GILMOUR SPACE

Bowen Orbital Spaceport

Hazard and Risk

Document ID: LAUNCH-35847011-2136

Version: 1.1

Published: 23/09/2021

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Executive Summary

This review reflects the work of Gilmour Space to identify, characterise and quantify the attendant and residual risks that arise from the construction and operation of the Bowen Orbital Spaceport to inform interested parties regarding the treatment of risks and regulatory compliance.

The Bowen Orbital Spaceport will be Australia's first purpose-built launch facility for small class orbital launch vehicles. It will be sited within the Abbott Point State Development Area and will host the first series of launches for the Gilmour Space Eris Launch vehicle beginning in 2022. The siting of the spaceport will allow safe and effective access to low Earth orbit for launch azimuths between approximately 25 and 71 degrees.

The activity of a spaceport in Australia is governed by several regulatory requirements including the Space Act and the Environmental Protection and Biodiversity Conservation Act. Gilmour Space has conducted a risk assessment under its risk framework to examine the attendant and residual risks to safety and environment to examine its ability to construct and operate the facility within the regulatory requirements.

Risks to the environment and safety were identified for both construction and operation of the facility and treatments identified to control exposure or mitigate the impacts as far as reasonably practicable. During the construction phase, Gilmour identified measures to reduce the environmental impact of activity to endemic species and the safety risks that arise from increased traffic in the access roads.

While diligent engineering and innovative design will seek to eliminate risk much as they do in the commercial aviation industry, the real possibility of off-nominal events persists. Risks were assessed and treatments identified to control exposure of sensitive environments to impacts from chemical contamination, blast effects and debris through construction of the facility and careful selection of nominal flight paths.

Independent experts were engaged to conduct an environmental analysis quantifying the potential effects of nominal and off nominal launches and informed these mitigations which we assess will comply with the requirement to avoid significant impact to environmental matters of national or state significance.

Risks to safety were identified and treatments identified to limit the exposure of personnel and property to noise, blast effects, chemical contamination, and debris. Treatments of safety risks rest on the removal of personnel, aircraft and vessels from areas that present unacceptable danger and selection of the flight paths to reduce the exposure of property including critical infrastructure to the hazards of off-nominal events or scheduled debris. No risks of trigger debris for critical infrastructure were identified.

The exclusion of persons from exposure to harm requires comprehensive simulation and analysis of potential debris paths from nominal and off nominal launches. The design of these exclusion areas, informed by proper analysis and validated by a suitably qualified third party will result in demonstratable compliance with the requirements of the Australian Space Act Flight Safety Code.

1 Introduction

Gilmour Space is committed to achieving sovereign orbital launch capabilities for Australia. The Australian space sector represents a small but significant sector of the Australian economy with significant growth potential. The establishment of an operational orbital launch facility will enable greater market participation for Australian space companies in both domestic and international markets.

1.1 Purpose

This hazard and risk review has been prepared to characterise and quantify the residual risks associated with the establishment and operation of an orbital spaceport facility at the identified site within the Abbot Point State Development Area (APSDA).

1.2 Scope

The scope of this review involves assessment of the systemic context, risk management processes, identified hazards, controls and treatment of residual risks including:

- Construction of the launch facility.
- Nominal launch of a vehicle along the proposed trajectory including scheduled debris (spent rocket stages).
- Mission failure modes and effects along the flight trajectory.

This report does not assess routine personal occupational or workplace safety risks which instead are addressed within the construction and operational safety plans.

1.3 Structure of this report

This hazard and risk review is structured as follows:

Section 1 – Introduction

Section 2 – Description of The Bos and Orbital Launch

Section 3 – Review of Regulatory Authorities and Standards

Section 4 – The Risk Methodology

Section 5 – Risk and Control Analysis

Section 6 - Summary of Residual Risks and Regulatory Requirements

2 Description of the Bowen Orbital Spaceport and Orbital Launch

2.1 BOS Location and Layout.

The Bowen Orbital Spaceport (BOS) will be purpose built as Australia's first orbital launch facility, enabling access to low Earth orbit for small payloads from Australian soil. Small launch vehicles are classified as those capable of lifting less than 2000kg payloads into orbit. Bowen is ideally suited for this classification of launch vehicles because of the sites latitude which takes advantage of the Earth's rotation, the sites proximity to the coast for eastward launches and its remote location with limited population centres and relatively sparse air and maritime traffic downrange.

Figure 1 - Bowen Orbital Spaceport Location

The BOS will comprise of three major facilities; a Launch Control Centre (LCC) co-located within the North Queensland Bulk Ports facilities, a Vehicle Assembly Building (VAB) and a Launch Pad (LPAD) with associated fuel and oxidiser storage pads at Lot 10 Abbot Point Road.

2.2 BOS Intended Activity

Launch operations are campaign activities that will begin with the delivery of launch vehicle components and culminate some 60-90 days later with the launch of a vehicle followed by up to 10 days of post launch activity to remediate and return the site to readiness for a new launch campaign. The first tranche of these campaigns will involve the Eris launch vehicle.

2.3 Eris Launch Vehicle

This review is intended to inform a Material Change of Use (MCU) Development Application (DA). While Gilmour Space intends for the first launch at the BOS to be achieved with an Eris launch vehicle matching the data used in this hazard and risk analysis, the data presented on performance and trajectory is necessarily representative of many similar small class orbital launch vehicles. The Eris vehicle is yet to achieve an Australian Launch Permit and will undergo design optimisations to performance, masses, and fluid quantities, all of which will be the subject to Launch Permit applications.

