10^{-7} threshold. The area defined by a probability threshold contour is called a probability threshold area.

In addition to gathering all the relevant information the applicant must be aware of and follow the recommendations contained in the "Risk Hazard Analysis" in the SLASO Flight Safety Code.

Step 2: Understand and describe the sequence of operations for the entire mission and the presence of hazardous materials, including any of the payload.

Step 3: Determine the third-party persons and property at risk. For uprange and downrange activities, including ELV launches, re-entry vehicle and RLV recovery, the area within the probability threshold contour is at risk.

Step 4: Describe typical accident scenarios. Reviewing the accident scenarios is a way for the applicant to understand the different failures and the likely consequences. Because no engineered system can reasonably guarantee a probability of failure lower than the 10^{-7} threshold, it is safe to conclude that the MPL will be based on an assumption that a mishap *will* occur and *will* place people and property at risk.

Step 5: Use the "Risk Hazard Analysis" in the SLASO Flight Safety Code to compute the probability of expected casualties and damages resulting from off-range launch vehicles.

PHASE TWO

Step 6: Screen out scenarios with low losses relative to other scenarios within each phase of flight. In other words, find the risk drivers for each phase of flight and don't spend time assessing losses from minor mishaps or in less densely populated areas. Low-loss scenarios are screened out, provided that there is no significant chance of aggregated losses from more than one scenario, in situations where scenarios are not mutually exclusive.

Step 7: Determine MPL for third-party loss scenarios. For the case where multiple, mutually exclusive losses might occur, investigate each scenario to determine the one that results in the greatest loss within the probability threshold.

To develop third-party casualty losses during flight, overlay the CA over the highest homogeneous population density in the area of concern.

To estimate third-party property loss, use whichever of the following two methods provides the higher MPL value:

1. 50 percent of the third-party casualty MPL recommendation; or

2. If there is a particular high-valued third-party asset individually facing an impact probability of 10^{-7} or greater, make an accurate engineering evaluation of the property losses due to those impacts.

To estimate the costs associated with environmental damage and clean-up, use whichever of the following two methods provides the higher MPL value:

1. 100,000 A$; or

2. If there is a particular high-valued third-party asset individually facing an impact probability of 10^{-7} or greater, make an accurate engineering evaluation of the cost associated

with restoring the environment to the condition which would have existed if that damage had not occurred.

Note that the environmental and clean-up costs include the cost of consequential damages that might result from the mishap such as an oil spill, if there is a probability 10^{-7} or higher that such an accident may happen. The consequential damages include direct effects of the debris impact on the facility and the consequences of those impacts on the facility, such as may result from the release from the facility of toxic, hazardous, or polluting materials.

For loss of use, the applicant will use whichever value is higher:

1. That obtained by multiplying the per capita Gross Domestic Product (GDP) of the country where casualties may result by the number of casualties estimated; or

2. If there is a particular high-valued third-party asset individually facing an impact probability of 10^{-7} or greater, make an accurate evaluation of the loss-of-use value.

Note that the loss-of-use costs include the cost of consequential damages that might result from the mishap such as loss of supply to customers, if there is a probability of 10^{-7} or higher that such an accident may happen.

Step 8: Select the MPL recommendation for third-party losses. The loss estimates made in Step 7 associated with the various accidents within the probability threshold area constitute the listing of losses from which the applicant must choose.

III. MPL PROBABILITY THRESHOLD

The insurance requirements that the permit applicant has to satisfy must protect third-party persons and properties from all events that are reasonably likely to occur.

A probability threshold is used as a quantitative measure to distinguish unlikely events from those which are sufficiently likely to warrant inclusion in the MPL.

Once the threshold probability is selected, the largest accident that could occur within that threshold is determined. The threshold chosen is such that the probability of all larger and more costly accidents is less than (more remote than) that threshold. With the threshold approach, insurance requirements can be expected to cover the full costs of all accidents within the selected threshold. The threshold for this study is set at a probability of 10^{-7} (1 in 10 million).

In order to establish the people and the properties exposed to risk from the launch vehicle, the bounding approach identifies an area around the planned flight trajectory that will contain all the impacts from debris resulting from any possible mishap, to within the 10^{-7} probability threshold. This is called the probability threshold area. In other words, the probability of any debris falling outside the probability threshold area is smaller (more remote) than the 10^{-7} threshold. The probability threshold contour is a line on a map that is the boundary of the probability threshold area.

Once the probability threshold area is obtained, the MPL bounding approach is made more conservative by assuming that there is an equally likely chance for an accident to occur anywhere inside the probability threshold contour. However, accident scenarios involving particular high-value facilities within the probability threshold area are only considered if there is a probability of 10^{-7} or higher of such specific accidents occurring.

IV. ESTIMATE OF COSTS FOR LOSSES

CASUALTIES

A monetary value of 5,000,000 A$ is attributed to each casualty. The MPL approach is conservative in not differentiating between fatalities and serious injuries, treating both as casualties.

PROPERTY

The applicant will estimate loss of property value by whichever of the following two methods provides the higher MPL value.

The loss of property value given by the MPL for uprange or launch area third-party property is half of the value of the estimated casualties. For downrange property losses or losses due to re-entry mishaps, property losses are believed to be sufficiently small so as to be included in whatever MPL value results from possible casualties. The downrange approach may be used from the time during the launch when the Risk Hazard Analysis supports the assumption that the property losses are sufficiently small so as to be included in whatever MPL value results from possible casualties, taking account of rounding. This typically occurs during upper stage flight.

If high-valued third-party assets are found to be within the probability threshold area during any phase of the mission, and if they are individually at risk at or within the 10^{-7} probability threshold, loss estimates to such high-value assets must be made by sound engineering and financial estimates that specifically address the facility's construction and the explosive or impact effects of the vehicle or its debris. Even though a rigorous evaluation should always be conducted for high-valued assets, the MPL methodology offers a way of obtaining an approximate value for such facilities.

To use the approximate method to calculate the loss of property to a high-valued asset, start by locating the assets with the highest value that lie within the probability threshold area and identify those individually at risk at within the 10^{-7} probability threshold. Calculate the portion of the assets that would be damaged by the impact of the vehicle or its debris, if the probability of such an impact is within the 10^{-7} probability threshold. The damaged portion of the asset is found by multiplying the asset area, or footprint, by the ratio given by the CA and the impact area (IA). The meaning of CA and IA is explained in more detail in a following section. The CA value for a specific vehicle has to be provided by the permit applicant while the numerical value of IA, when it is not given by the applicant, can be assumed to be 3,450,000 m^2 or one nautical mile squared in the uprange area. As explained later, the IA expands during flight, reaching exceedingly large dimensions later in flight. The loss of property is then given by multiplying the damaged surface of the facility by the property value per metre squared of the asset.

LOSS OF USE

The applicant will estimate the loss-of-use value by whichever of the following two methods provides the higher MPL value.

First, base the loss-of-use estimate of the expected impact of a mishap on the Gross Domestic Product (GDP) for the region at risk by multiplying the expected casualties by the per capita GDP of the region at risk. The MPL analyst should determine the average per capita GDP for the risk area in question.

If high-valued third-party assets are found to be within the probability threshold area and individually at risk within the 10^{-7} probability threshold, during any phase of the mission, loss-of-use estimates to such high-value assets must be based on engineering and financial estimates that specifically address the facility's construction and the explosive or impact effects of the vehicle or its debris, and the loss-of-use consequences which could reasonably be expected to ensue from such damage.

Note that, unlike the U.S. practice, the loss-of-use costs in the MPL methodology developed for the Commonwealth of Australia include indirect damages, such as the ones that could result from loss-of-supply claims by customers or other indirect consequential losses, if there is a probability higher than 10^{-7} that such an accident may happen. This is done because it can reasonably be anticipated that parties suffering consequential losses (loss of business and profits etc.) will include the estimated value of these consequential losses in calculating the amount of the insurance claim as well as the amount of damages in any legal claim. Most courts will give recognition to such consequential damages.

Second, even though a rigorous evaluation should always be conducted for high-valued assets, the MPL methodology offers a way of obtaining an approximate loss-of-use value for such facilities, following the same line of thought as for the determination of loss of property. The damaged property area already found in the calculation of the loss of property should be multiplied by the annual revenue per metre squared generated by the facility. If it can be determined that the time needed to restore the facility to the condition which would have existed if the damaged had not occurred is different from one year, the total amount of the loss of use has to be adjusted accordingly.

ENVIRONMENTAL DAMAGE AND CLEAN-UP COSTS

The applicant will estimate the cost associated with environmental damage and clean up by whichever of the following two methods provides the highest MPL value:

1. 100,000 A$; or

2. If there is a particular high-valued third-party asset individually facing an impact probability of 10^{-7} or greater, make an accurate evaluation of the cost associated with restoring the environment to the condition which would have existed if that damage had not occurred.

Note that, unlike the U.S. practice, the environmental damages and clean-up costs in the MPL methodology developed for the Commonwealth of Australia include indirect damages, such as the ones that could be originated by an oil spill caused by an impacting vehicle, if there is a probability higher than 10^{-7} that such an accident may happen. This is done because, it can reasonably be anticipated that parties suffering consequential losses (loss of business and profits, environmental cleanup etc.) will include the estimated value of these consequential losses in calculating the amount of the insurance claim as well as the amount of damages in any legal claim. Most courts will give recognition to such consequential damages.

EXAMPLE OF PROPERTY LOSS, LOSS-OF-USE AND CLEAN-UP COST

MPL evaluations using the two methods presented to calculate the loss of property, loss-of-use and clean-up costs follow. The calculations for both the uprange phase and the downrange phase are presented.

Uprange phase

Method 1

The calculations in the example assume that the MPL evaluation has determined that a mishap will cause 3 casualties. Each casualty is assigned a monetary value of 5,000,000 A$ and the Australian per capita GDP is assumed to be 40,000 A$. Note that the dollar values used were accurate for the year 1998.

Example Calculation of Method 1

Casualties: calculated by MPL process = 3

Loss of life value: 3 x 5,000,000 A$ = 15,000,000 A$

Loss of property: 50% loss of life = 7,500,000 A$

Per capita GDP per year = 40,000 A$

Time out of use = 1 year

Loss of use 3 x 40,000 A$ = 120,000 A$

Clean-up costs = 100,000 A$

Property, loss of use and clean-up MPL value = 7,760,000 A$

Total MPL value = 22,700,000 A$

Method 2

Locate the assets with the highest value that lie within the probability threshold area and consider accident scenarios that have probabilities within the 10^{-7} probability threshold. Calculate the portion of the assets that would be damaged by the impact of the vehicle or its debris. The portion of damaged asset is given by multiplying the total surface of the high-valued facility by the ratio given by CA divided by IA. The damaged property area is then multiplied by the property value per metre squared to obtain the loss of property and by the annual revenues per metre squared to obtain the loss-of-use cost. Finally, the environmental and clean-up costs are added.

Example Calculation of Method 2

For this second example it is assumed that there are two high-valued properties within the 10^{-7} probability threshold area: a farm and a factory. The parameters of a hypothetical impacting vehicle are given in Table 1 while the parameters for the farm and the factory are given in Table 2.

Table 1: Hypothetical vehicle parameters

Casualty Area CA3,250 m^2
Impact Area IA 3,450,000 m^2

Ratio

Table 2: Hypothetical farm and factory values

	Farm	Factory
Property size	47,000 m^2	20,000 m^2
Property value	15,000,000 A$	2,200,000,000 A$
Property value per m^2	319 A$	110,000 A$
Annual revenues	5,000,000 A$	750,000,000 A$
Revenue per m^2	106 A$	37,500 A$
Time out of use	8 months	15 months

From the values given in Table 1 and Table 2 it is possible to calculate the total loss for the high-valued asset farm and factory

Farm

Loss of property farm x 47,000 m^2 x 319 A$/$m^2$ = 14,118 A$

Loss of use farm x 47,000 m^2 x 106 A$/$m^2$ x = 3,127 A$

Clean-up costs = 100,000 A$

Property, use and cleanup loss: farm = 117,245 A$

Factory

Loss of property factory x 20,000 m^2 x 110,000 A$/$m^2$ = 2,071,563 A$

Loss of use factory x 20,000 m^2 x 37,500 A$/$m^2$ x = 882,768 A$

Clean-up costs (assumed) = 600,000 A$

Property, use and cleanup loss: factory = 3,554,331 A$

These two approaches will give only a rough approximation, however they are both relatively easy to determine from available data. In addition, notice how, even though the factory had very high property and use values, the property MPL value in this example is driven by the third-party loss of property calculated as 50% of the loss of life; the 7,500,000 A$ of the bounding approach.

Note that the estimates used in the example calculation for method 2 above should not be read as obviating the need for specific damage analysis of accident scenarios involving high-value assets that have a probability within the 10^{-7} threshold.

Downrange and re-entry phases

Downrange property losses and re-entry property losses are believed to be sufficiently small so as to be included in whatever MPL value results from possible casualties. However, if there is a particular high-valued third-party asset individually facing an impact probability of 10^{-7} or greater, for damage that could occur with a probability within the10^{-7} probability threshold, a specific assessment is made of the property loss, loss-of-use and environmental damage and clean-up values.

V. MPL ANALYSIS BY PHASE OF FLIGHT

ROADMAP FOR THE APPLICANT

Estimate third-party losses for the phases of flight uprange, downrange and re-entry. For each phase, develop the contours given by the probability of impacts and, for those areas within the probability threshold area, calculate the MPL value. Calculate specific assessments for accident scenarios involving specific high-value assets within the threshold area, if those accident scenarios have a probability within the 10^{-7} probability threshold. That value will show the contributions from casualties, from property loss, and any from environmental damage and cleanup as well as loss of use. The applicant will complete the estimation and fill out the form in section six.

It cannot be overemphasized that the MPL process, because of the remoteness of the threshold, all but assumes the occurrence of a mishap that places at risk the highest population density within the area of concern. Extensive or rigorous modelling at the tail of any normally distributed function becomes highly subjective and dependent on the mathematical models used, but the results of such scrutiny do not yield results more logical or understandable than a simplified analysis that uses a gross bounding criterion, as does this generic MPL methodology. Figures 2 and 3 are provided as illustrations of the simple logic behind the MPL estimation of public risk. The applicant may develop similar Event Trees for his own particular vehicle concept. Figures 4 and 5 are provided as useful examples of the simple event trees the applicant may want to use where applicable.

Figure 2. Public Launch Hazard Event Tree (FAA)

EVENT NODES

1 Launch vehicle failure: Probability that launch vehicle will fail, i.e., that the flight will not be successful. YES = P (launch vehicle failure) NO path = 1-P (launch vehicle failure)

2 Failure in launch area: Probability of a failure in the launch area during the early flight phase, typically within 60 seconds after launch. 0 < T <60. YES path = P (failure in launch area) NO path = 1-P (failure in launch area)

3 Fail on flight path: Probability of failure occurring on the original flight path. YES path = P (failure on original flight path) NO path = 1-P (failure on original flight path)

4 Deviates toward public areas Probability of deviation toward populated areas protected by impact limit lines (ILLs). YES path = P (deviates towards public areas) NO path = 1-P (deviates towards public areas)

5 Flight Safety System fails Probability that the Flight Safety System (FSS) will fail, i.e., 1- (reliability of the specific FSS being used). YES path = P (FSS failure) NO path = 1- P (FSS failure)

6 Failure over ocean areas Probability that flight failure will occur over ocean areas, i.e., 1- (probability that failure will occur during overflight of Micronesia, Australia, Asia or other populated downrange land masses). YES path = P (failure over open ocean) NO path = 1- P (failure over open ocean)

7 Fail on flight path Probability of failure occurring on the original flight path and will not deviate toward public areas. YES path = P (failure on original flight path) NO path = 1-P (failure on original flight path)

8 Deviates toward public areas Probability of deviation toward populated areas. YES path = P (deviates towards public areas) NO path = 1-P (deviates towards public areas)

9 Flight Safety System fails Probability that the FSS will fail. YES path = P (FSS failure) NO path = 1- P (FSS failure)

Figure 3: Public Launch Hazard Event Tree Nodes - Definitions (continued)
OUTCOMES

(a) **Mission success, public risks controlled**. *May directly follow event node 1.*

(a.1) **Shipping** Risks to shipping from booster or other discarded debris impacting within planned areas.

(a.2) **Air traffic, IP area clear** Planned air traffic exposures.

(a.3) **Orbital re-entry risks** Risks to third parties from eventual decay from orbit of on-orbit hardware.

(b) *May directly follow event nodes 3, 4, 7 and 9.*

(b.1) **Launch area shipping clear** Risks to shipping in the ocean area near the launch site.

(b.2) **Impact in broad ocean area -- low and random risk to shipping and air traffic.** Random risk to shipping and air traffic in the broad ocean areas.

(c) *May directly follow event nodes 5 and 9*.

(c.1) **Debris contained inside Impact Limit Lines (ILL)** Risks associated with debris that is contained within the ILLs.

(d) *May directly follow event Nodes 5, 6 and 9.*

(d.1) **Potential public casualties** Risks to the public in areas outside the ILLs.

Figure 3: Public Launch Hazard Event Tree Nodes - Definitions (continued)

Figure 4. ELV Public Launch Hazard Event Tree (proposed sample)

Figure 5. Suborbital Public Launch Event Hazard Tree (proposed sample)

Primary effects of debris

The debris hazards vary as a function of the destruct action, vehicle failure mode and time in flight of the occurrence. Debris is normally classified by ballistic coefficient, cross sectional area, total fragment weight and the number of fragments. The debris likely to cause the most serious damage is that with the higher ballistic coefficient. Other debris is considered less significant but may also cause damage and casualties. The permit applicant will be required to develop a debris catalogue and corresponding impact footprint along the instantaneous impact point (IIP) for his vehicle for any portion of the flight during which third parties are exposed.

The trajectory and pattern on the ground, or footprint, of the debris is a function of induced velocity, ballistic coefficient, altitude at the time of the occurrence and any wind drift effects. With most vehicles, the ground (or ocean) impact area (IA) of the debris is on the order of 3.45 km^2 when the vehicle's destruction occurs early in the flight, may grow to 85-175 km^2 as the vehicle continues to accelerate and ascend, and may reach to thousands of km^2 as the IIP for the upper stages crosses downrange land masses. For re-entry and recovery, the IA will be the size of most countries at the completion of the de-orbit burn and on the order of 3.45km^2 at parachute deployment or high key. Casualties and property loss result from the primary effects of impact by debris.

Secondary effects of debris

Potential secondary effects such as fires, explosions, building collapses and the like, will cause casualties. Because crash dynamics are so varied, use a factor or boundary of 1.5 times as many casualties as were estimated for the primary or initial debris. The value of 1.5 is considered conservative in that it may serve to overestimate casualties, but is based in part on crash dynamics observed during aircraft and launch vehicle crashes which often result in affected on-ground property suffering secondary damage beyond the initial impact and further placing any occupants at risk. Secondary effects of debris do not apply for downrange mishaps or re-entry because the vehicles or stages will be almost or totally devoid of propellants and atmospheric re-entry of the debris will consume some portion of the debris, which does not happen during an uprange mishap.