The Eris is a 3-stage small class orbital launch vehicle. The first and second stage propulsion systems are innovative hybrid rocket systems. These rocket systems use a stabilised high concentration Hydrogen Peroxide (H_2O_2) which is a non-cryogenic fluid, in combination with a solid polymer fuel grain. Hybrid rockets are inert, non-explosive, and safe to handle during pre-launch activities with adequate PPE controls. The third stage of the Eris vehicle is a traditional liquid oxygen and kerosene propulsion system.

Eris launch vehicles are approximately 23m tall, and the main body section of the rocket is approximately 2m in diameter. The majority of the materials on the launch vehicle are aerospace grade aluminium, stainless steel, and carbon fibre. The constituent components of Eris rockets and spent booster stages are presented in Table 1.

Table 1 - Estimate of Material Masses of a Typical Eris 001 Rocket for Context

Material		Mass, kg	Mass %	Risk in Environment
Liquid Fuel and Oxidiser	Hydrogen Peroxide	25,000	-	Rapidly Decomposes to H_2O & O_2, fire or burn hazard if contacted.
	Liquid Oxygen	500	-	Rapidly evaporates to O_2, fire or burn hazard if contacted.
	Kerosene	200	-	Combustible liquid. Will ignite if temperature is above a flash temperature (~60 °C) and if an ignition source is present.
Solid Launch Vehicle Structures	Aerospace Grade Aluminium (Fuselage and structure)	3,000	44%	Stable and inert in all environments.
	PE Polymer (Solid fuel grain)	2,500	37%	Stable and inert in all environments.
	Lithium-Ion Batteries	400	6%	Fire hazard in some circumstances.
	Electric Motors (Copper/Steel)	300	4%	Stable and inert in all environments.
	Stainless Steel	300	4%	Stable and inert in all environments.
	Carbon Fibre & Resin	300	4%	Stable and inert in all environments.
	Total	**32,500**		

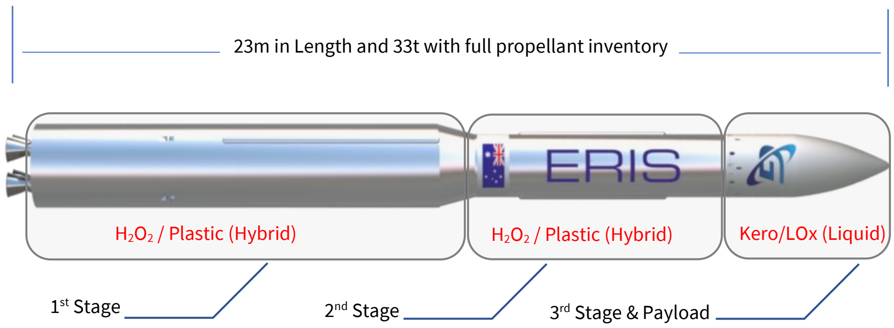

Figure 2- Eris SN001 Launch Vehicle

2.4 Launch Frequency

In 2022, Gilmour Space plans to launch 2 rockets, after which Gilmour Space aims to increase launch frequency towards a monthly cadence by 2025, however, launches will rarely occur from the BOS month on month as alternate launch locations become available, including Whalers Way in South Australia. An example of the possible launch frequency for the Bowen Orbital Spaceport is shown below in figure 2, which shows 20 launches. Gilmour predicts that up to 50 launches could be conducted from the BOS by 2032 if targets for development and launch vehicle contracts are achieved.

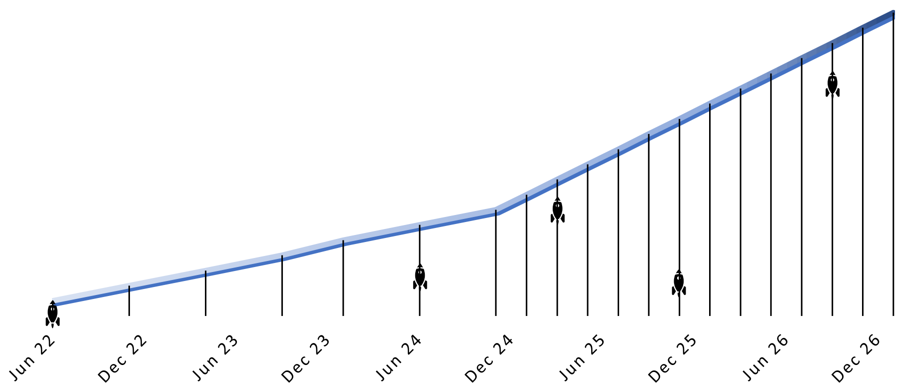

Figure 3- Possible Launch Cadence and Timing for First 20 Launches

2.5 Launch Azimuths and Orbit

The BOS is well placed to safely service a significant array of launch azimuths. Several key safe launch azimuths exist which bound these trajectories. There are strict public and property safety requirements for the planning of space activities detailed in the Space (Launches and returns) Act and its subordinate regulations, rules, and codes. These public safety requirements are enforced by mandating that each specific launch trajectory be comprehensively modelled by an independent, suitably qualified expert prior to submitting the application for an Australian Launch Permit to demonstrate the flight trajectory poses a less than 1x10^$^{-6}$ (one in a million) probability of a launch vehicle failure resulting in debris impacting an individual and a 1x10^$^{-4}$ probability of failure resulting in a third-party casualty.

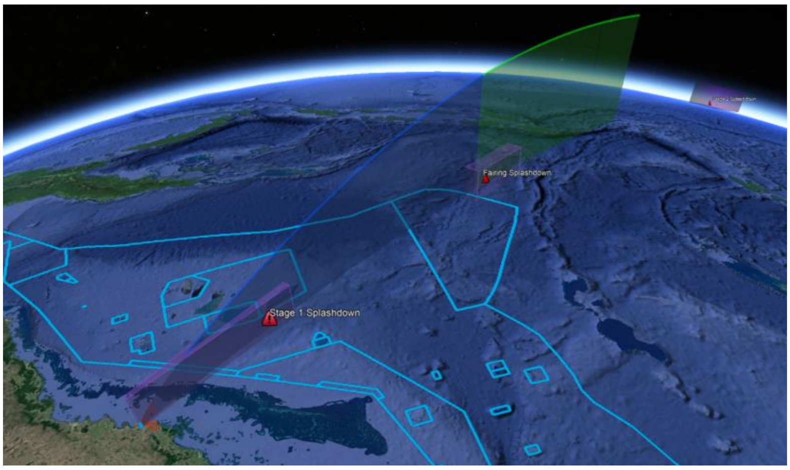

Figure 4 - BOS Nominal Launch Trajectory for 57° Azimuth Launch Overlayed with GBRMP and CSMP

2.6 Launch Campaigns

During an active launch campaign several phases of activity will occur, with a variable workforce at the BOS. Table 1 illustrates the typical launch campaign activity.

Table 2 Typical Launch Campaign Activity

Approximate Timing	Typical Activities
T-90 days Launch Readiness Activities	Launch vehicle components begin arriving at the VAB from GST's integration and test activity facility located in Helensvale, Queensland.
T-45 days Client Payload and Launch Approvals	Client payload is received at the VAB, where assembly and integration of the payload begins. Permits for launch activity must be approved by the Australian Space Agency on this date.
T-10 days Launch Pad Configuration	Launch pad preparation and testing. Launch support and recovery services established at the LCC.
T-5 days Launch Fluids Connection and Testing	Launch fluids are delivered. Target launch date and time is confirmed.
T-24 hours Weather Monitoring and Final Checks	Anemometry and weather monitoring begins to confirm forecast weather conditions for launch. The launch vehicle is fully integrated into the launch erector and fluid systems are connected.
T-4 hours Exclusion Zone Implementation	Public safety barriers and controls, airspace notifications, and marine exclusion zones are implemented.

Approximate Timing	Typical Activities
T-2 hours Launch Sequence Commence	Launch vehicle communications are confirmed, rocket is pressurised, final manual checkouts are performed, and Gilmour Space begins monitoring exclusion zones. Rocket filling and launch procedures to begin.
T- 30 minutes Launch Countdown	T- 30 minutes downrange exclusion zone and all GO/NO GO criteria confirmed clear for launch. Flight computers confirm final flight readiness checks. T-2 Rocket booster stage ignition begins.
T - 0 seconds	Rocket hold downs released - Launch

3 Review of Regulatory Authorities and Standards

The regulatory authority for space activities in Australia is the Australian Space Agency (ASA). This agency is responsible for issuing of Launch Facility Licences and Launch Permits for the safe launch and return of space objects. The requirements for planning, approvals and management that must be satisfied to be granted a Launch Facility Licence or Launch Permit are detailed in the Space (Launches and Returns Act) 2018.

3.1 The Space (Launches and Returns) Act 2018

The Space Act aims to hold all private commercial and government space activities to a high standard of integrity and ensure public safety, economic and environmental standards are met. The Space Act establishes a system for the regulation of space activities from Australia, or by Australians and implements Australia's obligations under UN Space Treaties.

3.2 The Environmental Protection and Biodiversity Conservation (EBPC) Act

The application for a Launch Facility Licence under the Space (Launches and Returns) Act requires commonwealth environmental consideration of the BOS activity and potential downstream effects to determine whether any significant impacts would arise from the intended actions.

This hazard and risk review is informed by the SMEC Environmental Assessment on GST's activities which considered the establishment of the Bowen Orbital Spaceport against these significant impact criteria.

Gilmour secured the services of an external provider to assess the potential and expected environmental impacts of construction and operational activities at the facility.

3.3 The Environmental Protection (EP) Act

The Environmental Protection Act 1994 seeks to protect the Queensland environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains ecological processes. The EP Act sets forth the process for consideration of whether an activity meets the threshold of an Environmentally Relevant Activity (ERA). The established construction and operational activities of the Bowen Orbital Space do not meet any ERA Thresholds.

The EP Act also allows that under the State Development Act, a development planning application or Material Change of Use shall be considered as a properly made submission for environmental approval.

3.4 State Planning Policy (SPP)

The SPP defines Matters of State Environmental Significance (MSES). This review is informed by the SMEC Environmental Assessment.

3.5 Abbot Point State Development Area (APSDA) Scheme

Declared in 2008, the APSDA was established under the State Development and Public Works Organisation Act 1971 to facilitate large-scale industrial, manufacturing and port-related development of regional, state, and national significance. Developments within the APSDA Scheme are approved by the Coordinator-General.

Current high impact industrial activities within the APSDA include:

- Industrial and port activities
- Coal bulk haulage
- Extractive quarrying industry

- Proposed future uses including possible renewable green hydrogen and energy production

3.6 Hazardous and Dangerous Goods Management

The legislation, best practice, standards, and codes for the treatment of Dangerous Goods is the subject of International Agreements, National and State Legislation and various codes of practice. These codes, standards and legislation are captured in the BOS Hazardous and Dangerous Goods Management Plan.

4 Risk Methodology

The Gilmour Space risk management methodology is derived from the principles, framework, and processes outlined in ISO 31000:2018 as well as other relevant risk management guidelines, legislative policies, and regulations. It details the strategy, roles, and responsibilities for risk management as well as explains the implementation of the Gilmour Space risk management framework.