Effects of toxic materials

At the present time and the foreseeable future, casualties and property damage due to the toxic effects of on-board propellants are discounted for mishaps occurring outside the boundary of the launch site, both in the uprange and downrange areas. The effects of toxic materials can be discounted because any such material would be unlikely to survive the initial fireball.

MISHAP SCENARIOS TO CONSIDER

The following accident scenarios are those that may, either individually or in combination, result in a vehicle potentially posing a hazard to third-party persons and resulting in property damage. As is evident, many of these scenarios most likely will result in activation of the vehicle's Flight Safety System (FSS). This section is included to prompt the applicant during his analyses.

i. Solid motor burn through

ii. Liquid propellant ignition

iii. Anomalous trajectory

iv. Flight Safety System failure

v. In-flight breakup

vi. Release of toxic gases

vii. Failure to pitch over

viii. Improper roll manoeuvre

ix. Shift or loss of inertial reference

x. Ascending stage or payload impacting airborne aircraft

xi. Descending stage, payload or re-entry vehicle impacting airborne aircraft

xii. Stage or re-entry vehicle impacting person or property after parachute descent

xiii. Stage, payload or re-entry vehicle impacting person or property after ballistic or autonomous approach

xiv. Stage, payload or re-entry vehicle igniting a fire on the ground

xv. Re-entry vehicle fails to separate from the upper stage or on-orbit platform

xvi. Re-entry vehicle re-enters but fails to re-enter at the planned-for position and time

xvii. Re-entry vehicle has an undetected critical system failure

xviii. Re-entry vehicle scattering debris during re-entry

xix. Re-entry vehicle releasing hazardous materials

CASUALTY AREA

Casualty Area

The permit applicant is to develop a break-up model, a debris catalog on his vehicle and refine that further into an Casualty Area for uprange and downrange phases of flight. The issues to be considered include the effects of inert debris falling vertically and/or ricocheting, explosive debris, debris fragment size and number (debris catalogue), horizontal and vertical cross-sectional area of the "standard person," angle of impact, and calculation of the composite or Casualty Area. The methodology for developing the CA is contained in the "Risk Hazard Analysis" of the SLASO Flight Safety Code. The applicant is to create his debris catalogue by converting the total non-volatile mass of the launch vehicle (including payloads) into ballistically lethal fragments. Following that, he is to assume that: all resultant fragments, either striking a person directly or glancing a person, will result in death or serious injury; that no individual debris casualty areas overlap; and that the dimensions of a "standard person" are 0.3m in radius and 2.0m in height. The standard person radius of 0.3 m is added to the dimension of each piece of lethal debris in the vehicle's debris catalogue. The equation to be used for calculating the CA is expressed as:

$CA = CA_{(inert)} + CA_{(explosive)}$

Where:

$CA_{(inert)}$ comprises a basic casualty area component $CA_{(basic)}$ which is made up of

debris falling vertically and diagonally, and components for debris skidding $CA_{(skid)}$.

For each debris group, the lethal debris area is the basic area plus the area found for

debris skidding. $CA_{(explosive)}$ is the explosive debris contribution to CA calculated from converting propellant weights into equivalent TNT weights and using an explosive overpressure threshold of 25 kPa.

The licence or permit applicant is to develop the CA for his vehicle based on the "Risk Hazard Analysis" in the current version of the SLASO Flight Safety Code apply that dimension in this MPL methodology.

Scaling factor to account for debris skidding. If a permit applicant is not able to develop the complete Casualty Area for its vehicle as detailed in the its "Risk Hazard Analysis" of the SLASO Flight Safety Code, SLASO requires that the applicant increase the basic casualty area developed in its debris catalog by a factor of 4.7, and furthermore instructs the applicant to use this scaled up casualty area, in conjunction with the $CA_{(explosive)}$, to obtain the CA for use in estimating MPL losses.

Casualty Area for small rockets. Because it is problematic to develop debris catalogues for very small rockets, typically due to resource limitations and the absence of data, the below Figure 6, which results from an interpolation of data contained in Research Triangle Institute's (RTI) "Small Rocket Risk Analysis", May 16, 1991, may be used to estimate the Casualty Area for unstable (tumbling) small rockets with a total impulse up to 200,000 pound-seconds. To be properly conservative, the applicant will use the amplified CA in estimating casualties. The small rocket permit applicant is to develop the Casualty Area as described above for larger vehicles, but, if SLASO authorizes it, the applicant may use the values found from Figure 6.

Figure 6: Interpolation of data obtained from the Research Triangle Institute for amplified effective casualty as a function of the total impulse per pound per second for small rockets

FOR AREA LOSSES

People - primary effects of debris

Losses to people within the probability threshold area are determined by layering the CA over an area containing the highest population density that can be found anywhere within the contours. For launches from Woomera, for example, that population density is likely to be based on Roxby Downs. For launches from Hummock Hill Island off Gladstone Queensland, Gladstone will likely have the population density to consider. For launches from the proposed Asia-Pacific Space Centre on Australia's Christmas Island External Territory, the population density to consider may reside on a launch area island.

For re-entry, people and properties within the probability threshold area are considered at risk. For re-entry and landing at Woomera for example, if the contour includes Port Lincoln, and if that is the most densely populated area at risk with an area equivalent to the debris footprint, the population at risk may be based on the population density that results from that city's 14,000 residents.

For RLV activities, the area at risk lies along and within the probability threshold area contours as the stage makes its descent, approach and landing. The population density at risk is the highest within the probability threshold area.

The number of casualties is estimated by the layering approach, where the CA is

layered on the highest population density cluster within the probability threshold area. For the uprange or launch area phase, and for recovery, the permit applicant is to find an area that is close to 3.45 km^2 in size (which corresponds to the impact area IA), that has the highest population density of all areas within the probability threshold area.

The calculation to use for layering is:

Casualties = (CA) x (D_{Pop})

CA = Casualty Area in m^2

D_{Pop} = Population density in persons/km^2, converted to persons/m^2

Casualties = x CA m^2

Small vehicles operating in areas of considerable population density yield only very small fractions of a casualty. For example, from the above relationship, a vehicle with an Casualty Area of 93 m^2 that is hazarding an area with a population density of 580 persons/km^2 (but populated to an area of about 3.45 km^2) will cause 5.39×10^{-2} casualties, or 0.0539 casualties. A vehicle with an Casualty Area of 3,700 m^2 posing a hazard to that same population density will cause 2.15 casualties.

Casualties are rounded to the nearest whole number. Casualties equal to or above 0.5, a half of a casualty, will be assigned as one casualty. Casualties below that number will be set at zero. Casualties in excess of 1.5 up through 2.49 will be assigned as two casualties. Casualties equal to or above 2.5 up through 3.49 will be assigned as three casualties, and so forth. In the above example that yielded 2.15 casualties, two casualties would be assigned.

People - secondary effects of debris

To determine the number of casualties from secondary causes, such as post impact structure collapses and fires, multiply the number of rounded up primary casualties by a factor of 1.5 to obtain the number of casualties from secondary causes. The total number of casualties for the phase is the total of the two values. Table 3 shows the results of sample calculations and the resulting casualty MPL value based on 5,000,000 A$ million per casualty. Because initial rounding takes place before entering Table 3, rounding to the nearest whole casualty number will suffice. Thus, in the first row, (one casualty from debris) x (1.5) = 1.5 casualties from secondary effects. That 1.5 casualty value is rounded up to 2.0, resulting in three total estimated casualties, as shown.

Table 3. Launch area/uprange casualty loss estimations from primary debris plus secondary effects

Casualties from Debris	Casualties from Secondary Effects	Total Estimated Casualties	Third-party persons MPL value at 5,000,000 A$ per casualty
1	2	3	15,000,000 A$
2	3	5	25,000,000 A$
3	5	8	40,000,000 A$
4	6	10	50,000,000 A$
5	8	13	65,000,000 A$
6	9	15	75,000,000 A$
7	11	18	90,000,000 A$
8	12	20	100,000,000 A$
9	14	23	115,000,000 A$
10	15	25	125,000,000 A$
11	17	28	140,000,000 A$
12	18	30	150,000,000 A$
13	20	33	165,000,000 A$
14	21	35	175,000,000 A$

Loss of property as a function of the casualty loss estimate

Third-party property losses are estimated at 50% of the value of the losses to third-party persons from the primary and secondary effects of debris. The applicant will determine the third-party property loss as shown in the equation below. Because of the conservative nature of the casualty loss estimations and the rounding that has already been done, further rounding is not needed.

The calculation to use for launch area property loss is:

$MPL_{(LAP)} = CAS_{(LA)} \times (0.5) \times (5{,}000{,}000\ A\$)$

where

CA = Casualty Area in m^2

$MPL_{(LAP)}$ = MPL value for launch area third-party property in A$

$CAS_{(LA)}$ = Casualties in the launch area

5,000,000 A$ = Cost per casualty

For example, if a total of 3 casualties for an MPL value of 15,000,000 A$ were estimated to result then the third-party property loss would be 7,500,000 A$.

Loss of property as a function of the specific facility

If the risk analysis conducted in accordance with the current version of the "Risk Hazard Analysis" in the SLASO Flight Safety Code shows a single high-value facility within the probability threshold area, such as an oil platform or mine, the applicant is required to conduct a special assessment to determine the damage that would be caused by impact on that facility by the vehicle, its stages or expected debris, if the probability of such damage occurring is higher than the 10^{-7} threshold. The assessment will be specific to the size and strength of the facility versus the impact and explosive effects of the mishap vehicle. The damage estimate thus calculated will be compared to any generated by the layering approach and its property bounding method, with the higher of the two values being assigned as the property MPL value for that phase of flight.

An approximate value of the loss of property can be obtained as presented in the previous section "estimating costs for losses" and here reported in general terms

$MPL_{(LOP)}$ = (Property Value m^2) x (   ) x (Facility size)

where

$MPL_{(LOP)}$ = MPL value for loss of property in A$

Property Value m^2 = Property value of the facility per metre squared, in A$

CA = Casualty Area for that flight phase

IA = Impact area of the vehicle debris

Facility size = Footprint area occupied by the facility expressed in m^2

Loss of use

For loss of use, the applicant will use whichever value is higher, the value obtained by overlaying the debris area over a facility of known size and annual revenue, if that facility itself is at risk within the 10^{-7} threshold, or that obtained by multiplying the per capita Gross Domestic Product (GDP) of the country where casualties may result times the number of casualties estimated.

$MPL_{(LOU)}$ = $CAS_{(LA)}$ x (GDP)

where

$MPL_{(LOU)}$ = MPL value for loss of use in A$

CAS = Casualties estimated

GDP = Per capita Gross Domestic Product, in A$, for Australia

Or

$MPL_{(LOU)}$ = (Revenues p.a./m^2) x (   ) x (Facility size m^2) x (Time out in months/12)

where

$MPL_{(LOU)}$ = MPL value for loss of use in A$

Revenues = Annual revenue of the facility per metre squared, in A$

CA = Casualty Area for that flight phase

IA = Impact area of the vehicle debris

Facility size = Footprint area occupied by the facility expressed in m^2

Time out = Time, in months, needed to reinstate the facility state to the same one it had before the accident, based on an estimated proportion to a year.

Environmental damage and cleanup

The applicant will estimate the cost associated with environmental damage and clean-up by whichever of the following two methods provides the higher MPL value: 100,000 A$; or, if there is a particular high-valued third-party asset individually facing an impact probability of 10^{-7} or greater, an accurate evaluation of the cost associated with restoring the environment to the condition which would have existed if that damage had not occurred.

Note that, unlike the U.S. practice, the environmental damages and clean-up costs in the MPL methodology developed for the Commonwealth of Australia include indirect damages, such as the ones that could be caused by an oil spill caused by an impacting vehicle, if there is a probability higher than 10^{-7} that such an accident may happen. The rationale for including indirect damages is that it can reasonably be anticipated that parties suffering consequential losses (loss of business and profits, environmental cleanup etc.) will include the estimated value of these consequential losses in calculating the amount of the insurance claim as well as the amount of damages in any legal claim. Most courts will give recognition to such consequential damages.

Launch area MPL value estimated _____________

Casualties x A$5 million _____________

Property (0.50 of casualty MPL value)

or _____________

Facility damage estimate

Loss of use (Casualties x GDP/capita)

or _____________

Facility damage estimate (Loss of use)

Environmental (100,000 A$)

or _____________

Facility damage estimate (Environment)

FOR DOWNRANGE OVERFLIGHT

For downrange, the people and property at risk are those within the probability threshold area. This is estimated to be a swath along the IIP extending hundreds of kilometres laterally. Property and people inhabiting the downrange area overflown by the IIP for an ELV's stages will likely be at a level of risk within the 10^{-7} probability threshold. If the hazard analysis supports that assumption, the number of casualties will be determined by overlaying the CA on the area with the highest known population density in the area being overflown (nominal trajectory ± lateral dimension). A key difference between the launch area or uprange methodology and this downrange one is that in the uprange, the debris and the highest population density at risk were about the size of 3.45 km^2, but here, the very large debris IA will likely cover major sections of countries. Thus, the population density chosen for the MPL estimation is the highest of the coastal regions of Australia or countries (e.g., Japan) or even geographic areas (e.g. North America) overflown. As with the launch area casualty estimations, the layering method is used.

The calculation to use for layering is:

Casualties = (CA) x (D_{Pop})

CA = Casualty Area in m^2 for this phase of flight

D_{Pop} = Population density in persons/km^2, converted to persons/m^2

Casualties = ( ) x (CA)

The third-party MPL value for downrange overflight is based only on the predicted number of casualties multiplied by the 5,000,000 A$ cost of a casualty. Losses due to toxic effects, explosive effects, property damage, loss of use, and environmental damage and cleanup are expected to be contained within the cost assigned to casualties. The downrange approach may be used from the time during the launch when the hazard analysis supports the assumption that the property damage, loss of use, and environmental damage and cleanup are expected to be contained within the cost assigned to casualties. This is typically during upper stage flight.

However, if there is a particular high-valued third-party asset individually facing an impact probability of 10^{-7} or greater, an accurate evaluation of the cost associated with property damage, loss of use and environmental damage and cleanup needs to be conducted.

Small vehicles, or small upper stages and payloads, operating in areas of considerable population density yield only very small fractions of a casualty. For example, if an upper stage and payload have an Casualty Area of about 186 m^2 during overflight near Japan, which has a population density of about 460 persons/km^2, the overflight will result in 8.56 x 10^{-2} casualties, or 0.0856 casualties. Because this casualty estimation is not even one tenth of a casualty, the MPL recommendation for downrange overflight will be zero for this example.

Downrange MPL value estimated ___________

Casualties x A$5 million ____________

Property (Included in casualty value)

or ____________

Facility damage estimate (Property)

Loss of use (Included in casualty value)

or ____________

Facility damage estimate (Loss of use)

Environment (Included in casualty value)

or ____________

Facility damage estimate (Environment)

FOR RE-ENTRY

Unplanned re-entry

The risk from *unplanned* re-entry of space components and payloads is sufficiently small to be considered negligible. Further MPL analysis in this area is not necessary.

Unplanned re-entry MPL value estimated ***Zero***

Planned re-entry

Planned re-entry

The MPL for a re-entry vehicle is analyzed assuming the vehicle remains intact, as it is designed to do. Within the probability threshold area for planned re-entry, CA is prescribed as two times the footprint. This is sufficient to include the additional area formed by increasing the object's dimensions by 0.3 m in all directions to account for the standard radius of a person.

The probability threshold area contour will be plotted at: the completion of the de-orbit burn; when the IIP first touches Australia; then at discrete intervals until the final contour, which is at parachute deployment or high key, depending on the vehicle type. Casualties will be estimated by overlaying the CA over the highest population density of an area equivalent to the IA of the debris that will result from a failure at each of the discrete points. Thus, there will be five or six casualty estimations for the re-entry, one for each of the probability threshold area contours and each based on the vehicle's CA acting on the highest population density equivalent to the changing debris footprint. The MPL estimate for re-entry will be based on the computation that yields the greatest number of casualties.

Estimate casualties by using the same layering technique as before. The value associated with property loss will be 0.5 of the value of casualties, with loss of use and environmental damage and cleanup estimated as previously. If less than one-tenth of a casualty is estimated, the MPL is set at zero. If a specific high-value facility is individually at risk, property loss, loss of use and environmental damage are set as previously, if the probability of such damage is higher than the 10^{-7} threshold.

The calculation to use for layering is:

Casualties = $(CA) \times (D_{Pop})$

CA = Casualty Area in m^2 for this phase of flight

D_{Pop} = Population density in persons/km^2, converted to persons/m^2

Casualties = ( ) x (CA)

Planned re-entry MPL value estimated ____________

Casualties x A$5 million _____________

Property (0.50 of casualty MPL value)

or _____________

Facility damage estimate

Loss of use (Casualties x GDP/capita)

or _____________

Facility damage estimate (Loss of use)

Environmental (100,000 A$)

or _____________

Facility damage estimate (Environment)

FOR RECOVERY

The MPL for the recovery or landing of an RLV is analyzed assuming the vehicle breaks up in a manner that produces the largest CA. Within the probability threshold area, the debris catalogue resulting from planned and unplanned destruct actions, adjusted for the 0.3 m radius of a person, will be scaled up by the 4.7 factor that addresses the effects of the debris sliding, bouncing or splattering. A blast component to the CA is not required because it is assumed the stage or vehicle has expended all or most of its propellant and the resulting debris will have little or no blast component.

As with planned re-entry, the probability threshold area contour will be plotted at: the completion of the de-orbit burn; when the IIP first touches Australia; then at discrete intervals until the final contour, which is at parachute deployment or high key, depending on the vehicle type. Casualties will be estimated by overlaying the CA over the highest population density of an area equivalent to the IA of the debris that will result from a failure at each of the discrete points. Thus, there will be five or six casualty estimations for the re-entry, one for each of the probability threshold area contours and each based on the vehicle's CA acting on the highest population density equivalent to the changing debris IA. The MPL estimate for re-entry will be based on the computation that yields the greatest number of casualties.

Estimate casualties by using the same layering technique as before. The value associated with property loss will be 0.5 of the value of casualties, with loss of use and environmental damage and cleanup estimated as previously. If less than one-tenth of a casualty is estimated, the MPL is set at zero. If a specific high-value facility is at risk, property loss, loss of use and environmental damage are set as previously, if the probability of such damage is higher than the 10^{-7} threshold.