In preparing this hazard and risk analysis, Gilmour Space conducted an assessment of the attendant risks of the construction and operation of a spaceport facility in the context of the APSDA and recorded these results in a risk register. This assessment considered:

- The local and remote environments of the BOS facility.
- Engineering designs for the BOS facility.
- Environmental Assessment Report.
- International literature as published by organisations such as NASA, ECSS, IAASS.
- Eris system engineering plans, failure modes effects and criticality analysis.
- Typical flight plan and trajectory analysis from the BOS.

The category of risks considered were safety, technical, schedule, finance, environment (including cultural heritage), legal and reputation. This hazard and risk review will describe key risks to safety and the environment, including their treatment through controls and mitigations as well as the subsequent residual levels of risk when judged against the regulatory standards.

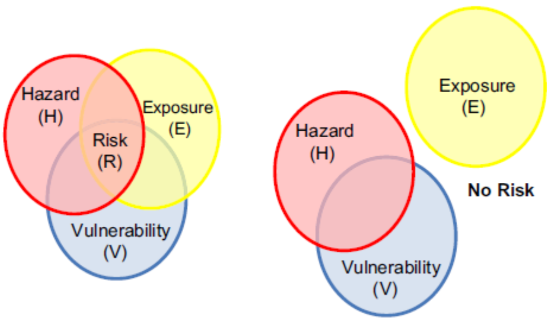

Figure 5 – Representation of how Exposure Removal through Implementation of Exclusion Zone Lowers Risks

5 Risk and Control Analysis

5.1 Overview

The risk assessment can be found in Appendix A for this review. It identifies residual risks from the construction and operation of the BOS facility which will be further discussed below. It is important to acknowledge that while all engineering effort will be made in the design of launch vehicle systems, the residual risk of failure during a launch albeit minimal remains credible. Therefore, the location for launch and the flight paths have been chosen to minimise these risks to the public and the environment.

The review of the construction and operational systems associated with the development of the BOS highlighted the key risk contexts below which are considered in the analysis.

- Risks to personal safety on site and downstream of launch site.
- Risks to property and operations within the APSDA.
- Risk to the coastal environment within the BOS site and the downstream terrestrial systems.
- Risks to the marine environment of the GBRMP and CSMP.
- Risks to the low earth orbit environment.

Worthy of note, no risks to critical infrastructure from trigger debris were identified for the proposed launch activity. Table 3 below highlights the hazards identified as related to activities associated with the BOS Spaceport within the contexts to which they are applicable for this analysis.

Table 3 – Identified Hazards for Risk Analysis

Phase & Identified Hazards	Applicable Risk Contexts				
	Personal Safety	APSDA	Coastal Env.	Marine Env.	LEO Env.
Construction and Operations					
Habitat Disruption	-	-	✔	✔	-
Soils Erosion and Sedimentation	-	-	✔	✔	-
Noise, Air Quality and Light Impact	-	✔	✔	✔	-
Chemical Contamination	✔	✔	✔	-	-
Traffic and Access Impact	✔	✔	-	-	-
Launch & Flight Activities					
Rocket Noise and Vibration	✔	✔	✔	✔	-
Hazardous and Dangerous Goods	✔	✔	✔	-	-
Thrust or Guidance Failure	✔	✔	✔	✔	-
Catastrophic Failure	✔	✔	✔	✔	-
Distant Focussing Overpressure	✔	-	-	-	-
Orbital Failure	-	-	-	-	✔

The Flight Safety Code mandates that for new launch vehicle risk consideration, the probability of failure to reach a successful orbit should be considered as 25%. This probability of failure represents the sum of the probabilities of various common failure modes such as loss of guidance, loss of engine thrust, and explosion of propulsion systems. The Flight Safety Code provides a list of various typical vehicle failure modes[1] and their probabilities. These compounded failure mode probabilities are used in this analysis to provide representative expectations of effects without actual historical flight data.

Table 4 - Mission Outcome Probability and Consequence Estimation based upon Space Act Flight Safety Code

Mission Outcome		Probability		Mission Consequence
Mission Successful		**75.0%**		Nominal scheduled debris
Mission Failure	Failure leading to improper orbital insertion	**25%***	(9.2%)**	Aero Breakup
	Engine shutdown, loss of thrust		(4.4%)**	Intact Impact or Aero Breakup
	Explosion somewhere in the liquid propulsion system		(3.5%)**	Catastrophic Failure
	Stage or payload separation failure – 2^{nd} or 3^{rd} Stage		(2.2%)**	Aero Breakup
	Guidance and Control - Loss of vehicle attitude reference		(1.8%)**	Intact Impact or Aero Breakup
	Engine Failure to start – 2^{nd} or 3^{rd} Stage		(1.3%)**	Aero Breakup
	Pitch attitude error, failure		(1.3%)**	Intact Impact or Aero Breakup
	Control system loss of thrust vector control		(0.9%)**	Intact Impact or Aero Breakup
	Software error		(0.4%)**	Intact Impact or Aero Breakup

The four mission consequences identified above in table 4 are described in this analysis as below:

Nominal Scheduled Debris – These are rocket booster stages which will land at nominal impact locations. Risks are identified and managed by the Flight Safety Analysis and Flight Management Plan reviewed and approved by the ASA.

Intact Impact – During flight the autonomous Flight Safety System (FSS) will detect anomalous behaviour of the vehicle and should react by terminating thrust. The vehicle will subsequently complete its ballistic path to impact.

Aero Breakup – When travelling at high velocities aerodynamic forces can result in mechanical structure failures leading to breakup during flight. No explosion risk is present. Chemical risks reduce with increasing altitude.

Catastrophic Failure – Severe failures which result in explosion, applicable during entire mission, however exposure to consequences from blast and chemicals rapidly reduces as vehicle gains altitude.