RLV recovery MPL value estimated ____________

Casualties x A$5 million ______________

Property (0.50 of casualty MPL value)

or ______________

Facility damage estimate

Loss of use (Casualties x GDP/capita)

or ______________

Facility damage estimate (Loss of use)

Environmental (100,000 A$)

or ______________

Facility damage estimate (Environment)

VI. MPL SUMMARY

The permit applicant will fill out the following table with the results of his MPL estimations and provide a copy to SLASO. The value of the top line in any loss area is the summation of the individual loss categories.

Launch area MPL value estimated ____________

Casualties x A$5 million ______________

Property (0.50 of casualty MPL value)

or ______________

Facility damage estimate

Loss of use (Casualties x GDP/capita)

or ______________

Facility damage estimate (Loss of use)

Environmental (100,000 A$)

or ______________

Facility damage estimate (Environment)

Downrange MPL value estimated ____________

Casualties x A$5 million ______________

Property (Included in casualty value)

or _____________

Facility damage estimate

Loss of use (Included in casualty value)

or _____________

Facility damage estimate (Loss of use)

Environment (Included in casualty value)

or _____________

Facility damage estimate (Environment)

Planned re-entry MPL value estimated _____________

Casualties x A$5 million _____________

Property (0.50 of casualty MPL value)

or _____________

Facility damage estimate

Loss of use (Casualties x GDP/capita)

or _____________

Facility damage estimate (Loss of use)

Environmental (100,000 A$)

or _____________

Facility damage estimate (Environment)

RLV recovery MPL value estimated _____________

Casualties x A$5 million _____________

Property (0.50 of casualty MPL value)

or _____________

Facility damage estimate

Loss of use (Casualties x GDP/capita)

or ______________

Facility damage estimate (Loss of use)

Environmental (100,000 A$)

or ______________

Facility damage estimate (Environment)

Upon completion of the MPL and this section, forward same to SLASO.

VII. CONTACT DETAILS

For further information about the licensing regime set out under the *Space Activities Act 1998*, including matters set out in this Maximum Probable Loss Methodology, interested parties should contact:

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COMMONWEALTH OF AUSTRALIA
SPACE LICENSING AND SAFETY OFFICE

FLIGHT

SAFETY

CODE

Department of Industry,

Science and Resources

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ISR - 2001/152**Table of Contents**

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1. INTRODUCTION

1.1 OVERVIEW

1.1.1 The *Space Activities Act 1998* provides legal authority for the Commonwealth Government of Australia to license certain space launch and re-entry activities from Australia and launches, from overseas sites, of payloads in which Australian nationals have an ownership interest. The Act establishes a licensing regime to regulate such activities and, in doing this, implements Australia's obligations under United Nations Conventions and bilateral agreements with other countries, ensures the protection of people and property, and provides a transparent, stable and predictable operating environment for those wishing to participate in space launch activities.

1.1.2 The Act is supported by the *Space Activities Regulations 2001*, which provide further detail about the licensing regime and material to be prepared in support of an application for a licence, permit or certificate under the Act. The Act is also underpinned by several documents addressing the safety of proposed launch activities from Australia and the determination of the minimum amounts for which insurance must be taken out in respect of of potential loss or damage.

1.1.3 This Flight Safety Code sets out the requirements of applicants to demonstrate that their proposed launch activities will be safe and effective. As such, it represents a critical element of evidence to be used to satisfy the Minister that the probability of the launch or launches, and any connected return, causing harm to public health or public safety, or causing substantial damage to property, is sufficiently low. The Code derives its legal authority from the *Space Activities Regulations 2001.* All individuals, organisations and companies seeking approval to conduct space launch activities in Australia must comply with the Code.

1.1.4 Specifically, this Code sets out the safety standards that must be achieved in respect of the risks posed to third parties by space launches and the methodology to be used to calculate the risk. The casualty safety standards are aimed at ensuring that the risks to public health and safety are low. The asset safety standards are aimed at ensuring the potentially catastrophic risks associated with designated assets are identified and are low. The standards also provide for restrictions to be applied to unproven vehicles overflying populated areas and for restrictions on new launch licensees flying in the vicinity of petroleum facilities. The standards to be observed in respect of drop zones and landing sites are also set out.

1.2 PRINCIPLES AND PHILOSOPHIES

1.2.1 Safety of the public, property and major national assets underpins the safety regime. The safety regime is based on a `safety case' approach which places responsibility for the ongoing management of safety on the launch operator. A launch proponent will present a safety case to the regulator to demonstrate that the risks associated with the operation of the launch facility, the launch vehicle and the proposed flight paths are as low as reasonably practicable.

1.2.2 The role of the regulator is to assess, accept and audit the adequacy of the safety case presented by the launch proponent. The regulator will also provide guidance to applicants in the preparation of the safety case.

1.2.3 The safety case in respect of the proposed site, launch vehicle and flight paths will need to be demonstrated before a space licence will be issued under the *Space Activities Act 1998*. This case should draw on all material provided with an application for a space licence, but in particular the Program Management Plans, completion of the Risk Hazard Analysis (including assumptions underpinning that analysis) and demonstrated capacity to meet the Launch Safety Standards. Individual launches from a licensed facility will need to satisfy the safety standards accepted under the licencee's safety case and, in so doing, to at least satisfy the safety standards for every launch.

1.2.4 The safety regime acknowledges public expectations that the risk of death or serious injury from commercial space activities should not exceed that from comparable industries. The Launch Safety Standards are the mechanism by which the community and certain assets with catastrophic potential are protected from any potential impact from space launch activities.

1.2.5 People and community facilities are protected by the third party safety standards. These limit the risk any individual may face as a result of a launch, the risk any individual may face as a result of regular operation of the launch facility, and the collective risk to the public. Collective risk limits the average number of casualties per launch and ensures that the number of people exposed to risk is limited. The launch will not proceed if these standards are not met.

1.2.6 Property that is regularly occupied by people or is in a significantly populated area is protected by the third party safety standards discussed above. Facilities that are remote from a significantly populated area and which are in need of special protection because of their catastrophic potential may be afforded that protection through the asset safety standards.

1.3 RESPONSIBILITY FOR ADMINISTRATION

1.3.1 Under the *Space Activities Act 1998*, the Minister has authority to issue licences and permits giving due regard to public health, safety of life and property, Australia's national security and foreign policy obligations, the impact on the environment, and the technical and corporate competency of the applicant. A body within the Department of Industry, Science and Resources - the Space Licensing and Safety Office (SLASO) - has responsibility for assessing all applications for instruments under the Act, as well as all material provided in support of such applications. Some of the powers of the Minister to issue licenses and permits may be delegated to the Director of the SLASO.

1.3.2 In particular, the SLASO will review and assess applications for licenses and permits, and provide recommendations on granting licenses or permits. The SLASO will also review and approve, for the purposes of granting a licence, all safety-critical designs, such as autonomous flight termination systems, system test and documentation for the overall airborne flight safety system, and has final authority for mitigating the risk to the public, to properties and to the launch area, including pre-launch and launch operations. Operational and engineering design for flight safety systems, ground force systems, scientific analysis and safety risk criteria for all launches will be rigorously assessed by the SLASO.

1.3.3 The safety case presented in accordance with the Launch Safety Standards and Risk Hazard Analysis, set out in this document, will be subject to rigorous scrutiny by the SLASO, including all data and assumptions underpinning the calculations. The final authority and responsibility to approve a launch rests with the Minister or his delegate. The Launch Safety Officer, located on the site of the launch, has powers to ensure compliance with a licence or permit, inspect the facility and any equipment contained therein, and to give directions to stop the launch or destroy the launch vehicle.

1.4 FLIGHT READINESS

1.4.1 The *Space Activities Act 1998* and *Space Activities Regulations 2001* set out all requirements of applicants, upon which the process to approve launch activities will be based. This process includes a number of steps which are pre-requisite to an approval to launch being granted, and involves assembly, testing and check-out, and verification that all vehicle systems are operating as required and in proper configuration for launch. Material to facilitate this process will be drawn from documentation submitted about the type of launch vehicle and the Program Management Plans. In applying for a space licence, the applicant will include the results of all testing and checkout of the launch vehicle in their material on the type of launch vehicle for review by SLASO. The applicant will also identify all hazardous ground operations and procedures for review, as set out in the Emergency Plan. The SLASO will monitor compliance with such operations and procedures.

1.4.2 The SLASO will engage in a process to assess the readiness of arrangement for flight, drawing on material provided in applications for both a space licence and launch permit. In this context, all anomalies and failures of systems will be identified and corrective actions assessed to ensure compliance with established requirements. Any anomaly or corrective action that degrades or compromises public safety will be scrutinized and the SLASO may seek further information on these matters [under authority of Section 60 of the Act]. The applicant will also demonstrate that risk levels are within the established standards identified in this Flight Safety Code by conducting a risk assessment in accordance with the methodologies and processes set out in this Code. Should any of the assumptions or data on which the assessment was based change prior to the launch, such changes should be provided to the SLASO, along with confirmation that the Launch Safety Standards are met.

1.4.3 Based on information provided in the Program Management Plan for the launch or return, the SLASO will review final readiness for the launch not more than two days prior to that launch or return. The purpose of the review is to assess whether:

1. system and personnel readiness problems are identified and are associated with a plan to resolve them;

2. all systems needed for flight have been verified and are ready; and

3. each participant is aware of his or her role on the day of flight.

1.4.4 Where arrangements or assumptions have changed and compliance with the Launch Safety Standards is in doubt, the Launch Permit will be suspended or revoked, as appropriate.

The Launch Safety Officer has authority under the *Space Activities Act 1998* to oversee all pre-launch activities.

1.5 RISK MANAGEMENT

1.5.1 Risk management is the process whereby the risk is computed, compared to a standard of acceptability and, where necessary, mitigated until the risk reaches an acceptably low level. The risks in this case are those to the public and to property not owned by the applicant which arise from the launch of a launch vehicle. In the case of expendable launch vehicles, the period to which risk analysis applies will be the period from the commencement of the launch and concluding 30 days after the commencement of the launch. In respect of reusable launch vehicles, the re-entry phase will be the period beginning when the relevant re-entry maneuver has commenced and ending when the object has come to rest on Earth. Risk criteria will be more conservative when the consequence of a single event is significant, that is it can result in many casualties or in very high financial loss.

1.6 RISK COMPUTATION

1.6.1 From a mission-planning standpoint, risks from impacting inert and exploding debris and from toxic gases are the primary considerations. Risks shall be calculated in accordance with the Risk Hazard Analysis Methodology set out in Section 4 of this Code. Sufficient detail, through test and analysis, that the risks will not exceed the Launch Safety Standards shall be provided to the SLASO. All assumptions and data underpinning the results of the analysis must be documented in the Launch Safety Plan and provided to the SLASO as part of the application for a launch permit. Such assumptions and data will be closely scrutinised by the SLASO.

1.7 FLIGHT SAFETY SYSTEMS

1.7.1 A Flight Safety System (FSS) is a risk mitigation method that detects an aberration in launch vehicle health or positioning and terminates flight in response. The system, manually or autonomously activated, is required as a means of controlling the vehicle to minimize the risk to life and property. With the exception of certain sub-orbital missions, evidence is required that a FSS has been installed on all vehicles that will be licensed under the *Space Activities Act 1998*. The system is to be operable throughout the entire powered flight phase and re-entry phase of a mission, must be at least single fault tolerant, and be capable of terminating the flight when nominal flight conditions have been transgressed by a predetermined margin. The system may be destructive resulting in the intentional breakup of a vehicle or nondestructive such as engine thrust termination enabling vehicle landing or safe abort. The system may be manually operated or fully autonomous. If the system is fully autonomous, it must incorporate at least one level of redundancy with a reliability requirement for successful operation of 0.999. If the FSS it to be activated manually, it must operate with a reliability of 0.998 with 95% confidence. On any manually operated FSS, evidence is required that tracking and monitoring of the flight will take place. The technology to be adopted will not be stipulated, however evidence is required to demonstrate effectiveness and reliability.

1.7.2 Evidence is required to demonstrate that all flight-safety-critical systems/components are at least single fault tolerant; that is they will incorporate one level of redundancy. This aims to prevent potential single point failures.

1.7.3 Evidence is required to demonstrate that reusable launch vehicles incorporate a positive fail-safe reentry system to ensure that reentry flight occurs under the conditions necessary to ensure that the risks to public safety do not exceed prescribed levels. The reentry command may be autonomous with the uplinking of current meteorological data and need not include a person in the loop. The technology to be adopted will not be stipulated, however evidence is required to demonstrate effectiveness and reliability.

2. DEFINITIONS

2.1 This Flight Safety Code uses a number of terms which are unique to the space launch industry and which have meanings of particular relevance to this Code. Terminology is thus defined as set out below and should be read in context of this Code. These definitions do not override those set out in the *Space Activities Act 1998* .

asset risk: the risk to a Designated Asset or Protected Asset.

casualty area: an area around a debris impact point in which a person who is present will become a casualty in the event of that debris impact.

casualty expectation: the average number of casualties that can occur as a result of an event if the event were to be repeated thousands of times.

catastrophic chain of events: assessed according to the criteria set out in the "Administrative Arrangements for the Classification of Assets for Space Launch Activities".

collective risk: the total casualty expectation from a launch or return.

controlled area: a drop zone area or landing site area.

debris: any material that poses a hazard if it falls to ground as a result of the intended or unintended break up of a space object.

debris footprint: the impact distribution for debris predicted to result from a particular event.

Designated Asset: an asset designated by the Minister for Industry, Science and Resources and set out in the List of Designated and Protected Assets.

dispersion footprint: an area in which returned space objects, scheduled debris, or debris returns to land, defined by an impact probability isopleth or a standard deviation boundary.

drop zone: an area for the impact of scheduled debris.

drop zone area: a four standard deviation dispersion footprint around the nominal impact point of scheduled debris.

impact probability: the probability of a space object, or debris, impacting on a location, area, facility or person.

impact probability isopleth: a line on a map connecting places of equal impact probability.

***individual risk*:** the risk to a single person exposed to a launch or return, or a series of launches or returns.

hazard: a potential source of casualty or loss.

landing site: an area for the planned return of a space object including a re-usable launch vehicle.

landing site area: a four standard deviation area around the nominal impact point for the return of a space object or re-usable launch vehicle.

mature vehicle: for the purpose of the methodology for failure probability determination, a launch vehicle that has had greater than five successive successful launches.

nominal impact point: planned or intended impact point of scheduled debris or for the return of a space object.

population centre: a person, group of persons or area of population, considered as a single entity for the purpose of the methodology of risk determination.

Protected Asset: a Designated Asset defined as protected by the Minister for Industry, Science and Resources and set out in the List of Designated and Protected Assets.

risk isopleth: a line on a map connecting places of equal risk.

scheduled debris: planned or intended debris from a successful launch.

significantly populated area: a city, town or settlement, but not an isolated house or homestead.

standard person: a hypothetical object of cylindrical shape with a circular base of radius 0.3 metres and linear height of 2 metres.

successful launch: for the purposes of flight safety, a launch which does not suffer a malfunction that could pose a hazard to the public.

trigger debris: debris capable of triggering a catastrophic chain of events on a Designated Asset (see Section 3.2).

unproven vehicle: a launch vehicle that has not achieved five consecutive missions without a failure that could pose a hazard to life and/or property.

3. LAUNCH SAFETY STANDARDS

The party responsible for the launch or return of a space object is required to meet the following launch safety standards for risks posed to third parties.

3.1 THIRD PARTY CASUALTY SAFETY STANDARD

3.1.1 The maximum third party collective risk (the sum of casualty risks to all individuals in the general public) on a per launch basis:

10^{-4} per launch.

3.1.2 The maximum third party individual risk on a per launch basis:

10^{-7} per launch

3.1.3 The maximum third party individual casualty risk on a per year basis:

10^{-6} per year

3.2 ASSET SAFETY STANDARDS

Designated Asset

3.2.1 The maximum probability of debris impact on a Designated Asset on a per launch basis:

10^{-5} per launch

3.2.2 The maximum probability of debris impact on a Designated Asset on a per year basis:

10^{-4} per year

3.2.3 The maximum probability of *trigger debris* impact on a Designated Asset on a per launch basis:

10^{-7} per launch

3.2.4 The maximum probability of *trigger debris* impact on a Designated Asset on a per year basis:

10^{-6} per year

Trigger Debris

3.2.5 Trigger debris is space debris of a particular shape, weight, velocity or explosive potential that is capable of triggering a catastrophic chain of events on a Designated Asset or Protected Asset. Trigger debris is determined on the basis of expert engineering analysis commissioned by the launch proponent and agreed by the owners of the space launch facility and the relevant asset.

3.2.6 In the event the parties do not agree within a reasonable time, the Minister will determine such debris based on expert engineering analysis (commissioned by the owner of the space launch facility) and cases put forward by the owners of the asset and launch facility. Further arrangements for the determination of trigger debris are set out in the "Administrative Arrangements for the Classification of Assets for Space Launch Activities".

Protected Asset

3.2.7 A Protected Asset must be at least 10km outside the 10^{-7} impact probability isopleth for trigger debris on a facility of its physical dimensions, on a per launch basis.

3.3 UNPROVEN LAUNCH VEHICLE SAFETY STANDARDS

3.3.1 An unproven launch vehicle shall be restricted from flying in the vicinity of significantly populated areas. In this context, "in the vicinity of" means within 50 kilometres.

3.4 NEW SPACE LICENCE SAFETY STANDARDS

3.4.1 A launch vehicle shall be restricted until it has completed three consecutive successful launches under a space licence. Designated Assets will be treated as Protected Assets until three consecutive successful launches have been completed under a space licence.

3.5 CONTROLLED AREA SAFETY STANDARDS

3.5.1 A controlled area is an area for the intended impact of returned space objects, called a landing site, or for scheduled debris, called a drop zone. A controlled area is defined as a four standard deviation dispersion footprint around the nominal impact point for the return of a space object or for scheduled debris. The probability of impact within the controlled area is 0.99967. The third party casualty and asset risk safety standards also apply in controlled areas.

Drop zones

3.5.2 A drop zone is an area for the impact of scheduled debris from a space object. Scheduled debris may include jettisoned booster rockets, rocket motor stages, payload fairings, nose cone, or other debris which is scheduled to fall to ground as a result of a successful launch.

3.5.3 To meet the per launch third party individual risk standard, the launch must not proceed if a third party individual may be within the area around the nominal impact point defined by the 10^{-7} individual risk isopleth during the time period for the drop. The launch must not proceed unless the area within the 10^{-7} individual risk isopleth is monitored and an all clear signal is given from the drop zone, unless the licensee can establish that pre-launch surveillance of the drop zone is not necessary because of adequate exclusion arrangements in the case of land drop zones, or because of sufficiently low likelihood of persons being in the drop zone area in the case of marine drop zones.

3.5.4 The launch must not proceed unless every individual within the drop zone area during the relevant period has been informed of the launch.