5.2 Construction and Operations Risks

In examining the construction and operational activities, several notable risks were identified to personal safety, and the environment. These include:

- Introduction of weeds and pest species leading to habitat disruption.
- Disruption of soil and vegetation or the exposure of acid sulphate soils leading to contamination of the habitat and waterways.
- Noise, air quality and light impacts causing stress or behavioural changes to endemic species.
- Chemical contamination of soils and waters.
- Increased traffic and access impacts.

[1] Australian Space Agency Flight Safety Code Table 8

Risks inherent in construction and operation of the Bowen Orbital Spaceport are controlled as discussed below.

5.2.1 Habitat Disruption

The introduction of weeds and pest species to an environment have the potential effects of disturbing or degrading native ecological systems. Activities which form part of the management of these risks include the sanitising of vehicles and material brought onto site as well as auditing and remediation of identified weed and pest threats. These activities are established in a Land Management Plan and seek to reduce the risk so far as practicable to maintain existing habitats on the site.

To further support the maintenance of the existing habitats, all practical effort has been made in the selection and engineering design to be in areas which are pre-disturbed, or where clearing of vegetation poses negligible impacts to the existing ecosystems or habitats. The site selection has been informed by the detailed SMEC Environmental Assessment.

5.2.2 Soil Erosion and Sedimentation

Risks to the environment due to soil disturbance and vegetation removal exist during construction activities (potentially exacerbated by seasonal variations). These risks will be managed by a compliant civil engineering erosion and sediment control design for the access track and infrastructure on the site and the implementation of typical erosion and sediment control management tools and techniques.

Examples of activities which control and mitigate possible impacts from construction works include soil testing and treatment as well as wastewater discharge treatment. Implementation of an Erosion and Sediment Control Management Plan will mitigate the risks, resulting in no long-term impacts from establishing the development site.

5.2.3 Noise, Air Quality and Light Impacts

The existing background noise and air quality of the APSDA is a mix of natural sources and the additional noise, dust, and debris from existing industry within the APSDA. This existing noise, dust, and debris from existing industry includes extractive quarrying, road and rail bulk haulage and ongoing upgrades to port infrastructure. The location of the BOS infrastructure is remote to sensitive receptors within the APSDA and the required construction methods are typically short in duration. Impacts to the environmental noise within the APSDA is assessed as negligible[2].

Dust, debris and emissions from heavy vehicles and power generation during the construction of the BOS which may affect the existing air quality will be managed as is typical for civil construction works. Available mitigations exist to manage impacts to negligible levels. Detailed methods and implementation of any dust and debris risks are identified and documented in the Erosion and Sediment Control Plan and Environment Management Plans for the BOS.

Artificial light pollution impacts from the BOS from outdoor work activities such as site civil works will be minimised through execution during daylight hours to limit generation of light pollution to all environments where practicable, and the requirement for consistent night-time works is currently not foreseen. Environmental impacts through artificial light are assessed as negligible[3].

[2] SMEC EAR 4.5
[3] SMEC EAR 4.7

5.2.4 Chemical Contamination of Soils and Waters

Hazardous and dangerous goods required at the BOS during construction and operational phases are fuels and maintenance fluids for power generation and cleaning agents for the upkeep of facilities as well as for the rocket and payload assembly and integration.

These substances introduce risks which will be managed using standard controls such as storage and use areas complete with bunding containment and ventilation where appropriate adequate PPE, training, emergency response procedures and waste management protocols will be utilised. These methods and procedures are documented in the Hazardous and Dangerous Goods Management Plan and the Waste Management Plan prepared for the BOS.

The risks associated with commissioning and operational phases are controlled in the same way as those described in the management of hazardous and dangerous goods for launch activities. It is important to note that for construction and operation activities there are no considerations required for launch, which will be discussed below.

5.2.5 Traffic and Access Impacts

The identified risks to the environment and public safety due to the increased traffic include the potential to increase the erosion of the development area leading to potential contamination of waterways, and the increased traffic leading to higher risk of traffic incidents.

The risk of environmental degradation due to traffic is adequately controlled by implementation of an Erosion and Sediment Control Management Plan during all development phases.

The residual safety risk associated with the potential for a traffic incident exiting the Bruce Highway is closely assessed through the BOS Transport and Access Management Plan. The risk of traffic incidents is considered low with no fatal accidents recorded at the proposed access locations and is reduced further to the extent reasonably practical by avoidance of peak hours use where practical, carpooling and awareness training.

5.3 Launch and Flight Risks

Launch includes all activities associated with fluids upload on the launch pad, ignition, lift-off, and flight of the vehicle to orbit. The hazards during this phase present risks to personal safety, property, and the environment due to blast overpressure, chemical contamination, and debris. These risks are highest during the early phase of launch, with the risks rapidly receding as the vehicle gains altitude and velocity from the launch location.

The risks identified with the launch and flight include:

- Rocket noise and vibration causing stress and/or behavioural changes to endemic species.
- Contamination due to spilling of hazardous and dangerous goods associated with filling operations.
- Catastrophic failure of the launch vehicle leading to blast overpressures, possible chemical contamination, and debris.
- Autonomous Flight Safety System initiation (and subsequent ballistic return to Earth).
- Falling components or debris.
- Failure to reach nominal orbit leading to potential orbital debris.

5.3.1 Rocket Noise and Vibration during Launch

Modelling of noise impacts from launch activities is based on testing data obtained during the Eris Hybrid Rocket research and development program. This modelling indicates that during a launch, noise levels not above 120 dB can be expected at the nearest sensitive receptor which is Saltwater creek, approximately 450 metres directly north of the launch pad location shown in figure 6 below.