3.5.5 The launch must not proceed if a Designated Asset is within the drop zone area.

3.5.6 The launch must not proceed unless the party responsible for the launch is able to monitor and record the location of all drops intended to fall into a drop zone area proximate to a Designated Asset (50 kilometres from the outer boundary of the drop zone area). The location of actual drops will be published within 5 working days of completion of the launch.

Landing site

Landing site

3.5.8 A landing site is an area for the planned return to the earth of a space object, including a reusable launch vehicle. To meet the per launch third party individual risk standard, the return must not proceed if a third party individual may be within the area around the nominal impact point defined by the 10^{-7} individual risk isopleth during the time period for the return.

3.5.9 The return must not proceed unless every third party individual within the landing site area during relevant period has been informed of the launch and of the nominal impact point and the nominal impact time.

3.5.10 The return must not proceed if a Designated Asset is within the landing site area.

3.5.11 The return must not proceed unless the party responsible for the return is able to monitor and record the location of all returns intended to fall into a landing site area proximate to a Designated Asset (50 kilometres from the outer boundary of the landing site area). The location of actual returns will be published within 5 working days of completion of the launch.

3.6 FLIGHT SAFETY SYSTEMS STANDARDS

A Flight Safety System (FSS) is to be operable throughout the entire powered flight phase and re-entry phase of a mission, must be at least single fault tolerant, and be capable of terminating the flight when nominal flight conditions have been transgressed by a predetermined margin. If the system is fully autonomous, it must incorporate at least one level of redundancy with a reliability requirement for successful operation of 0.999. If the FSS it to be activated manually, it must operate with a reliability of 0.998 with 95% confidence. On any manually operated FSS, evidence is required that tracking and monitoring of the flight will take place.

4. RISK HAZARD ANALYSIS METHODOLOGY

4.1 Introduction

4.1.1 Risk analyses are conducted to measure the risk to the public from a potential launch or re-entry mishap and to ensure that operations that may exceed a nominated threshold are not permitted. The public includes all persons except those participating in the launch or re-entry. The acceptable risk level adopted for commercial space missions should not exceed the risk expectations of the general public.

4.1.2 The hazards under consideration for launch operations in Australia are the consequences of debris striking persons either directly as inert debris or as explosive debris and as overpressure effects in the event of that explosion, and the consequences of debris striking designated assets. (Rocket launches also create toxic and distant focussing overpressure hazards. These are not usually considered in the design of a mission, but are a consideration as part of the "go - no go" decision on the day of launch. Procedures to determine if these are potential considerations are included as appendices.) The spent stages of expendable launch vehicles are to be treated as inert debris and appropriate analysis is to be conducted for their potential effects. The risk measure is generally known as Casualty Expectation (E_c) and is a calculation that expresses the collective risk (average number of casualties per launch) to the population exposed to the debris hazard. That is to say, the E_c calculation applies to the total population at risk rather than to each individual within that population as the concept of collective risk is inherent in the methodology. The average risk to an individual can be calculated by dividing the E_c figure by the number of persons in the population exposed to the hazard. This average individual risk can also be computed for specified classes of people or for people in each of various locations. A casualty is defined as a fatal or serious injury to a person.

4.2 Casualty Expectation

4.2.1 E_c is the average number of casualties that can occur if the proposed launch were to be repeated thousands of times. Its dimension is number of people and hence is not a probability. Mathematically the formal equation is

E_c = 1 × Probability (exactly 1 casualty) + 2 × Probability (exactly 2 casualties)

+ 3 × Probability (exactly 3 casualties) + ... = [Sigma] i × Probability (i)

4.2.2 The above equation is generally of little use however, since the probabilities of exactly two or more casualties are usually very small compared to a single casualty, particularly due to inert debris. Later in this section, a more useful formula is introduced.

4.2.3 A casualty is defined as either the serious injury or death of a person exposed to the launch. In order to be reasonable about the degree of injury, it is normal to use the term "serious injury" as defined in the *Air Navigation Act 1920* that broadly states that it is sufficiently severe to require hospital care. There are two reasons for using casualty as the risk measure instead of fatality:

4.2.3.1 The effects of rocket launches can be due to direct impact of debris, overpressure from explosions, and toxic gases from burning propellants. The ratio of casualties to fatalities is quite different in each of these cases. Direct impact by non-exploding debris can cause both injuries and fatalities. There may be no fatalities from toxic gases while there are hundreds of casualties. With overpressures, direct impingement on people close to the source can cause both injuries and fatalities while broken glass from distant focusing of overpressure can produce many injuries but few or no fatalities. Thus, if fatality is the only measure, consequences from toxic gas and distant breakage of glass can be overlooked and not indicate the true consequence of the accident.

4.2.3.2 The cost established in the courts of a severe injury versus a fatality is often about the same.

4.2.4 Casualty Expectation is a measure of <u>risk</u>. Whereas <u>hazard</u> describes the intensity of the effect, for example the intensity of the overpressure loads from an explosion over a region. Risk takes into consideration the extent and probability of the explosion hazard together with where the people are with respect to the explosion and their vulnerability to the explosive effects.

4.2.5 The simplest Equation for calculating E_c is

$$E_c = P_E \, P_{I|E} \times N_F \times A_C \times N_P / A_P$$

where

P_E is the probability of the event. This can be the probability of failure resulting in a particular failure response mode occurring during a brief interval of flight time, [Delta]t (a failure response mode is the dynamic characteristics, such as a tumble turn, that occurs due to a particular vehicle failure);

$P_{I|E}$ is the conditional probability given the event (failure response mode occurring during [Delta]t) that fragments of a particular fragment group (a group contains fragments with common characteristics such as their weights, ballistic coefficients, etc.) will land on a particular population centre;

N_F is the number of fragments in the group

A_C is the casualty area associated with each fragment in the particular fragment group. Casualty area is a region within which an individual is a casualty due to direct fragment impact, explosive effects from impact, secondary debris caused by roof penetration, etc

N_P is the number of people in the population centre; and

A_P is the area of the population centre.

Note that the ratio of N_P/A_P is the population density of the population centre.

4.2.6 The above E_c is for a single event (particular failure response mode of the vehicle occurring during a specific [Delta]t) for one class of fragments and for a specified population center assumed to have uniformly distributed population. This equation would be appropriate for calculating the E_c arising from sub-orbital missions because they can be described by few events, can be geographically contained, and would not need to overfly population centres.

4.2.7 The potential risks posed by commercial satellite launch services on the other hand present more complex hazard scenarios that need to be addressed in a more comprehensive manner. This is achieved by adopting an equation for calculating E_c that embraces the general case.

4.2.8 The more general definition of casualty expectation for a particular time interval is

where the subscripts i, j and k are the indices for failure mode, fragment group and population centre, respectively, and

P_{pf} = probability of failure from any failure mode prior to the current time interval (note that if the vehicle failure rate is sufficiently low, the value of $1-P_f$ is always near 1.0 and can be assumed to be 1.0 without significantly affecting the risk calculations)

P_i = probability of failure mode i occurring during the time interval

$P_{I,ijk}$ = probability of impact for failure mode i, fragment category j and population centre k

$A_{c,ij}$ = casualty area for failure mode i, fragment j

$N_{f,j}$ = number of fragments in fragment category j

$N_{p,k}$ = number of people in population centre k

$A_{p,k}$ = area of population centre k

$D_{p,k}$ = $N_{p,k}$ / $A_{p,k}$ = population density for population centre k

4.2.9 For the prediction of the risk (E_c) prior to a launch, the failure rate of the vehicle is considered. To do this, the flight time of the vehicle is usually divided in many very short successive time intervals. During each of these time intervals each of the credible response modes are considered as they derive from the vehicle failure modes. (Candidate vehicle failure response modes are failure on-course [explosion or thrust termination], malfunction turn off-course ranging from gradual to severe turns, failure to initially pitch over, gross azimuth malfunction, etc.). For each of these modes the debris footprint (impact distributions for all categories of debris) is computed for the debris predicted to result from the particular failure response mode and failure time interval, [Delta]t. The footprint is then used to compute the impact probability for each fragment category for each affected population area. Then the corresponding E_c is computed for each fragment for each population centre and these are summed over all fragments and population centres, resulting in the conditional E_c given that the failure response mode occurs during [Delta]t. This is then repeated for each of the credible modes of vehicle failure that could occur during the time interval [Delta]t. If there is a Range Safety System (man-in-the-loop or autonomous) it may activate and terminate thrust and possibly break up the vehicle during the vehicle malfunction. This action should also be modeled to more accurately determine where debris would impact.

4.2.10 In order to get the E_c contribution for the time interval, the probability for each mode of failure is introduced. This is generally computed from the predicted or assumed rates of the failure response modes by multiplying the rates by the duration of the short time interval. The E_c contribution is then multiplied by this probability. To account for the fact that the vehicle cannot fail during the current time interval if it has already failed at an earlier time, the result is also multiplied by the probability that the vehicle has not already failed, which is computed from the total failure rate (versus time, all failure modes) up to the time of the current time interval. Typically this last probability is very close to 1.0 and does not significantly alter the resulting E_c.

4.2.11 The E_c for a small time interval, as defined above, could be interpreted as an "instantaneous" E_c, although the value of E_c will be dependent on the particular value selected for the duration of the time interval. Note that the failure probability for a segment of flight time covering the small time interval (say for a segment of flight during which the projected debris pattern is crossing over a densely populated area) could be set to a selected value (with corresponding values for each failure mode that add up to this failure probability) so as to emphasise the risk potential in that segment. Note also that, in general, a given population centre will be exposed to the hazard for more than one time interval. Thus, the contribution of a single interval would not be comparable to an acceptable risk criterion for the total risk to the population centre.

4.2.12 The total collective E_c for the mission, or for a specified segment of flight, is computed by summing the E_c values for all applicable time intervals. The E_c for specific population centres can be computed by considering each population centre separately in the above process (i.e. by eliminating the summation over population centres, considering only a single centre).

4.2.13 Calculating the E_c for the return of spent booster stages and fairings can be performed with the understanding that the event has a probability of 1.0 (actually [1 - probability of failure to that point in flight]). Further details for analysing this case are in Section 5.

4.2.14 Each element of the general E_c computation is described in greater detail below.

4.3 Mutually Exclusive Events

4.3.1 Because E_c is a function of the probability of failure and other potentially variable parameters, it also must have changing and mutually exclusive values at each failure time interval, [Delta]t. Individual E_c calculations for each time interval are mutually exclusive because they are derived from mutually exclusive failure probabilities.

4.3.2 An extension of the mutually exclusive concept dictates that it is inaccurate to add the Ec of the first stage of flight to the Ec from the second stage of flight to get a total Ec and ignore the fact that a vehicle that fails during first stage cannot fail during second stage. The failure during the second stage can only occur when there is no failure during the first stage of flight. This problem is accounted for by the expression $(1-P_f)$ in the E_c general equation and is best illustrated by using an event tree.

4.3.3 Consider a hypothetical mission involving a vehicle with three primary periods of flight (stage I, stage II and return from orbit) with the probability of failure during the first stage of

0.1, the probability during the second stage of 0.1, and the probability during re-entry of 0.05. In addition, assume that the average consequences in terms of casualties given a Stage failure are:

Ec (given a Stage I failure) = 0.00015,

Ec (given a stage II failure) = 0.00010, and

Ec (given a failure during reentry) = 0.00005.

4.3.4 If the failures in the previous periods of flight were to be ignored in the event tree (See Figure 1), then the probability of failure during Stage II is 0.10 instead of the 0.09 in the figure; and the corresponding probability of failure during reentry is 0.05 instead of the 0.045 in the figure. If these probabilities are used and substituted into the figure, the total Ec becomes 27.5×10^{-6} instead of the correct value of 26.25×10^{-6}. (Note: The digits after the decimal point are shown here to help demonstrate the computation, but this type of analysis generally does not have an accuracy to warrant more than two significant figures, i. e., in this case, 26.25×10^{-6} becomes 26×10^{-6}.)

The process shown above should really be done continuously through flight (e.g. you cannot fail at 100 seconds if you have already failed at 50 seconds). By ignoring conditionality of the probabilities, the risks are always overestimated, although the effect is less as the estimated failure rate decreases.

4.3.5 The event tree for the example above is shown in Figure 1.

Period of Flight | Comb- ined prob. | Conse- quence given the event | Ec given period of flight

(Ec given failure in the particular Stage)

Stage I flight | Stage II flight | Return from orbit

Stage I fails | 0.100 | 0.00015 | 15.0×10^{-6}

prob = 0.1

Stage I succeeds
Stage II fails

0.090 | 0.0001 | 9.00×10^{-6}

prob = 0.9 | prob = 0.1

Stage II succeeds
Reentry fails

0.0405 | 0.00005 | 2.025×10^{-6}

prob = 0.9 | prob = 0.05

Reentry succeeds | 0.7695 | 00

prob = 0.95

Total

26.0×10^{-6}

Figure 1. Sample Event Tree to Illustrate Ec Computed with Consideration of Failure Conditional upon Success in the Previous Stage

4.4 Computing Probability of Failure

4.4.1 The probability of each possible outcome can be divided into the probability of success (P_s) and the probability of failure (P_f). The sum of these probabilities must be equal to 1.0 and can be expressed as:

$$P_s + P_f = 1.0$$

Where P_f represents the value of the probability of failure (all failure modes) at a discrete time interval during a launch event (eg first stage boost). If P_i represents the probability of failure mode i occurring during the discrete time interval, the probability of any failure mode occurring, P_f is defined by Ó P_i.

4.4.2 The probability of failure can be determined from historical records for mature launch vehicles or from comparative analyses and engineering failure mode analyses (eg Failure Mode Effects and Criticality Analysis) for new launch vehicles. Although it is recognised that actual mishaps often differ from predicted outcomes, failure analysis nevertheless serves as a valuable tool for assessing the potential risk to public safety.

4.4.3 Launch vehicles can be classified into four categories when considering failure probability: new ELVs, new RLVs, mature ELVs and mature RLVs. The determination of failure probability is easiest with the mature vehicles because it can be based on statistics from actual launch history. For new vehicles, the problem is different. Vehicle development organizations have tended to use optimistic estimates of reliability and corresponding failure probability because of their desire to claim a high likelihood of mission success. On the other hand, range safety organizations have felt it necessary to require more, sometimes much more, conservative estimates in support of their responsibilities to protect people and property on and near their ranges.

4.4.4 The best basis for an estimate of the performance of a new vehicle is how other vehicles of its class have performed in the past, and this is the basis of the approach used here. It is also reasonable to separate ELVs and RLVs because the RLV will have redundancies and robustness in some systems that should either reduce the failure rate or provide less risky abort modes where recovery is a goal and, presumably, because of the greater investment in quality control.

4.4.5 Use of the total failure probability of a vehicle alone is not sufficient for a risk analysis. Where an estimate of mission failure probability is adequate from a mission performance standpoint, the failure probability for a risk analysis must be broken down into separate vehicle failure response modes for a sequence of time intervals. It is appropriate to use a mechanism such as an event tree to show all of the different responses and then allocate probabilities for each of the responses. There are two options for obtaining the conditional probabilities for the different responses:

4.5.1 Generic probabilities based on the general experience of all vehicles over the last 10 to 20 years; or

4.5.2 Probabilities based upon the manufacturer's own failure mode and effect analyses and reliability analyses.

4.4.6 Failure probability for a specified flight time interval divided by the length of the interval yields a failure rate, if the failure rate over that time period is assumed constant. Failure rate is frequently higher earlier in the flight and thus the failure rate can decrease over the powered flight period. In that case, the integral of the failure rate over time is equal to the failure probability. If there is no direct evidence of this decrease, then a constant rate can be assumed. Note that the failure rate is determined over periods of powered flight only and not over coast periods. Thus if a launch is over 500 seconds of operation with 200 seconds of coast, then the powered flight phase for failure rate considerations is 300 seconds. There can be event-related failures (staging, failure of an engine to start, etc.) and these should be given consideration not as rates but as discrete probabilities at those particular times. During an exoatmospheric coast phase the IIP does not move, thus any failure during that time can be treated like an event-related failure, i.e. discrete.

4.4.7 The following models are to be used for the four classes of vehicles:

New Vehicles

The following equation is to be used for calculating the failure probability[1] for new ELVs and RLVs.

[2]

where n is the number of launches of a vehicle and r is the number of failures. "*a*" is a failure probability assigned to a first launch. For instance, from actual ELV launch history about 25% of the new vehicles have failed, thus we will assign *a* = 0.25.[3] The parameter x is an arbitrary factor that weighs the importance of general vehicle flight experience (past history of ELVs) against the actual flight experience of this particular vehicle (r failures in n launches). "x" can have any value from zero to infinity. If x = 0, no credit is given to past generic flight experience and if x = [infinity], no credit is given to actual flight experience of the vehicle. We will propose x = 4 because it starts with the generic launch experience but allows the computed P_f to adapt fairly rapidly to actual flight experience. Thus for ELVs

For RLVs, consideration may be given to the higher levels of redundancy and other features that establish high reliability and reusability, where the licensee can demonstrate that a new RLV will have reliability greater than a new ELV. To date, the only RLV is the man-rated Space Shuttle which by actual experience (as of 1 March 01) has a failure probability of 1/102 based on number of failures, r, divided by number of launches, n. It is assumed that at the time of a first launch no RLV can be proven to have the Space Shuttle reliability. However, to account for the expected higher reliability of RLVs, a model is proposed that allows a new RLV to have a failure probability between that of a new ELV and the Space Shuttle. Assume a lognormal probability distribution characterizing the uncertainty in the estimate of the failure probability of the new RLV. Let the 5-percentile of the cumulative probability distribution be set at the 0.01 probability level (corresponding to the Space Shuttle) and the 95-percentile set at the 0.25 probability (that of a new ELV).

The prior mean estimate of the new RLV failure probability is then calculated as follows:

Given that the 5-percentile and 95-percentile are 0.25 and 0.01, respectively, then:

lognormal median, M = $[(95\text{-percentile})*(5\text{-percentile})]^{1/2} = (0.25*0.01)^{1/2} = 0.05$

error factor, K = [(95-percentile)/(5-percentile)]$^{1/2}$ = (0.25/0.01)$^{1/2}$ = 5

standard deviation, [sigma] = ln(K)/1.65 = 0.9754

mean, m = M exp([sigma]^2/2) = 0.080

= the proposed value of "*a*" for RLVs

The P_f equation for RLVs becomes (using x=4)

[4]

Note that whereas the P_f equation given for new ELVs should be considered normative for P_f computation, the above equation for RLVs must be considered indicative and cannot be adopted before the licensee provides sufficient evidence that the proposed new RLV will indeed have reliability greater than that for a new ELV.