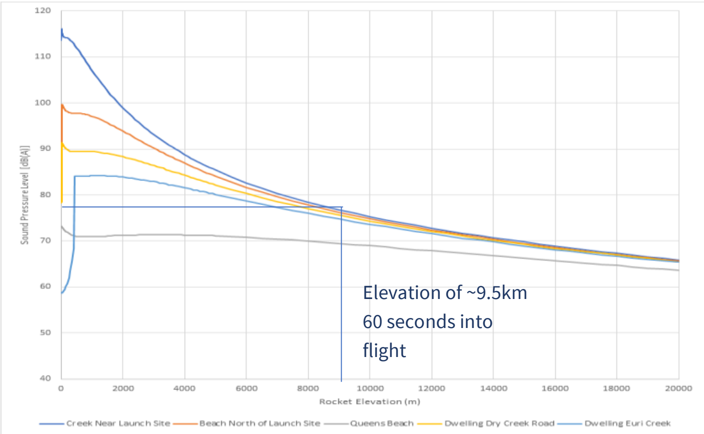

Figure 6 - Predicted Noise at Sensitive Receptors vs Elevation of Rocket after Launch

This noise impact is short duration and is anticipated to dissipate to levels below 75 dB within 60 seconds dependent on weather conditions. Noise experienced at ground level during a launch is expected to be of similar amplitudes, frequency, and durations to those which occur during severe thunderstorms. The time between launches is expected to be significant with maximum cadence of launch activities expected to be approximately once per month.

Personnel exclusion zones will be in place based upon minimum safe distances for potential blast effects and debris, these exclusion zones exceed the distances required to protect personnel from noise impact. Noise impacts to personnel and sensitive receptors generated by launch activities are negligible measured against existing standards and requirements for noise hazards.

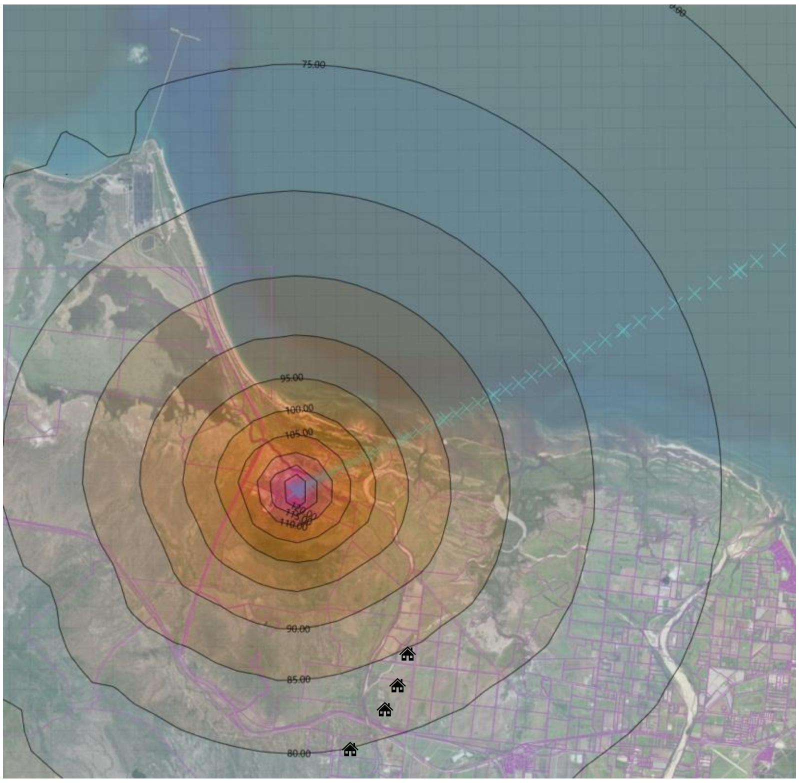

Figure 7 - Predicted Maximum Noise Contour Map at 15 Seconds after Launch and 500m Altitude.

Ground vibration was considered as a potential impact to infrastructure and sensitive receptors within the APSDA, coastal and marine environments. Conservative calculations which assume the highest possible ground transmissibility using the methodology within AS2187.2 produce a potential maximum ground vibration value (34mm/s) greatly below the recommended threshold criteria of 100 mm/s[4] established as the threshold peak particle velocity for infrastructure. Impacts from ground vibration to downstream infrastructure or environments are not considered significant risks and are as low as reasonably practicable.

5.3.2 Distant Focussing Overpressure (DFO)

Distant focusing overpressure (DFO) is an atmospheric phenomenon that can enhance and reflect a blast overpressure from an explosion on or around the launch pad during the early stages of launch leading to impacts on distant communities such as the breakage of windows which could result in personal injury[5]. The

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[4] A Richard & A Moore, *Effect of Blasting*, Alan Richard, ACARP project C14057, 2008
[5] SII-Distant-Focusing-Overpressure-text.pdf (nasa.gov)

atmospheric conditions which lead to the possibility of this reflection effect are well understood by meteorologists.

The risk of DFO have been assessed using the methodologies as defined in the IASS sponsored publication of Safety Design for Space Operations[6] for a maximum credible yield for a fully provisioned Eris vehicle of 5,335kg TNT equivalent. The maximum distance for DFO effects using this maximum yield potential is 3.5km from the point of explosion. Analysis of sensitive receptors indicates there are no inhabited buildings within this radius from the launch.

5.3.3 Chemical Contamination During Filling Operations

During prelaunch activities, risks exist to the environment associated with the transport, storage, use and disposal of hazardous and dangerous goods such as oxidisers and fuels. These risks are mitigated by siting the BOS away from important sensitive ecosystems. The site design also includes the use of earthen berms and swales, code compliant bunding and spill containment and the provision of deluge water availability to dilute any spillage for safe removal and waste treatment.

The decision to use hybrid rocket technology and stabilised H_2O_2 as an oxidiser has been carefully made in consideration of the inherent safety of transportation, storage and use of stabilised H_2O_2 when simple controls are implemented[7,8] including cooling of the product, contamination avoidance, and the ability to dilute and contain spills. The detailed risk considerations and controls for the transport, storage, use, management, and disposal of hazardous and dangerous goods on the BOS are described in the Hazardous and Dangerous Goods Management Plan.

5.3.4 Catastrophic Failure During Launch

The risks of a catastrophic event (explosion) include blast overpressure effects, possible chemical contamination from unexploded fluids, and debris. The risk of catastrophic failure is present from the time that a launch vehicle begins provisioning on the launch pad until the end of stage 3 burn.

[6] Safety Design for Space Operations, Ch5.2 Elsevier 2013
[7] M Ventura et al., '*Rocket Grade Hydrogen Peroxide (RGHP) for use in Propulsion and Power Devices - Historical Discussion of Hazards*', AIAA, 2007
[8] D Davis et al., '*Fire, Explosion, Compatibility and Safety Hazards of Hydrogen Peroxide*', NASA, 2005

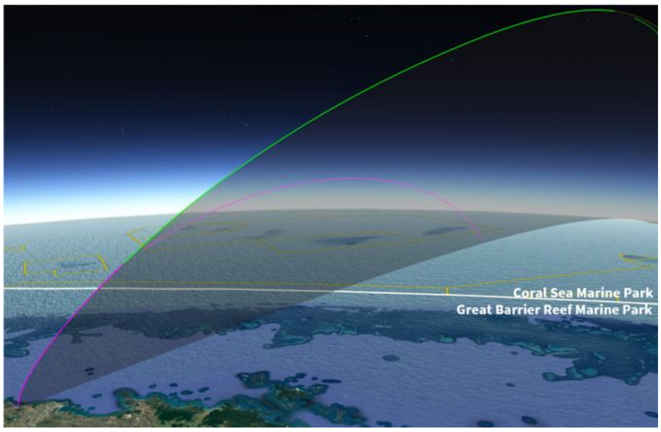

Figure 8 - Indicative Overflight Path of 57° Azimuth Launch – 1st Stage (Magenta), 2nd Stage (Green), 3rd Stage (Yellow)

Using the methods recommended by the US Federal Aviation Administration[9], a fully provisioned Eris launch vehicle has a Net Explosive Weight (NEW) of approximately 5,335 kg. This NEW conservatively acknowledges the extremely unlikely possibility that all bi-propellant fuels are dynamically mixed and exploded, while a full load of H_2O_2 is decomposed and vaporised to oxygen gas and high temperature steam.

The potential exposure to the hazards from blast overpressure effects, chemical contamination and debris vary depending on the phase of flight. The effects of blast overpressure and chemical contamination rapidly reduce to negligible levels during flight with increasing vehicle altitude and velocity. The risk of chemical contamination specifically is decreased due to the likelihood that the initiating event is likely to consume the launch vehicle's inventory of kerosene and liquid oxygen or initiate runaway decomposition of the contained H_2O_2 due to heating or contamination.

Debris hazards are not removed by increasing altitude and velocity, but the risk of exposure is significantly reduced by reduction in the density of any generated debris field. Debris risk is a significant driver for the design of flight paths to ensure that the likelihood of personnel or property damage (including critical infrastructure) is as low as reasonably practicable and below regulatory requirements.

Additional controls will be implemented to address the specific threat of fluids being carried by prevailing winds into areas where they may impact personnel. To ensure that a catastrophic failure does not lead to exposure of personnel to harmful fluids a GO/NO GO criteria based upon prevailing winds will be incorporated in range safety procedures.

The impacts on the environment of a catastrophic failure and associated blast overpressure and chemical hazards are present only during initial lift off and brief overflight of the coastal environment. These impacts are controlled and mitigated by the selected site location which is remote to the main environmentally significant habitats of the Caley Valley Wetland, located west of Abbot Point Road.

[9] US DoD, '*Defense Explosives Safety Regulation 6055.09 Edition 1*', 2019

It is unlikely that any residual kerosene or liquid oxygen will remain after an intact impact, however it is possible that H_2O_2 will be unexploded and may be released at high concentrations to the immediate environment. H_2O_2 will fully decompose to oxygen gas and water vapour in sunlight and immediately on contact with organic material if spilled on land (half-life <1hr in natural soils) [10]. If H_2O_2 is spilled into the marine environment it will be harmful to the immediate area of release however, will dilute rapidly below toxic levels and decompose to existing background levels in the marine environment over time (half-life in water varies greatly dependent on a number of factors: from 1hr to 5 days in sea water or up to 10 days in still fresh water without organics present).

Based on the quantities of launch fluids and vehicle materials and design, effects from any impact to the BOS site and coastal and marine environments are expected to be highly localised, short term and readily remediated as noted in the SMEC Environmental Assessment[11].

5.3.5 Flight Safety System Initiation

To control the risk of an off-nominal flight path due to thrust or guidance failures, a Flight Safety System (FSS) is fitted to the Eris vehicle which autonomously initiates termination of launch vehicle power and propulsion systems. Modern FSS are typically software driven autonomous systems, which removes the requirement for human decision making[12] allowing for near instantaneous response to failures, thus reducing the potential for harm significantly. Autonomous FSS undergo testing programs to ensure their safe and reliable operation in all circumstances.