The tables that follow show some scenarios that reflect how P_f could change with flight experience

Table 1. P_F Computations for Several ELV Launch Sequences (a=0.25, x=4)

Condition	P_f before 1st Launch	P_f after last Launch
ELV succeeds on 1st launch	0.25	0.20
ELV fails on 1st launch	0.25	0.40
ELV succeeds on 1st 5 launches	0.25	0.111
ELV has one failure in 5 launches	0.25	0.222
ELV succeeds on 1st 10 launches	0.25	0.071
ELV has one failure in 10 launches	0.25	0.143

Table 2. P_F Computations for Several RLV Launch Sequences (a=0.08, x=4)

Condition	P_f before 1st Launch	P_f after last Launch
RLV succeeds on 1st launch	0.08	0.064
RLV fails on 1st launch	0.08	0.264
RLV succeeds on 1st 5 launches	0.08	0.036
RLV has one failure in 5 launches	0.08	0.147
RLV succeeds on 1st 10 launches	0.08	0.023
RLV has one failure in 10 launches	0.08	0.094

Mature Vehicles

A mature vehicle is defined as a vehicle that has had greater than five successive successful flights (subject to judgement, additional flights might be required if, for example, a near-miss or other reliability problem may have occurred without causing a total failure). When a vehicle is considered mature, its P_f can be computed directly from the number of failures, r, in n flights. However, a probability model is needed that will not produce a P_f equal to zero when the launch experience is no failures (r=0) in n launches. This is avoided by using the confidence distribution associated with the proportion, r/n, for all r and n.[5] The confidence distribution is based on the binomial distribution and the computation (outside of reading directly from tables) is rather complex. The average of the upper and lower 50% confidence bounds is used to estimate the median of the distribution. This number is always larger than zero even if r=0.

After five successive successes, the mature vehicle methodology can be applied at any time that its result produces a lower failure probability than that produced by the new vehicle methodology.

The following tables provide the P_f for new and mature vehicles for n=0 to 100. The mature vehicle model is valid after five successive successes and when its value is less than the value from the new vehicle P_f model. The new vehicle model assumes a=0.25 and x=4. If these values are changed, the numbers in the tables must change accordingly. The selection of a=0.25 is based on recent past experience with new vehicles.

Table 3. Failure Probabilities for New and Mature Vehicles

	r=	0		r=	1		r=	2		r=	3	
n	r/n	New Vehicle Pf Model	Mature Vehicle Pf Model	r/n	New Vehicle Pf Model	Mature Vehicle Pf Model	r/n	New Vehicle Pf Model	Mature Vehicle Pf Model	r/n	New Vehicle Pf Model	Mature Vehicle Pf Model
0	-	0.250	-									
1	0.000	0.200	Not appl.	1.000	0.400	Not appl.						
2	0.000	0.167	Not appl.	0.500	0.333	Not appl.	1.000	0.500	Not appl.			
3	0.000	0.143	Not appl.	0.333	0.286	Not appl.	0.667	0.429	Not appl.	1.000	0.571	Not appl.
4	0.000	0.125	Not appl.	0.250	0.250	Not appl.	0.500	0.375	Not appl.	0.750	0.500	Not appl.
5	0.000	0.111	Not appl.	0.200	0.222	Not appl.	0.400	0.333	Not appl.	0.600	0.444	Not appl.
6	0.000	0.100	0.055	0.167	0.200	Not appl.	0.333	0.300	Not appl.	0.500	0.400	Not appl.
7	0.000	0.091	0.047	0.143	0.182	0.161	0.286	0.273	Not appl.	0.429	0.364	Not appl.
8	0.000	0.083	0.042	0.125	0.167	0.142	0.250	0.250	0.261	0.375	0.333	Not appl.
9	0.000	0.077	0.037	0.111	0.154	0.127	0.222	0.231	0.233	0.333	0.308	0.340
10	0.000	0.071	0.033	0.100	0.143	0.115	0.200	0.214	0.210	0.300	0.286	0.307
12	0.000	0.063	0.028	0.083	0.125	0.096	0.167	0.188	0.176	0.250	0.250	0.257
15	0.000	0.053	0.023	0.067	0.105	0.077	0.133	0.158	0.141	0.200	0.211	0.207
20	0.000	0.042	0.017	0.050	0.083	0.058	0.100	0.125	0.107	0.150	0.167	0.156
25	0.000	0.034	0.014	0.040	0.069	0.047	0.080	0.103	0.086	0.120	0.138	0.125
30	0.000	0.029	0.011	0.033	0.059	0.039	0.067	0.088	0.072	0.100	0.118	0.105
35	0.000	0.026	0.010	0.029	0.051	0.034	0.057	0.077	0.062	0.086	0.103	0.090
40	0.000	0.023	0.009	0.025	0.045	0.029	0.050	0.068	0.054	0.075	0.091	0.079
45	0.000	0.020	0.008	0.022	0.041	0.026	0.044	0.061	0.048	0.067	0.082	0.070
50	0.000	0.019	0.007	0.020	0.037	0.024	0.040	0.056	0.043	0.060	0.074	0.063
75	0.000	0.013	0.005	0.013	0.025	0.016	0.027	0.038	0.029	0.040	0.051	0.042
100	0.000	0.010	0.003	0.010	0.019	0.012	0.020	0.029	0.021	0.030	0.038	0.032
(1) New vehicle Pf model												
Pf = (ax+r)/(x+n)	a =	0.250	x =	4.0								
(2) Mature vehicle Pf												

model

Pf = Mean of upper & lower 50% confidence of a proportion (r/n)

Table 3 (cont.). Failure Probabilities for New and Mature Vehicles

.	r=	4		r=	5		r=	6	
n	r/n	New Vehicle Pf Model	Mature Vehicle Pf Model	r/n	New Vehicle Pf Model	Mature Vehicle Pf Model	r/n	New Vehicle Pf Model	Mature Vehicle Pf Model
4	1.000	0.625	Not appl.						
5	0.800	0.556	Not appl.	1.000	0.667	0.935			
6	0.667	0.500	Not appl.	0.833	0.600	0.813	1.000	0.700	0.845
7	0.571	0.455	Not appl.	0.714	0.545	0.704	0.857	0.636	0.839
8	0.500	0.417	Not appl.	0.625	0.500	0.620	0.750	0.583	0.739
9	0.444	0.385	Not appl.	0.556	0.462	0.553	0.667	0.538	0.660
10	0.400	0.357	0.404	0.500	0.429	0.500	0.600	0.500	0.597
12	0.333	0.313	0.338	0.417	0.375	0.419	0.500	0.438	0.500
15	0.267	0.263	0.272	0.333	0.316	0.337	0.400	0.368	0.402
20	0.200	0.208	0.205	0.250	0.250	0.254	0.300	0.292	0.303
25	0.160	0.172	0.165	0.200	0.207	0.204	0.240	0.241	0.244
30	0.133	0.147	0.138	0.167	0.176	0.170	0.200	0.206	0.208
35	0.114	0.128	0.118	0.143	0.154	0.146	0.171	0.179	0.175
40	0.100	0.114	0.103	0.125	0.136	0.128	0.150	0.159	0.153
45	0.089	0.102	0.092	0.111	0.122	0.114	0.133	0.143	0.136
50	0.080	0.093	0.083	0.100	0.111	0.103	0.120	0.130	0.123
75	0.053	0.063	0.055	0.067	0.076	0.069	0.080	0.089	0.082
100	0.040	0.048	0.042	0.050	0.058	0.052	0.060	0.067	0.061

(1) New vehicle Pf model

Pf = (ax+r)/(x+n)

(2) Mature vehicle Pf model

Pf = Mean of upper & lower 50% confidence of a proportion (r/n)

<u>Vehicles with Combinations of New and Old Subsystems</u>

Vehicles change; they may switch or add stages or change guidance systems. This complicates the definition of flight experience per the definitions presented above. The most conservative approach is to consider a vehicle subsystem change as making the vehicle go back to being a new vehicle with no flight experience. This can be used as the starting point. If the applicant does change a stage, for example, but wants to claim successful flight experience for the rest of the vehicle, he must first develop a subsystem failure probability model using the vehicle prior to modification that allocates probabilities to subsystems and sums to the P_f as formulated above. He must then assume no flight experience for the entire vehicle, i.e. use the new vehicle formulation given above, and determine what allocation would be given to that element that is new. The probability of failure of the new element resulting from the allocation is then introduced into the original model to produce a new system failure probability. It is important that in the process of performing a risk analysis, that the period of performance of the new element must reflect the higher failure probability rate.

This method can also be applied to RLVs that have the opportunity to test part of the system repeatedly before the first launch of the integrated system. Those parts of the system that have been proven can be assigned a lower failure probability while those untested elements must conform to the general rules described above.

A simple example of this method is illustrated in Table 4. Assume a two-stage vehicle that has been launched many times and has an established failure probability equal to 0.04. Assume also, based on experience and manufacturer FMEAs, etc., that the failure probability is allocated as follows:

(1) Stage I propulsion P_f is 35% of the system P_f,

(2) Stage II propulsion P_f is 35% of the system P_f and

(3) Guidance and control P_f is 30% of the system P_f.

The applicant chooses to change the Stage II propulsion. What is the revised total P_f for the system?

Table 4. Revised Vehicle System Failure Probabilities

Total Failure Probability, P_f	P_f, Orig. System	P_f, All New System	P_f, Modified System
	= 0.04	= 0.25	
Stage I Engine - 35%	**0.014**	0.0875	0.014
Stage II Engine - 35%	0.014	**0.0875**	0.0875
Guidance and Control - 30%	**0.012**	0.075	0.012
Revised Total Probability, P_f	0.1135		

Another case is when a mature vehicle has an added new stage. In this case, the first step assumes that the vehicle is entirely new and the probabilities are allocated accordingly. The second step goes back to the original vehicle and computes the allocation and resulting failure probabilities based on actual experience. In the final step, the numbers for the mature stages/systems are substituted into the model based on the new system. This produces a P_f model that has a lower failure probability that an all new vehicle, but has a higher failure probability than the original mature vehicle and allocates the higher failure rate to the new stage.

4.4.8 Allocation of response modes and determination of failure rate

A risk analysis uses the failure rate of the vehicle, which normally varies with the stage of flight. If data about the vehicle that indicate otherwise are not available, the failure probability can be allocated evenly between each stage of flight unless the vehicle is part mature and part new as discussed above. The failure rate is generally higher at the beginning of stage operation because of the possibility of failure to start. Again if data are not available, a small percentage of the failure probability of the stage (e. g. 5%) can be assigned to the startup failure probability. The remaining failure probability of the stage can be distributed uniformly over the time of powered flight of the stage unless there are data that indicate that the failure rate will not be constant.

The vehicle response due to the malfunction is important. If the failure initiates a turn that can move the vehicle off the nominal flight path, it will produce dispersions in the impact points of the intact vehicle or the vehicle debris into areas away from the nominal trajectory. These types of failures need to be accounted for separately from those failures that produce engine shutdown or other failures that do not cause deviations of the vehicle from the nominal flight path prior to vehicle breakup or initiation of free fall.

Example: Using the example from 4.7, assume that the powered flight time of Stage I is 100 seconds and that of Stage II is 200 seconds. Table 5 gives the failure rate of the modified system in Table 4 .[6]

Table 5. Vehicle Failure Rates

	Failure probability and failure rate
Failure probability for Stage I engine start-up	= 0.02×0.014 = 0.00028
Engine failure rate during Stage I operation	= 0.98×0.014/100 = 0.000137 failures/sec
Guidance and control failure rate during Stage I and Stage II operation	= 0.012/300 = 0.00004 failures/sec
Failure probability for Stage II engine start-up	= 0.02×0.0875 = 0.00175
Failure rate during Stage II operation	= 0.98×0.0875/200 = 0.000429 failures/sec

Table 5 defines the assignment of failure probabilities and failure rates between stages but does not allocate between vehicle responses that stay within the trajectory plane versus those that deviate off to the right or left. Assume that when the guidance and control fails it produces motion out of the plane of the trajectory 66% of the time. The failure probabilities and failure rates are now allocated as shown in Table 6.

Table 6. Vehicle Failure Rates and Probabilities Allocated Between

Failure Response Modes

	Failure probability and failure rate	
	On-trajectory response mode (in-plane)	Off-trajectory response mode (out of plane)
Failure probability for Stage I engine start-up	0.00028 (from previous table)	0.0
Failure rate during Stage I operation	Engine + 0.33 of G&C failure rate = 0.000137 + 0.33×0.00004 = 0.00015	0.666 of G&C failure rate = 0.666×0.00004 = 0.0000266

Failure probability for Stage II engine start-up	0.00175	0.0
Failure rate during Stage II operation	(from previous table) Engine + 0.33 of G&C failure rate = 0.000429 + 0.33×0.00004 = 0.000442	0.666 of G&C failure rate = 0.666×0.00004 = 0.0000266

This example demonstrates the computation and allocation of failure probabilities and failure rates for two different response modes. The particular allocations are for demonstration only and should not be the basis of a licensee computation. The computation by the licensee should either be based upon vehicle history, FMEA or general launch vehicle experience.

4.4.9 Generic allocation of failure probabilities

Table 7 was developed from actual launch history of a variety of ELVs. It allocates the probability of failure between a number of generic failure classifications. The numbers in the table are intended to provide guidance to what may be expected, but should not be used in a risk analysis for a vehicle unless there are no vehicle specific sources. If they are used, the values should be varied parametrically to determine if the final results of the risk analysis are materially affected by the particular allocation of probabilities.

Table 7. Probabilities of Various Vehicle Failure Modes Based on

International Launch Vehicle Data (1987-2000)[7]

Failure Mode	Vehicle Response	Percentage of failures (out of 100%)
Engine failure to start	Vehicle has no thrust, forward acceleration ends	5.7%
Failure of engine to reignite	Vehicle has no thrust, forward acceleration ends	7.1%
Control system - loss of thrust vector control	Vehicle tumbles or turns away from the velocity vector at the time of the failure	10.0%
Guidance and control - loss of vehicle attitude reference	Either the vehicle moves in a different plane than the intended trajectory plane or takes on a new heading and moves stably in that direction	4.3%
Engine shutdown, loss of thrust	Vehicle stops accelerating, stays intact unless it is destroyed by RS or breaks up aerodynamically	30.0%
Explosion somewhere in the liquid propulsion system	Vehicle loses thrust and breaks up with some high velocity fragments	7.1%
Solid rocket motor explosion	Vehicle loses thrust and can produce high velocity fragments	2.9%
Pitch attitude error, failure	Pitch attitude wrong but vehicle remains in the original trajectory plane	4.3%
Stage, booster or payload separation failure	Hang-up of separation or preliminary separation can lead to various abort behaviors (aerodynamic breakup, explosions, etc.)	15.7%
Software error	Can lead to wrong orbital condition or affect the control system response	4.3%
Steering or thrust failure	Not considered a failure mode that affect public	8.6%

leading to improper orbital insertion safety

4.4.10 Any flight that is launched internally in the country or over another country has the potential for causing debris to fall on people. For launches of new vehicles, the following criteria must be met:

4.4.10.1 The preflight risk prediction that includes the phased reliability criteria must fall within the required Launch Safety Standards.

4.4.10.2 An unproven vehicle may be restricted from flying in the vicinity of significantly populated areas.

4.4.11 As indicated in Section 2, a $P_f = 1.0$ can be adopted when calculating E_c for spent ELV stages being returned to earth as the failure mode can be described as propulsion system shutdown.

4.4.12 Unproven vehicles are those that have not achieved five consecutive missions without a catastrophic failure (a failure that could conceivably hazard life and property) and therefore are subject to the phased reliability criteria.

4.4.13 A significantly populated area includes a township or settlement but not a homestead.

4.5 Computing Probability of Impact and Casualty Expectation for Different Flight Phases

Calculating Downrange Risk by the Corridor Method

4.5.1 A relatively simple risk analysis procedure can be used if the risks to be computed are downrange of the general launch area, do not involve return from orbit and do not involve actions due to range safety criteria that will distort the impact distributions. The elements of the methodology are pictured in Figure 2.

4.5.2 The equations associated with the methodology are as follows:

Impact Probability on a population centre: $P_I = P_I\,(\text{downrange}) \times P_I\,(\text{crossrange})$

where

$P_I\,(\text{downrange}) = (\text{failure rate}) \times (A_{pop})^{1/2} / (\text{IIP rate})$

$P_I\,(\text{crossrange}) = \int p(y)dy$ where the integration limits are $y_c - ½\,(A_{pop})^{1/2}$ and $y_c + ½\,(A_{pop})^{1/2}$

and where p(y) is the probability density function for crossrange dispersion for the particular fragment category. The US FAA has published Advisory Circular 431.35-1 "Expected Casualty Calculations for Commercial Space Launch and Reentry Missions" which provides appropriate equations for calculating the probability of debris impact on populated areas. Further information is also available in the FAA document "Supplemental Guidance for Unguided Suborbital Launch Vehicles" which can be found on website http://ast.faa.gov/contest/sag_uslv.htm.

4.5.3 The casualty expectation assuming fragment group "i" is hazarding a specific population centre or asset is calculated by using the following equation:

$E_{Ci} = P_I$ ´ N_{frag} ´ $A_{cas.frag.}$ ´ N_{pop} / A_{pop}

(Note P_I is a product of the probabilities described in Figure 2)

The total casualty expectation E_C from all fragment groups on the population centre is:

E_C = [[summation]]E_{Ci}

This method must be applied to all potentially affected population centres to obtain the total casualty expectation. Development of the population library is discussed in the section on Population Density. The impact points used in the above analysis are drag corrected and associated with the appropriate fragment group.

A further issue in relation to public risk due to the landing of re-entry vehicles or expended ELV stages is that the landing area or exclusion zone must be sufficiently large to ensure that the returning vehicle or stage will land there with a high degree of predictability. The landing size or footprint is to be calculated by adopting four standard deviations (4-sigma) to the nominal dispersal characteristics of the returning vehicle. The 4-sigma footprint describes the area where the vehicle will land with a 0.99967 probability assuming that no major system failure has occurred. Any major failure would therefore be considered under the standard accident debris scenario rather than as a planned return.

4.5.4 A simpler version of the corridor method uses only the vacuum impact points and groups all of the casualty areas of all the fragments into a single casualty area. This will produce approximate results that can be used in mission planning, but should not be used for a final casualty expectation prediction.

Figure 2. Diagram of the Elements of the Downrange Corridor

Methodology

4.5.5 In using the method described in 4.5.4, one should be cautioned that it could easily underestimate the crossrange effects of debris. If the crossrange standard deviation is based on the normal variations in the guidance and performance of the vehicle, it will be ignoring any velocity imparted to the debris from any explosion or other energy release in the breakup and also any malfunction/tumble behavior of the vehicle prior to breakup or abort. Thus, some perturbation analysis must be performed beforehand to produce crossrange uncertainties due to perturbations to the debris and perturbations due to malfunction behavior. These standard deviations can be root sum squared with the guidance and performance dispersions. If the results indicate marginal risk acceptability, it may be wise to consider performing a more robust debris footprint methodology that can simulate the actions of the range safety abort system.

Calculating Risk from Scheduled Debris (Spent Stages, Fairings etc)

4.5.6 During an ELV launch, certain elements of the rocket are jettisoned as the launch progresses. As each stage burns out, it is separated and follows a ballistic path to impact. In addition, certain other panels, fairings, etc. may be jettisoned. This scheduled debris happens with every successful launch and thus the mission must be planned carefully such that these items of debris do not create an unacceptable risk.

4.5.7 The procedure to compute the scheduled debris risk is as follows:

4.5.7.1 Define the state vector (position and velocity) of the stage at the time of jettison.

4.5.7.2 Determine the aerodynamic characteristics of the spent stage (drag coefficient, aerodynamic reference area, weight) and compute a drag corrected impact point. Consideration should be given as to whether the stage tumbles or stabilizes at a particular attitude during descent.

4.5.7.3 Develop impact uncertainties of the stage based on the uncertainties in the vehicle state vector at the time of jettison (is the vehicle flying fast, slow, high, low, right or left?). Also consider any perturbation velocities that may be applied during jettison, the effect of winds and wind uncertainties and aerodynamic lift effects. This process should produce a standard deviation of impact uncertainty in the uprange and downrange direction and another standard deviation in the crossrange direction. A more sophisticated analysis may produce an impact covariance matrix representing the impact dispersions that may indicate some rotation of the dispersions relative to the downrange and crossrange directions, but this is normally of secondary significance.

4.5.7.4 Using the standard deviations computed above, assume a bivariate normal distribution with its mean at the nominal impact point and with its two axes aligned respectively with the downrange direction and the crossrange direction (orthogonal). Note that if the dispersion along the uprange-downrange direction is large, the uprange dispersion component will be smaller than the downrange component. If this is the case, the analyst has the option of adjusting the nominal impact point to make the distribution symmetrical in the uprange-downrange direction, or to use a different standard deviation for the uprange direction than that for the downrange direction.

4.7.5.5 If there is an island, offshore oil platform, or any other population centre that is potentially at risk, the impact probability can be computed by integrating under the bivariate normal distribution. Figure 3 and the equation presented in Section 4.5.8 show the bivariate normal distribution, the threatened impact area, A, and the equation for computing the probability of impact.

Figure 3. Bivariate Normal Distribution Showing Impact Uncertainty

and the Area at Risk

4.5.8 The equation below is the calculation of the impact probability of a single object in an area, A, where the impact distribution is a bivariate normal distribution with the major and minor axes aligned along the x and y directions, respectively. The centre of the area, A, is at (x_A, y_A). Assume that x is in the downrange direction, and y is crossrange, positive to the left looking downrange. The mean for this distribution is assumed to be at the nominal impact location for the stage (or fairing or fragment), thus $\mu_x = \mu_y = 0$. For small values of P_I and few impacting stages/fragments, the individual P_I can be multiplied by the number of stages/fragments to get the total P_I.

[8]

[radical][sigma][sigma][pi][sigma][sigma]×[sigma][sigma]

4.5.9 The above process should be repeated for every jettisoned of stages, fairings, etc. Unless they are dropped together and have similar ballistic characteristics, the risks from each piece should be treated separately. When using this method it is important to realise that stages, fairings, etc. cannot be grouped in the same bivariate distribution unless they have the same mean impact point and downrange and crossrange uncertainties. If they do not, a new distribution must be computed for each. Two or more identical objects jettisoned at the same time can be treated together, however, and the impact probability (for relatively small P_I) is simply the product of the number of objects times the P_I for one. The same is true for casualty expectation, E_C, which can now be calculated from the equation in Section 5.3 above.

4.5.10 Probability-of-impact isopleths show the geographic distribution of impact probability on a map and depend on application. The isopleth positions change with the area of the people or place at risk, with the size of the debris fragments and the number of debris fragments. For example, the 1×10^{-7} P_I isopleth for impact on a person for a spent stage represents a boundary outside of which the stage will impact on a person only once in 10^7 opportunities. The 1×10^{-7} P_I isopleth on a large facility for that same spent stage would be further away from the nominal impact point than the 1×10^{-7} P_I isopleth on a person, because of the facility's larger size.

×

×

Figure 4. Sample P_I Isopleths

Calculating Risk from Failures in the Launch Area

4.5.11 Launch area risks are the most difficult to compute. At this time in flight, the IIP is not moving rapidly downrange and consequently the corridor method of risk analysis is not appropriate. Moreover, the abort criteria play a very important part and are used to restrain the motion not only laterally but also from moving back toward the launch site. Thus the analysis must model aborts in multiple directions. The programs to model all the aspects of launch area risks have become very elaborate. This discussion proposes a general approach along with certain requirements for sufficiency. One reference that offers insight into a more elaborate methodology is a paper by Baeker, Haber and Collins[9]. The procedure that follows suggests a Monte Carlo methodology.

- Establish the nominal trajectory and the normal deviations around the trajectory due to variations in performance and steering.

- Compute the malfunction turn behaviour of the vehicle if it goes into a tumble turn, normally assuming that the turn can be in any direction. Do this every several seconds of flight as necessary and for different thrust offset angles ranging from minimum to maximum. Assign a probability distribution to the likelihood of the magnitude of the thrust offset angle, given that the vehicle is in a malfunction turn.

- Determine the maximum product of dynamic pressure and angle of attack allowable by the structural design of the vehicle.

- Develop a debris list by category of ballistic coefficient

- Start a simulation just after lift-off. Randomly select a thrust offset angle and fly a malfunction turn until vehicle breakup or violation of abort criteria (the abort criteria can be based on vehicle attitude, violation of an abort limit line by the vacuum IIP or other). At breakup calculate the drag-corrected trajectories of each debris category using a randomly selected wind profile (generated by varying the wind using the mean wind and a wind uncertainty model). Repeat this process many many times for that initial failure time and then collect the impact data in separate groups for each debris category. Develop mean and impact covariances for each debris category to form a bivariate normal distribution. The bivariate normal distribution is of the same form as that used for the impact dispersion of empty stages. The next step of the sequence is to compute the impact probability for each population centre and the corresponding casualty expectation. All of these calculations are weighted according to the failure probability during that interval. The casualty expectations are stored for each population centre.

The above sequence is repeated for each flight time interval. The method is valid both for the launch area and beyond the launch area. The total casualty expectation is the sum of the casualty expectations from each time interval.

4.5.12 Impact probability isopleths can be computed by establishing a grid with an impact area at each intersection of the grid. An impact area size is then defined. For example, if the probability of impacting on a person is the objective then use an area of one square metre. If impact probability is needed for a larger area, e.g. a large building of 100 m by 100 m, then use an area of 10,000 square metres. Once the impact probability has been computed for each of the grid points, contours (isopleths) can be drawn that represent constant levels of impact probability.

4.6 Establishing a Debris Catalogue

4.6.1 Historically two methods have been used to define the debris that results from the destruct or breakup of a launch vehicle. The first is to use the vehicle breakup data provided by the vehicle manufacturer as part of the requirements for launch. These data includes the various parameters required for risk analysis such as fragment ballistic coefficient, weight, projected area and imparted velocity at breakup. Usually these data pertain to the debris that would result if flight termination action (destruct or thrust termination) were taken on the vehicle. These data are reviewed by the range safety organisation, or its supporting contractors, to verify its reasonableness/validity. Also the data may be improved using specially developed breakup models. This is particularly true for the debris resulting from the pressure rupture or destruct of a solid rocket motor, where models have been developed to predict the sizes and weights of the resulting pieces of solid propellant and motor casing. Data for other modes of vehicle breakup, such as breakup due to an explosion of the vehicle or due to aerodynamic and inertial loads acting on the vehicle, are usually estimated based on the flight termination breakup data, although in some cases the vehicle manufacturer may provide data for these other breakup modes.

4.6.2 The second method used to define the debris is to obtain from the vehicle manufacturer a detailed listing of the various parts and components making up the vehicle. This list is then used, with the aid of the manufacturer's structural engineers, to estimate the various pieces that will result. The parameters defining the debris pieces (ballistic coefficient, weight, projected area, etc.) are then computed based on the characteristics of the pieces. Velocities imparted due to an in-flight explosion are estimated using various software models. In fact these models also attempt to predict the sizes and weights of the fragments resulting from an explosion, but usually the results need to be "massaged" to get a reasonable debris list.

4.6.3 For the purpose of performing risk analyses, the debris data are grouped into "fragment groups" consisting of fragments having similar characteristics. Average characteristics are then computed and applied to all fragments in the group.

4.7 Computing Casualty Area

4.7.1 When debris impacts, there is a region on the ground in which a person who is present will become a casualty. The definition of casualty is severe injury (at least a visit to the hospital) or death. A person can become a casualty both outside and inside a shelter because of:

4.7.1.1 direct impact from debris,

4.7.1.2 being struck inside the structure from debris created by the fragment (e.g. roof failure),

4.7.1.3 direct overpressure and impulse from an explosion of vehicle or propellant and

4.7.1.4 debris effects internal to a structure on occupants due to a nearby explosion of a vehicle or propellant.

4.7.2 Characteristics of the debris that affect the casualty area are cross-sectional area, impact velocity, weight, impact angle, drag coefficient, and explosivity. Also the number of fragments is essential, since it is normally assumed that each fragment will land sufficiently away from any other to make the likelihood of two fragments striking the same person very unlikely. This is assumed to be the case too with explosive fragments that can have much larger casualty areas.

4.7.3 The issues to be considered when calculating casualty area include the effects of inert debris falling vertically and/or ricocheting, explosive debris, debris fragment size and number (debris catalogue), horizontal and vertical cross-sectional area of the "standard person", angle of impact, and calculation of the composite or effective casualty area. All of the above debris scenarios will depend on the type of launch vehicle failure e.g. the debris casualty area for a launch vehicle impacting intact can be expected to be significantly less than for an in-air explosive failure. Four underlying assumptions to be adopted are that

(1) the debris catalogue converts the total non-volatile mass of the launch vehicle (including payloads) into fragments that are potentially casualty producing,

(2) all fragments with weight and impact velocity above a specified threshold, either striking a person directly or glancing a person will result in death or serious injury,

(3) no individual debris casualty areas overlap, and

(4) the dimensions of a "standard person" are 0.3 metres in radius and 2.0 metres in height.

4.7.4 A methodology for calculating Casualty Area A_c is presented in the US FAA Advisory Circular mentioned above and for the information of and use by applicants is summarised below. However, the preferred methodology for calculating Casualty Area is addressed in a more comprehensive manner in Appendix 1.

4.7.5 The equation for calculating Casualty Area A_c is expressed as follows:

$A_c = A_{c(inert)} + A_{c(explosive)}$

where:

$A_{c(inert)}$ comprises a basic component $A_{c(basic)}$ which is made up of debris falling vertically and diagonally, and a ricocheting or skid component $A_{c(skid)}$, and

$A_{c(explosive)}$ which is the explosive debris contribution to Casualty Area calculated from converting propellant weights into equivalent TNT weights and using an explosive overpressure threshold of 25 kPa (overpressures of up to 65 kPa will be considered on a case by case basis).

$A_{c(basic)}$ can be calculated as a circular area encompassing the sum of the radius of a "standard person" and the radius of the fragment (vertically falling debris) plus the projected area encompassing the radius of a person plus the radius of the fragment multiplied by the tangential height of a "standard person" (diagonally falling debris). The equation for calculating $A_{c(basic)}$ is:

$A_{c(basic)} = \eth (r_p + r_f)^2 + 2(r_p + r_f)h_p$

where:

r_p is the radius of the "standard person",

r_f is the radius of the fragment, and

h_p is the height of the "standard person" divided by the tangent of the impact angle.

4.7.6 The figures below provide a diagrammatic clarification of how $A_{c(basic)}$ is determined:

Figure 6. Debris Falling Vertically

Figure 7. Debris Falling Diagonally

4.7.7 $A_{c(skid)}$ represents the adjustment to Casualty Area resulting from ricocheting or skidding fragments. This component of A_c is addressed in a study conducted by the Research Triangle Institute - Report No RTI/5180/60-31F of 13 April 1995 that the FAA has made available through AST's Web Site. The report provides the basis for calculating $A_{c(skid)}$. The study shows that the basic casualty area can be increased by a factor of 1.7 to 7.0 as a result of ricocheting or skidding fragments. The worst-case scenario using a factor of 7.0 should not be automatically adopted because factors such as altitude of the failure or type of terrain (pavement, soft ground) have a marked effect on the E_c computation.

4.7.8 The FAA Advisory Circular also addresses the explosive debris contribution to Casualty Area and this is summarised below:

$A_{c(explosive)}$ can be calculated from the equation:

$A_{c(explosive)} = \eth R_e^2$

where:

$R_e = K \times W^{1/3}$

and:

R_e is the radius for the explosive casualty area,

K is a distance scaling factor, and

W is the TNT equivalent weight of the propellant.

4.7.9 The factor K is addressed in a number of publications and two references provided by the US FAA are US DOD 6055.9-STD, DOD Ammunition and Explosive Safety Standards dated August 1997 and Chemical Propulsion Information Agency Publication 394, Hazards of Chemical Rockets and Propellants dated 30 June 1985.

4.7.10 As is mentioned above, the preferred method for calculating Casualty Area A_c has been prepared for the Australian Space Licensing and Safety Office by ACTA Inc. This methodology is fully self-contained and enables applicants to readily calculate A_c . The methodology is presented in detail in Appendix 1 and the subject matter is covered under the following headings:

4.7.10.1 Inert debris effects:

people in the open; and

people in structures.

4.7.10.2 Explosive debris effects:

determination of explosive yield - liquid propellants;

determination of explosive yield - solid propellants;

determination of overpressure and impulse;

impact on people in the open; and

impact on people in structures.

4.7.11 All the required equations, tables and graphs necessary for completing the calculation are provided in the methodology at Appendix 1.

4.8 Population Density

4.8.1 Population data must be generated for all locations that can potentially be at risk due to a launch. The population at risk is defined as that which has an individual risk of at least 10-9 due to debris on a per launch basis.

4.8.2 There are two options for defining population: distinct population centres and population density. The preference is the use of population centres because it allows for consideration of sheltering. Sheltering can be treated by percentages of the population in each sheltering category (in the open, in light shelters, etc.).

4.8.3 Generally, population data are required to be in more detail nearer the launch site, often requiring data for individual buildings. As the distance from the launch site increases, the data can be defined in terms of towns, cities and large open areas. To account for the rural populations, the flight corridor is usually divided into large rectangular areas to pick up the spread-out rural population. The populations in the cities and towns are, of course, not included in the populations of those rectangular areas.

4.8.4 The alternate form of population data is population density. It is available in regions defined by ranges of degrees or minutes of latitude and longitude. The advantage is that all of the population is accounted for. The disadvantage is that municipalities and other more densely populated areas are not efficiently defined and it is difficult to deal with sheltering. The most desirable approach is to develop population centre data down to the smallest available size and then define open area population using the population density data with the population of the accounted for municipalities removed.

4.9 Launch Safety Standards

4.9.1 The Casualty Expectation standard adopted must acknowledge public expectations that the risk of death or serious injury from commercial space activities should not exceed that from comparable industries. It should also be recognised that in adopting the E_c philosophy it is more difficult to accurately measure actual risk than to determine that the risk is below a certain acceptable threshold.

4.9.2 Collective risk is the total risk to the public from a launch. The E_c used as a measure of risk to the public for licensing purposes should be based on the total risk over all phases of flight where the public is exposed, i.e. ascent to orbit and return from orbit. Risks in orbit are generally to physical assets and not to people and thus can be excluded. The total risk as defined above is the "collective" risk.

4.9.3 Individual risk, i.e. the highest risk to any single person exposed to the launch, must also be controlled but limits on individual risk are not sufficient to control the collective risk. Individual risk does not take into account the number of people exposed to the hazard. Collective risk is absolutely necessary as the primary measure of mission risk. Individual risk should be included as a secondary measure that must also be satisfied at some level of acceptability but never as a sole criterion.

4.9.4 From a mission-planning standpoint, risks from impacting inert and exploding debris should be the primary considerations. Risks from toxic gases must be considered if the vehicle has fuels that can produce these gases either in a normal launch or an aborted launch. Distant focusing overpressure (DFO) from a ground explosion from an abort in the launch area may cause window breakage to occur up to 30 km from the launch site. Both the toxic gas risk and the DFO risk are dependent upon the weather conditions at the time of launch. They are generally looked upon as constraints on the day of launch due to weather. As a constraint they can lead to a launch hold if the launch risk including toxic and DFO risk exceeds the acceptable risk standard. These hazards are generally not considered in overflight risks.

4.9.5 The three criteria to be satisfied are:

4.9.5.1 collective risk to the public on a per launch basis (Casualty Expectation Standard);

4.9.5.2 the highest risk to an individual of the public on a per launch basis; and

4.9.5.3 the highest risk to an individual of the public on a per year basis.

4.9.6 The populations of foreign countries as well as Australia must be considered under the same criteria. Individuals supporting the launch do not have to be considered under the public risk category.

4.9.7 The following are the standards to be met and include ascent, descent and landing operations:

4.9.7.1 Casualty expectation standard 1×10^{-4} casualties per launch (collective risk).

4.9.7.2 Maximum individual risk (casualty) 1×10^{-7} per launch.

4.9.7.3 Maximum individual risk (casualty) 1×10^{-6} per year.

4.9.8 In analyzing the risk to property (designated high value assets), a different standard called the Asset Risk Standard is used. Using the probability of failure, the chance of impact, the area of the asset and the area of the debris footprint a calculation can be performed that determines the risk to the asset. If this risk of the asset of being damaged is greater than 1×10^{-5} then the asset is under too large a risk and the flight path would need to be reconsidered. The 1×10^{-5} standard has been adopted from the US Federal Aviation Authority (FAA) advice presented in a publication titled "Supplemental Application Guidance for Unguided Suborbital Launch Vehicles." If the debris is "trigger debris," i.e. its impact could initiate a set of events that could produce great damage or many casualties, the standard for probability of impact becomes 1×10^{-7}.

4.9.9 During the flight of the launch vehicle it is common for one and sometimes two stages to be dropped as their fuel is consumed. Also early in flight, once the atmosphere has thinned enough, fairings that enclose and protect the satellite in its early passage through the lower atmosphere are jettisoned. Each of these pieces has a planned drop zone defined as a four standard deviation footprint that contains 0.99967 of all impacts. Within each zone, calculations are performed to determine risks to people or property. Drop zones are usually selected to be free of people. The casualty safety standards do apply in drop zones, so the launch must not proceed if any individual is within the 1×10^{-7} individual risk isopleth. If the asset risk exceeds 1×10^{-5}, or if the asset risk from "trigger debris" exceeds 1×10^{-7}, then the drop zone would be inappropriate and would need to be relocated. This method applies to drop zones on land or sea.

4.9.10 Applicants are required to prepare contour (isopleth) maps for the launch and re-entry phases of each mission, which present the impact probabilities and individual risk densities. The following contour (isopleth) maps are specifically required:

(a) map showing the 1×10^{-7} individual risk isopleth and the 10^{-9} individual risk isopleth. The individual risk isopleth is to be calculated on the basis of a person in the open.

(b) map showing the 1×10^{-7} probability of impact isopleth for "trigger debris" on a hypothetical object of the same physical dimensions as a designated asset. (One such map for each designated asset in the vicinity and each type of "trigger debris". In this context "in the vicinity means within 50km.)

(c) map of each drop zone and landing site, showing the four standard deviation controlled area and the 1×10^{-7} individual risk isopleth. (One such map for each drop zone.)

(d) map of each drop zone and landing site, showing the four standard deviation controlled area, the 1×10^{-7} "trigger debris" probability of impact isopleth on a hypothetical object of the same physical dimensions as a designated asset. (One such map for each designated asset, if any, in the vicinity of the drop zone or landing site and for each type of "trigger debris".)

5. CONTACT DETAILS

For further information about the licensing regime set out under the *Space Activities Act 1998*, including matters set out in this Code, interested parties should contact::

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APPENDIX 1

PREFERRED METHODOLOGY FOR COMPUTING CASUALTY AREA

Inert Debris Effects

Inert Debris Effects on People in the Open

Several factors should be considered in the computation of casualty areas for inert debris. These include the size of the fragment, the size of a person, the velocity vector at impact, and whether the fragment remains intact after impact or disintegrates (splatters). If it stays intact, it may ricochet or slide, depending on the velocity vector (magnitude and angle), the effective coefficient of restitution and the effective coefficient of friction between the fragment and the ground. Included in ricochet are the effects of tumble as well as rebound or bounce.

For a direct impact from debris falling vertically, the casualty area takes into account both the projected area of the debris and the projected area of the human body from above. Usually, somewhat conservatively, the radius of the human body is assumed to be 0.3 m. If the velocity and weight of the fragment exceeds criteria presented in Figure A1-1, the person becomes a casualty. The criterion in Figure A1-1 is for "average general public." The associated casualty area is

$A_C = [pi] [(A_P/[pi])^{1/2} + r_P)]^2$ (this will also referred to as the

basic casualty area)

where A_p = projected area of the fragment, and

r_P = representative radius of a person

Figure A1-2 is provided as a guideline for "reasonableness" for total basic casualty area. The plot contains the total casualty area for several common ELVs (without identification) as a function of vehicle inert debris weight, i.e. no solid or liquid propellant and no solid rocket motor casing.

These numbers make use of the debris lists developed by the vehicle launch

organization. There is a very distinct trend and estimates of basic casualty area should generally fall within ±20% of the trend line of the data.

Figure A1-2 Basic Casualty Area Versus Total Weight Of Inert Debris for Several Different Expendable Launch Vehicles

The casualty area grows when considering angular strike and the dynamic effects of impact on the ground and subsequent motion. The casualty area for impact at an angle [alpha] relative to vertical is

$A_{[alpha]} = [pi] [(A_P/[pi])^{1/2} + r_P)]^2 + [(A_P/[pi])^{1/2} + r_P)]*h*tan [alpha]$

where h is the reference height of a human being.

To handle the aspects of bounce, skid, roll and breakup and splatter upon impact involve speculation with shapes, coefficients of restitution, friction coefficients, and the vulnerability of people to the fragment after bounce, skid, roll, etc. This process is complex and speculative. A reasonable model covering the post impact behaviour is to multiply $A_{[alpha]}$ by a factor of four.[10] Thus, considering impact at an angle ([alpha] degrees from vertical), the recommended formula for casualty area is

$A_{[alpha]} = 4 [pi] (A_P/[pi])^{1/2} + r_P)^2 + [(A_P/[pi])^{1/2} + 2r_P)] h tan [alpha]$

Figure A1-3 was also developed from some common ELV data. It provides the number of debris fragments as a function of inert vehicle weight. An estimate of the total basic casualty area from Figure A1-2 divided by an estimate of the number of fragments f

Inert Debris Effects on People in Structures

Inert Debris Effects on People in Structures

If a fragment is heavy enough and the velocity is high enough, it can penetrate the roof of a structure and either impact directly on occupant or cause structural debris to impact on an occupant. Since each different location of impact on the roof will have a different effect, the work to develop relationships was performed on impacts over thousands of locations on the roofs and over many roof types that were finally apportioned into several categories. After fragment penetration into the structure and the secondary debris was determined, the same rules were applied to the vulnerability of the occupants as to people standing in the open. The result is the set of curves shown in Figures A1-4, A1-5 and A1-6 for fragments falling at terminal velocity with drag coefficients of 0.75 for high and medium, and 0.87 for low density fragments (Based on the general shapes and masses expected in each fragment group; light fragments can represent skin panels while heavy fragments can represent heavy engine equipment, and medium, the fragments in between). The vertical scale gives the average casualty area due to roof penetration for three different general roof classes. Each figure represents a different class of fragment densities. Note that as fragments weigh less and have lower impact velocities, they are less likely to penetrate. In these cases the average casualty area converges to the minimum casualty area for a person.

A subset of the numerical results is listed in Tables A1-1 to A1-3. The following trends can be noted:

(1) The smallest casualty area is approximately 0.3 m^2, which corresponds to the projected area of an average person with a radius of 0.3 m

(2) No casualties internal to a structure are expected from fragments less than 0.4 kg.

Below a certain fragment weight, heavier structures tend to offer more protection, as they do not fail. However as fragments become heavy enough to fail the heavier structures, more casualties may be expected due to heavier secondary debris. Some of the irregularities of the curves may be attributed to the fact that as the fragment size increases, the fragment may no longer fit between the joists of a roof structure, hence the probability of penetrating through a relatively weak roof plate drops to zero. Meanwhile the kinetic energy may become large enough to fail the joists, resulting in steep increments of casualty area. It is similar when the fragment becomes too large to fit between the girders. These irregularities are consistent with the discontinuities observed in the individual HACK/CF[11] runs. Averaging over different building designs within a structure category and Principal Component Analysis tends to smooth the discontinuities.

Table A1-1. Building Casualty Area for High Density Fragments

FragmentMean Impact Casualty Area (m^2)

Mass (kg)	Fragment Area (m^2)	Velocity (m/s)	Light Structure Roof	Medium Structure Roof	Heavy Structure Roof
0.045	.000708	36.9	0	0	0
0.143	0.00152	44.5	0	0	0
0.454	0.00329	54	0.301	0	0
1.43	0.00708	65.5	0.367	0.351	0
4.54	0.0152	79.2	0.646	0.387	0
14.3	0.0329	96	1.27	0.468	0.391
45.4	0.0708	116	1.66	0.604	0.522
143	0.152	141	3.7	2.01	0.665
454	0.329	171	8.17	7.67	5.26
1430	0.708	207	14.1	17.3	14.1
4540	1.52	251	20.1	27.7	28.3

Table A1-2. Building Casualty Area for Medium Density Fragments

Fragment Mass (kg)	Mean Fragment Area (m^2)	Impact Velocity (m/s)	Casualty Area (m^2)		
			Light Structure Roof	Medium Structure Roof	Heavy Structure Roof
0.045	0.00189	22.6	0	0	0
0.143	0.00406	27.3	0	0	0
0.454	0.00876	33.2	0	0	0
1.43	0.0189	40.2	0	0	0
4.54	0.0406	48.5	0.563	0.509	0
14.3	0.0876	58.8	1.41	0.519	0
45.4	0.189	71.3	1.87	0.742	0.411
143	0.406	86.3	3.75	1.75	0.821
454	0.876	105	9.94	7.36	2.53
1430	1.89	127	18.2	20.1	12.1
4540	4.06	154	32.6	41.2	33.4

Table A1-3. Building Casualty Area for Low Density Fragments

Table A1-3. Building Casualty Area for Low Density Fragments

Fragment Mass (kg)	Fragment Area (m²)	Impact Velocity (m/s)	Casualty Area (m^2)		
			Light Structure Roof	Medium Structure Roof	Heavy Structure Roof
0.045	0.0139	7.71	0	0	0
0.143	0.0299	9.36	0	0	0
0.454	0.0645	11.3	0	0	0
1.43	0.139	13.7	0	0	0
4.54	0.299	16.6	0	0	0
14.3	0.645	20.1	0	0	0
45.4	1.39	24.4	1.76	0	0
143	2.99	29.5	4.17	0.698	0
454	6.45	35.7	6.32	2.31	0
1430	13.9	43.3	23.1	19.8	0
4540	29.9	52.4	62.0	66.2	12.3

Explosive Debris Effects

Determination of Yield from Impacts of Explosive Debris - Liquid Propellants

The curves in Figure A1-7 were obtained from Project Pyro[1213], which was a test program, performed in the 1960's.

Figure A1-7. Equivalent TNT Yield of Rocket Liquid Propellant Explosions as a Function of Impact Velocity

More recent research has been performed on the yields at impacts below 50 m/s.[14] However, impacts at these low velocities are not expected except very near the launch pad and thus are not included in this discussion.

Determination of Yield from Impacts of Explosive Debris - Solid Propellants

A general formula for the equivalent TNT yield of solid propellant in an explosion resulting from impact is[15]

$$\text{Fraction of TNT} = 1.28 / [1 + e^a(2.2046\times W)^b(3.2808\times V/S)^c]$$

where W = total propellant weight (kg)

V = impact velocity (m/s)

S = surface hardness factor

S = 2.92 for water

S = 1.81 for soft soil

S = 1.41 for concrete

S = 1 for steel

a = 12.16

b = -0.156

c = -1.55

Determination of Overpressure and Impulse from an Explosion

The overpressure and impulse from an explosion can be determined by the Blast Calculator model published by Ward, et al at the Australian Ordnance Council Conference, Parari '99, in Canberra. The most recent version of the Blast Calculator Model (4) was reported by Swisdak, et al at the 2000 Explosive Safety Seminar in New Orleans, LA and is available upon request from Michael Swisdak (swisdakmm@ih.navy.mil).

Note that the impulse from a propellant explosion may be less at the same overpressure level than for a TNT explosion. However, until a substantive relation-ship is developed, it is best to use the overpressure and yield from a TNT explosion.

Explosive Debris Impact on People in the Open and People in Structures

People in the Open

For estimating the probability of slight and severe casualties from a blast wave, the following effects were considered:

1. Soft tissue effects - damage to lungs, GI tract, larynx, and eardrum (rupture for serious and temporary hearing loss for slight)

2. Whole Body Translation - general body impact only

Lovelace data for each of the soft tissue damages were used to define the combined pressure and impulse (P-I) associated with the 1% (threshold) and 50% probability of serious injury. These levels were then used to define probit functions for each effect. P-I diagrams for serious injury due to whole body translation were constructed using two different methods:

1) The TNO fatality probit function for whole body translation was scaled based on the ratio between the impact velocity for fatality and serious injury at the 50% probability level. The fatality-to-serious injury ratio was based on comparing the impact velocity at the 50% probability level based on the BEI skull fracture model for large masses;

2) TNO fatality probabilities for a given P and I were directly translated to serious injury probabilities by using the ratio between casualty and fatality probability based on the BEI skull fracture model for large masses;

P-I diagrams for soft tissue and whole body translation effects and for slight injury, serious injury and fatality have been developed based on the methods described above. These P-I diagrams were then used to determine the effective casualty and fatality distance as a function of yield. Figures A1-9 and A1-10 show the effective distance and a comparison against constant overpressure lines.

People in Structures

Structures are usually thought of as providing protection to people from debris and blast waves. However, a blast wave can produce considerable harm to people inside the structure, either due to flying glass shards or elements (panels, etc.) of the structure itself.

Figure A1-8 shows the general approach adopted for systematically estimating casualty probabilities. This approach[16] is very similar to one used in a recent WS Atkins study to determine fatality probability functions for structures subjected to vapor cloud explosions[17] (Jeffries, 1997).

The steps shown in Figure A1-8 capture the basic phenomena that define the effects of air blast loading on a structure and its occupants. First, the blast loading on the structure is defined and the window glazing is checked for breakage. If breakage occurs, the flying shards are tracked and their impact on a building occupant is used to estimate their contribution to the probability of casualty given an explosive event occurs, [P(c|e)]. After glass breakage occurs, the loads acting on the structure are revised to account for venting and the external cladding checked for failure. If wall or roof segments fail, the cladding debris is tracked and its impact on building occupants used to estimate their contribution to the probability of casualty. If the building is susceptible to collapse, the blast loads are revised again to reflect the potential for additional venting and the structure checked for collapse. If the building construction is susceptible to collapse, the impact of large building components striking occupants is used to estimate their contribution to the probability of casualty. The contributions due to glass breakage, debris throw and collapse are then combined. Depending on the level of blast loading and the type of construction, the overall casualty probability may be dominated by glazing breakage alone, or from combinations of glass breakage, cladding failure and/or collapse. Figure A1-10 includes the blast effect on occupants of a single structure type, a pre-engineered metal building with a particular glass area to floor area ratio. The curve shows that for large yields at a distance, it is more risky to be inside than outside. If the launch vehicle has the potential for a large explosion on impact, consideration should be given therefore to the risk to building occupants. The 2-psi (13.8 kPa) curve in Figure A1-10 offers a reasonable upper bound.

Figure A1-8. Steps for Estimating Casualty Probability Given an Explosive Event

Figure A1-9. Casualty and Fatality Distance for People in the Open Exposed to a Blast Wave from an Explosion

Figure A1-10. Effective Casualty Radius for Severe Injury from a Blast Wave for People in the Open or in a Light Structure

APPENDIX 2

RISK ANALYSIS EXAMPLES

1. Vehicle Description

Consider a two-stage expendable launch vehicle with the following characteristics:

- First launch

  - Using the formula for P_f, probability of failure during the first launch is 0.25

  - Assume that the total failure probability of each stage is equal, i.e. 0.125 (note that if other vehicle specific data are available that can improve the failure probability estimate it should be used)

  - Assume that the failure probability during each stage is apportioned as follows;

    § Failure of the rocket motor to ignite -10%

    § Failure of the guidance and control - leading to a malfunction turn away from the direction of the nominal velocity vector - 25%

    § Failure in the propulsion system leading to an explosion and break up of the vehicle (on-course) - 50%

- Liquid propelled (LOX and kerosene)

- First stage - 20m x 3m, inert weight = 6K kg[18]

- Second stage and payload - 10m x 3m, inert weight 5K kg

- Impact range of first stage = 150 km

- Vacuum IIP rate at the time of jettison of the first stage - 2 km/sec

- Impact dispersions of the jettisoned first stage

  - Down-range standard deviation = 10km

  - Cross-range standard deviation = 5km

- Basic casualty area (no bounce, slide, skip, splatter or off-vertical impact)

  - Stage I - 900 sq. metres (estimated from Appendix 1, Figure A1-2)

  - Stage II and payload - 600 sq. metres (estimated from Appendix 1, Figure A1-2)

- Estimated number of fragments

- Stage I -800 (guessed from Appendix 1, Figure A1-3)
- Stage II and payload - 700 (guessed from Appendix 1, Figure A1-3)

2. Determination of Risk to a Designated Asset from the Jettisoned First Stage

Assume that the asset has the dimension of 100 m by 100 m. To compute the impact probability of the stage on the asset, find the nominal drag-corrected impact point for the stage and locate the position of the impact point relative to the asset location. For this example, assume that the mean impact point of the stage falls 10 km short and 4 km to the left. The impact area for the computation is defined as the area of the asset increased by 1/2 booster length in each direction with a radius of 1/2 booster length filling in the corners. Using the equation in Section 4.5.8, the value of P_I for jettisoned stage impact on the asset is $P_I = 2.01\times10^{-5}$ (shown in the table from a spreadsheet that follows).

If the P_I is to be less than 1×10^{-7} (or any other criterion), the equation in the footnote to Section 5.8 can be rearranged as follows to place a minimum value on the allowable offsets (mean impact point of the stage), x and y. The condition is satisfied if - 2[ln(2[pi][sigma]$_x$[sigma]$_y$/A)+ln(P_I)] <= (x/[sigma]$_x$)^2 + (y/[sigma]$_y$)^2 where P_I is an input parameter in the equation. The values that satisfy this inequality for $P_I = 1\times10^{-5}$, 1×10^{-6} and 1×10^{-7} for these particular values of A, [sigma]$_x$ and [sigma]$_y$ are shown below.

Table A2-1. Minimum Value of [(x/[sigma]$_x$)^2 + (y/[sigma]$_y$)^2] Allowable to Satisfy Specified P_I

Required P_I	Minimum value of (x/[sigma]$_x$)^2 + (y/[sigma]$_y$)^2
1×10^{-5}	17.4
1×10^{-6}	27.6
1×10^{-7}	35
1×10^{-8}	41

Note in the table that follows on the next page, that when computing P_I for a single person in the open, P_I is never larger than 8.77×10^{-7}. This would not be true if the impact uncertainties for the stage were reduced.

If the impact probability from the empty stage on a person standing in the open is needed, then the basic casualty area (not considering breakup, slide, roll, skid, splatter or angular impact) is the plan form of the stage plus 0.3 m all around. This is approximated by the basic casualty area formulation in Appendix 1, i.e. A_C = [pi] [(A_P/[pi])$^{1/2}$ + r_P)]^2 where A_p is the plan form area (160 m^2) and r_p = 0.3 m^2. Thus, for this case, A_C = 173.7 m^2. If a multiplier of 4 is introduced for post impact behaviour, and if the stage falls at 5 degrees off the vertical, the casualty area becomes 274.1 m^2.

Tables A2-2 to A2-5 summarize the computations.

Table A2-2. Asset Dimensions and Stage Impact Dispersions

Asset length, m =	100
Asset width, m =	100
Down-range stand dev.(sigma x), km =	10
Cross-range stand dev.(sigma y), km =	5

Table A2-3. Casualty Area Computations for Impacting on a Person

Impacting stage dimensions (m)	*x* =20
	y =3
Number of objects	n =1

Half width of person (m) rp =0.3
Height of person (m) h =2
Multiplier on basic casualty area for bounce, slide, roll and splatter M =4
Ave. angle of impact (deg off vert)) alpha =5
R = (xy/pi)^(1/2)+rp, (m) R =4.67
AC = M*pi*R^2+sqrt[(x+2rp) *(y+2rp)]*h*tan(alpha)], (m^2) AC =275.5
Equivalent radius of AC, (m) RC =9.36

Table A2-4. Sample Computation of Risks Due to Impacts of Spent Stages on Designated Assets

Area at Risk	Asset Area (m^2)	Effective Impact Area (m^2)	DR Location in Drop Zone (x) (km)	CR Location in Drop Zone (y) (km)	(x+sqrt (A)) / Sigma x	(x-sqrt (A)) / Sigma x	P(x)	(y+sqrt (A)) / Sigma y	(y-sqrt (A)) / Sigma y	P(y)	Pi = P(x)*P(y)	Ec per Person on Designated Asset
Designated Asset	10000	14314	0	0	5.98E-03	-5.98E-03	4.77E-03	1.20E-02	-1.20E-02	9.55E-03	4.56E-05	1.26E-06
	10000	14314	5	0	5.06E-01	4.94E-01	4.21E-03	1.20E-02	-1.20E-02	9.55E-03	4.02E-05	1.11E-06
	10000	14314	10	0	1.01E+00	9.94E-01	2.89E-03	1.20E-02	-1.20E-02	9.55E-03	2.76E-05	7.61E-07
	10000	14314	-10	4	-9.94E-01	-1.01E+00	2.89E-03	8.12E-01	7.88E-01	6.93E-03	2.01E-05	5.53E-07
	10000	14314	15	0	1.51E+00	1.49E+00	1.55E-03	1.20E-02	-1.20E-02	9.55E-03	1.48E-05	4.08E-07
	10000	14314	20	0	2.01E+00	1.99E+00	6.46E-04	1.20E-02	-1.20E-02	9.55E-03	6.17E-06	1.70E-07
	10000	14314	25	0	2.51E+00	2.49E+00	2.10E-04	1.20E-02	-1.20E-02	9.55E-03	2.00E-06	5.52E-08
	10000	14314	30	0	3.01E+00	2.99E+00	5.30E-05	1.20E-02	-1.20E-02	9.55E-03	5.06E-07	1.39E-08
	10000	14314	35	0	3.51E+00	3.49E+00	1.04E-05	1.20E-02	-1.20E-02	9.55E-03	9.97E-08	2.75E-09
A person		276	0	0	8.30E-04	-8.30E-04	6.62E-04	1.66E-03	-1.66E-03	1.32E-03	8.77E-07	
		276	5	0	5.01E-01	4.99E-01	5.84E-04	1.66E-03	-1.66E-03	1.32E-03	7.74E-07	
		276	10	0	1.00E+00	9.99E-01	4.02E-04	1.66E-03	-1.66E-03	1.32E-03	5.32E-07	
		276	15	0	1.50E+00	1.50E+00	2.15E-04	1.66E-03	-1.66E-03	1.32E-03	2.85E-07	

276	20	0	2.00E+00	2.00E+00	8.96E-05	1.66E-03	-1.66E-03	1.32E-03	1.19E-07
276	25	0	2.50E+00	2.50E+00	2.91E-05	1.66E-03	-1.66E-03	1.32E-03	3.85E-08
276	30	0	3.00E+00	3.00E+00	7.36E-06	1.66E-03	-1.66E-03	1.32E-03	9.74E-09
276	35	0	3.50E+00	3.50E+00	1.45E-06	1.66E-03	-1.66E-03	1.32E-03	1.92E-09

Notes:
(1) If more than one identical objects are impacting, the total P_i for N objects = $1-(1-P_i1)^N$
(2) When the area to be impacted is much larger than the stage, the impact area is defined as the area of the structure (e.g. an oil platform) increased by 1/2 stage length in each direction with a radius of 1/2 stage length filling in the corners.
(3) The impact area for a person is the same as the casualty area since impact by an object of this size can be assumed to always produce a casualty

Table A2-5. Offset Requirements to Keep P_I Below Specified Level

Computation of offset required to maintain P_I less than specified value for an area that is large relative to the jettisoned stage

P_I value =	1.00E-05	1.00E-06	1.00E-07	1.E-08	1.00E-09
sigma x (km) =	10	10	10	10	10
sigma y (km) =	5	5	5	5	5
impact area (km^2))=	1.43E-02	1.43E-02	1.43E-02	1.43E-02	1.43E-02
(x/sigx)^2+(y/sigy)^2 >	3.03	7.64	12.24	16.85	21.45
If y=0 then x >	17.4	27.6	35.0	41.0	46.3
x/sig x =	1.7	2.8	3.5	4.1	4.6

Computation of offset required to maintain P_I less than specified value for a single person standing in the open with the jettisoned stage breaking up upon impact

P_I value =	1.00E-05	1.00E-06	1.00E-07	1.E-08	1.00E-09
sigma x (km) =	10	10	10	10	10
sigma y (km) =	5	5	5	5	5
impact area (km^2))=	2.76E-04	2.76E-04	2.76E-04	2.76E-04	2.76E-04
(x/sigx)^2+(y/sigy)^2 >	Not poss.	Not poss.	4.34	8.95	13.55
If y=0 then x >	Not poss.	Not poss.	20.8	29.9	36.8
x/sig x =	Not poss.	Not poss.	2.1	3.0	3.7

Adjustment for Failure Probability

Technically, any vehicle that fails prior to staging will not present a risk from a jettisoned stage. In this case, it was assumed that the vehicle would fail during first stage flight with a probability of 0.125. Thus the probability of jettisoning an empty stage should be 0.875 not 1.0. Presumably then, all of the impact probability figures associated with an empty stage presented in this section should be lowered by multiplying the P_I by 0.875.

Failure of the Next Stage to Start

At staging, the first stage is jettisoned and the second stage rocket engines are ignited. If these engine(s) fail to ignite, the second stage will fall in the general region of the jettisoned first stage. The difference will be that the second stage will be full of propellant, have a higher ballistic coefficient and may break up depending upon either the action of the abort system or aerodynamic loads. The probability of this event will be the probability of having succeeded during the first stage of flight but failing at the beginning of the second. Thus,

$P_f = 0.875 \times 0.125 \times 0.10 = 0.0109$. Next, look at each case:

1. If the vehicle is aborted and the propellants are jettisoned, then the risks are similar to those of an empty stage. Note that the dimensions of the stage will be different than that of the jettisoned first stage and the nominal impact point and impact dispersions may be different because of differences in the ballistic coefficient, wind effects, etc. Since the fuel jettison takes time, the ballistic coefficient will be changing as the propellant mass in the vehicle is being reduced.

2. If there is no abort, and no vehicle break up, the stage can impact intact and explode. The rules for computing yield from an explosion upon impact are described in Appendix 1. The extent of damage from an explosion is based upon overpressure and impulse from the explosion. If there is no capability to evaluate damages to the asset more precisely, use 24 kPa as the overpressure which if exceeded will produce unacceptable damage or casualties.

3. If the stage is destroyed or breaks up aerodynamically, the propellants will be dispersed, but the casualty area will now have to take into consideration many inert pieces. The casualty area, based on weight of inert debris should fall within the range shown in Appendix 1. Appendix 1 also has a range of number of pieces as a function of total inert debris weight. When a stage or vehicle breaks up, the impact probability computation must consider the fact that the pieces spread and impact over a wider area. A simple model for computing impact probability is to divide the total casualty area by the number of pieces; this will give a single reference casualty area. Then compute the impact probability of that single piece assuming that the impact dispersions are the same for all pieces. This is not a particularly robust assumption because each fragment or fragment group could have a different mean impact point and different values for their impact dispersions. If this could have a serious affect on the conclusions of a risk analysis, then a more complete study involving debris details, trajectories and dispersions must be performed.

However, to demonstrate the effect of multiple debris pieces, this example will be continued. Assume a total inert debris mass of 6000 kg that represents approximately 800 pieces with an average fragment weight of 7.5 kg. Based on Appendix 1, a total basic casualty area of 900 m^2 falls within the bounds of past practice. Divided by 800, the average basic casualty area is 1.1 m^2. If we are interested only in whether any fragment strikes a designated asset, then the dimension of a human in the basic casualty area equation must be removed. Since $A_C = [pi] [(A_P/[pi])^{1/2} + r_P)]^2$ with $r_P = 0.3$ m, , the adjusted casualty area is $A' = A_p = [pi] [(A_C/[pi])^{1/2} - r_P)]^2 = [pi] [(10/[pi])^{1/2} - 0.3)]^2 = 0.267$ m^2. Adding the radius associated with this dimension around the 100 by 100 m designated asset gives the effective impact area associated with a small fragment hitting the asset. Using the same procedure as that for a spent stage, compute the impact probability of the smaller fragment on the asset. Then assume that all fragments are statistically independent of each other. The probability of at least one fragment impacting on the Designated Asset is $P_{IN} = 1-[1-P_I]^N$ where P_I is the impact probability on the Designated Asset for a single fragment and N is the number of fragments. This P_{IN} is conditional upon the probability of the second stage motor failing to ignite and the probability that the stage will break up either due to abort action or aerodynamic loads.

The lesson from the above exercise is that breaking up into many pieces increases the impact probability. On the other hand, however, the consequence of impact from any of many pieces is much less than the consequence of impact of a single intact stage and payload, with a potential ensuing explosion.

Special Consideration for Protected Assets

If Protected Assets are to be an additional 10 km radially from the 1×10^{-7} impact probability isopleth, consider using the impact probability isopleth for an intact jettisoned stage.

3. Determination of Risk to a Designated Asset and/or People from the Failure of Vehicle During Powered Flight (Down Range Beyond the Launch Area)

Downrange risks can be computed with the corridor model suggested in Section 4.5.4. This model operates, like the jettisoned stage model, with separate impact probability computations in the downrange and cross-range directions. Like the former, the cross-range uncertainty is represented by a normal distribution. However, in the downrange direction, the distribution is represented by selecting an interval of distance along the locus of the IIP[19] and computing the probability that the vehicle will fail during the time that the IIP is within the interval. In this model, the interval distance is the square root of the area of a particular population centre. The cross-range impact probability is calculated using the distances from the mean path of the IIP to the inner and outer edges of the population centre. The population centre is usually assumed to be square for convenience of computation.

The table below shows that the failure rate during flight is 0.0005625. If this is during second stage flight, and the first stage had a failure probability of 0.125, and the start-up failure probability for the second stage is 0.125×0.057 = 0.007125, then the failure rate below is reduced accordingly.

Table A2-6. Failure Rate Computations

Vehicle failure probability = (ax+r)/(x+n)	Pf =	0.25
Parameters used in vehicle failure probability computation	a =	0.25
	x =	4
	r =	0
	n =	0
Powered flight time - 1/2 each stage (sec)	tp =	400
Total start-up failure prob. (both stages)	Psu =	0.01425
Average failure rate (failures/sec)	fr =	0.0005894

The tables on the following page provide parametrically

(1) the impact probability of an intact empty second stage and payload (flight aborted, but the vehicle not broken up and not containing propellant at impact), and

(2) the risk to a single person on the Asset.

If we assume that:

- the cross-range uncertainty of the IIP of the second stage and payload is 8 km

- the IIP rate is 2 km/sec,
- the offset of the IIP from the asset is 12 km,

then the impact probability of the stage and payload on the Asset (from the tables) is 6×10^{-8}.

If we want to find the cross-range position of the locus of IIP that produces a $P_I = 1\times10^{-7}$, interpolate the values in the table, giving a result of approximately 8.8 km cross range. If the Asset is to be protected at a level of $P_I = 1\times10^{-7}$ plus an additional 10 km, then the offset must be 18.8 km.

The comments about explosive or aerodynamic break up of the stage discussed in the previous section apply here. Having many pieces instead of one will raise the impact probability. However, the individual effect of a single fragment will be much less than the effect of the entire stage and payload.

This entire process can be applied to many populations centres, not just one. The best approach is to first determine the total population of an area of concern. Then subtract the total population of all of the identified communities from the total population of the area at risk to determine the population in the countryside. The countryside can then be divided into large areas with very low populations, with each area being treated as a population centre. The casualty area for these population centres does not need to take into account fragment dimensions to compute impact probability, the contribution is too small.

Table A2-7. P_I and E_C Using Corridor Model for Various IIP Rates, Cross-Range Standard Deviations and Offsets of an Asset from the Nominal Locus of the IIP.

Cross Range Standard Deviation of Locus of IIP (km) =	2						
	IIP Rate (IIPR) - km/sec						
		1	2	5			
		PI	Ec/pers	PI	Ec/pers	PI	Ec/pers
Offset of Asset from Nominal IIP (yc) - km	0	1.5E-06	2.4E-08	7.4E-07	1.2E-08	3.0E-07	4.7E-09
	4	2.0E-07	3.2E-09	1.0E-07	1.6E-09	4.0E-08	6.4E-10
	8	5.0E-10	8.0E-12	2.5E-10	4.0E-12	9.9E-11	1.6E-12
	12	2.3E-14	3.6E-16	1.1E-14	1.8E-16	4.5E-15	7.3E-17
	16	2.2E-20	3.4E-22	1.1E-20	1.7E-22	4.3E-21	6.9E-23
	20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cross Range Standard Deviation of Locus of IIP (km) =	4						
	IIP Rate (IIPR) - km/sec						
		1	2	5			
		PI	Ec/pers	PI	Ec/pers	PI	Ec/pers
Offset of Asset from Nominal IIP (yc) - km	0	7.4E-07	1.2E-08	3.7E-07	5.9E-09	1.5E-07	2.4E-09
	4	4.5E-07	7.2E-09	2.2E-07	3.6E-09	9.0E-08	1.4E-09
	8	1.0E-07	1.6E-09	5.0E-08	8.0E-10	2.0E-08	3.2E-10
	12	8.2E-09	1.3E-10	4.1E-09	6.6E-11	1.6E-09	2.6E-11
	16	2.5E-10	4.0E-12	1.2E-10	2.0E-12	5.0E-11	7.9E-13
	20	2.8E-12	4.4E-14	1.4E-12	2.2E-14	5.5E-13	8.8E-15
Cross Range Standard Deviation	8						

of Locus of IIP (km) =							
		IIP Rate (IIPR) - km/sec					
		1	2	5			
		PI	Ec/pers	PI	Ec/pers	PI	Ec/pers
Offset of Asset from Nominal IIP (yc) - km	0	3.7E-07	5.9E-09	1.8E-07	3.0E-09	7.4E-08	1.2E-09
	4	3.3E-07	5.2E-09	1.6E-07	2.6E-09	6.5E-08	1.0E-09
	8	2.2E-07	3.6E-09	1.1E-07	1.8E-09	4.5E-08	7.2E-10
	12	1.2E-07	1.9E-09	6.0E-08	9.6E-10	2.4E-08	3.8E-10
	16	5.0E-08	8.0E-10	2.5E-08	4.0E-10	1.0E-08	1.6E-10
	20	1.6E-08	2.6E-10	8.1E-09	1.3E-10	3.2E-09	5.2E-11

Other Considerations

If the vehicle impacts intact, the cross-range dispersions are primarily due to normal guidance and performance variations, wind dispersions and possibly dispersion due to a malfunction turn. The problem gets much more complicated if the vehicle breaks up. The many pieces of debris will vary in size and ballistic coefficient; they will have different velocity impulses due to any explosion; and they will all be affected by any vehicle malfunction turn. The more effective way of doing this analysis is to divide up the debris into categories that have commonality in ballistic coefficient and velocity impulse for each category. Then compute a drag corrected IIP for each of the different categories. These drag corrected IIPs will have different arrival times and may be offset from one another because of wind and earth rotation effects. The risk analysis is then performed for each debris category, for all population centres, and then summed.

FOOTNOTES:

[1] A failure for purposes of public safety must fall into the category of having a consequence that could lead to harm to people or property. Thus achieving a wrong orbit does not apply.

[2] The process is a Bayesian statistical process using a beta distribution and a "normalization" factor, A. The equation could be written as $P_f = (r_0A + r)/(n_0A+ n)$ where r_0 and n_0 are the "prior" number of failures and "prior" number of launches respectively. The term "prior" is a Bayesian term representing augmented data.

[3] The use of 0.25 is probably conservative, because a number of the new vehicle failures have been mission failures but have not been of the type to affect public safety.

[4] If one were to continue to adhere strictly to the Bayesian methodology, the update to a posterior estimate of P_f would be done with a lognormal instead of a beta distribution. However, the beta form is easier and within the accuracy requirements of the problem.

[5] For the experimental confidence for a proportion, r/n, see Natrella, Mary Gibbons, "Experimantal Statistics," National Bureau of Standards Handbook 91, U. S. Dept. of Commerce, Washington, D.C., USA, August 1, 1963.

[6] This example does not take into consideration the discussion in Section 3.5 where a failure in Stage II cannot occur if Stage I has already failed. Ignoring this produces a small conservatism in the results, but makes the mathematics easier.

[7] Based primarily on data from "World Space Briefing," January 2001, Teal Group Corporation

[8] When A is << than $_x$ and $_y$, the equation in 5.8 can be simplified to be

$P_I = A/(2\ _{xy})exp[-1/2((x_A/_x)^2+(\ y_A/_y)^2)]$

[9] Baeker, James B., Jon D. Collins and Jerold Haber, "Launch Risk Analysis," Journal **of Spacecraft and Rockets**, Vol. 14, No. 12, December 1977, pp 733-738.

[10] ACTA is currently performing research on post impact behavior taking into consideration a human vulnerability model. A study by Robert Montgomery and James Ward, "Casualty Areas for People in the Open from Impact Inert Debris," (Research Triangle Institute Report No. RTI/5180/60-311, 1995) presents a fairly complete model including a splatter model. The model requires a number of assumptions of the type mentioned in the text above. The proposed factor of four (currently used by ACTA with its LARA program) provides results that are similar to the RTI results, except for the RTI splatter which can, at times, produce a much larger casualty area.

[11] Technical paper on the computer program, HACK. presented by David Bogozian (Karagozian and Case) and Mark Anderson (ACTA Inc.) at the 1998 Explosives Safety Symposium, Orlando Florida.

[12] Willoughby, A. B., et al, Study of Liquid Propellant Blast Hazards, AFRPL-TR-65-144, URS Corp., Burlingame, CA, June 1965

[13] Willoughby, A. B., et al, Liquid Propellant Explosive Hazards, AFRPL-TR-68-92, Vol. 1, 2, 3 URS Corp., Burlingame, CA, December 1968

[14] Tomei, E. J. "Explosive Equivalence of Liquid Propellants," JANNAF conference paper presented in Houston, TX, April 21-23, 1998.

[15] The above formulation was developed by Wilde and Anderson and is based on a fit to a combination of theoretical results (PIRAT program) and test data. An alternative model, which separates out impact orientation and case size, was developed by RTI and is based solely on the PIRAT theoretical results. It can be obtained from the U. S. Air Force at Patrick Air Force Base, Florida.

[16] Chrostowski, Jon D. Gan, Wenshui, Wilde, Paul D., and Bogosian, David, "Generic Building Models for Air Blast Loading," Explosives safety Seminar, New Orleans, LA, July 2000.