Immediately after lift-off, the Launch vehicle will rapidly climb vertically for approximately 15 seconds to a height of 500m before commencing a manoeuvre to begin steering toward its target azimuth for the mission. FSS activation during the very early stages of launch (<35 seconds) presents a risk from vehicle impact at the launch site or immediate coastal environment leading to the catastrophic failure effects described above. FSS activation after this point will result in the vehicle debris impacting in the marine environment.

[10] SMEC EAR 4.8.3

[12] T Sgobba et al., '*Safety Design for Space Operations*', 2015, International Association for the Advancement of Space Safety.

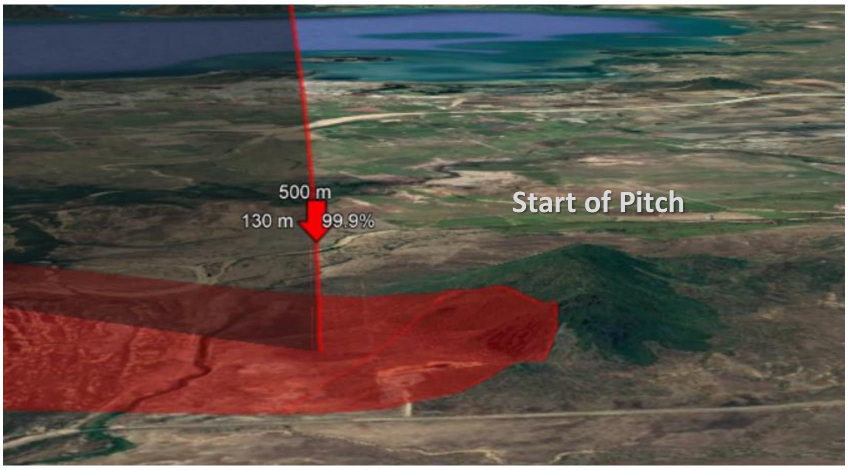

Figure 9 - Lift-off and Vertical Flight Path above the BOS Launch Pad

5.4 Controlling the Risk by Controlling Exposure

Note - All flight safety simulation and analyses will be reviewed by a suitably independent expert before approval is considered by the Australian Space Agency.

Once filling operations begin, the minimum safe distances for persons and property from the BOS are based upon the exclusion distance where it is improbable that any person could be impacted by blast overpressure. This distance is calculated as 274m and is applicable to all personnel including those involved in the launch activities. This exclusion zone sits entirely within the Lot 10 area for which Gilmour Space has complete control to implement exclusions. This exclusion zone is depicted in Figure 10.

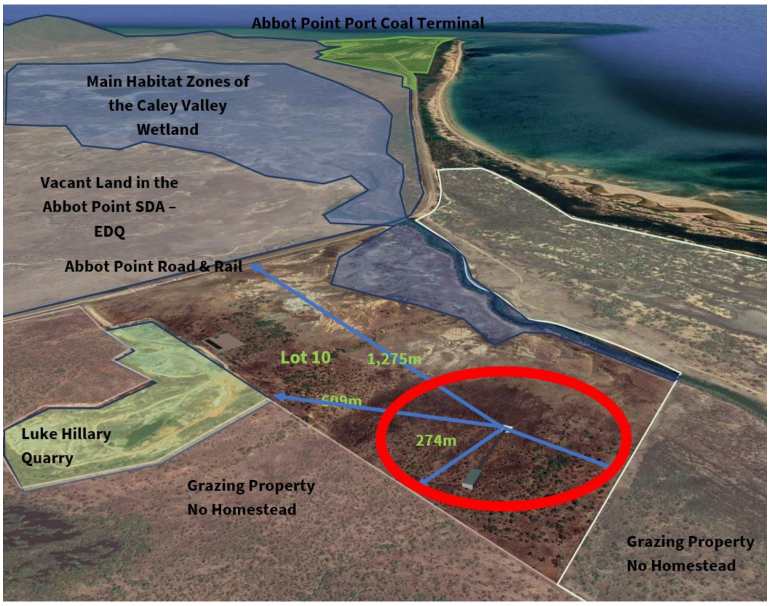

Figure 10 - BOS Exclusion Zone for all Persons During Launch Activity

In any nominal launch, scheduled debris will fall from the vehicle trajectory through the atmosphere to impact the earth. In any of the failure modes described above, either a full vehicle or a debris cloud will also fall from the nominal trajectory, through the atmosphere to earth. Control of the risk to personnel including those in aircraft or vessels will be achieved via the establishment of exclusion zones at the BOS site, as well as restricted and danger[13] areas downrange of the launch location.

In assessing the necessary exclusion areas surrounding the BOS and downrange, potential failure modes and debris models must be understood. Gilmour Space intends to create a methodology for the design of exclusion zones[14] that meet the regulatory requirements of the Australian Space Act Flight Safety Code for vehicles that will launch from the BOS. Each vehicle Launch Permit application needs to demonstrate compliance with that methodology as approved by the Australia Space Agency.

To show the likely exclusion zone design, Gilmour Space has modelled the trajectory of the Eris launch vehicle and used modelling data on aerodynamic and explosive breakup failure modes. The resultant understanding of the statistical spread of potential debris allows construction of terrestrial, air and maritime exclusion zones to control the risk to safety.

[13] The terminology for declared areas of exclusion on the high seas and super adjacent airspace is yet to be confirmed.
[14] In collaboration with Civil Aviation Safety Authority, Australian Maritime Safety Agency and the Australian Space Agency

The exclusion zones depicted below in figures 11 and 12 are intended to demonstrate a typical design that would meet the regulatory requirements shown in table 5.

Table 5 Acceptable Risk Criteria[15]

	Collective Risk per launch	Individual Risk per launch	Annualised 3rd Party Risk
Personnel Casualty	$1x10^{-4}$	$1x10^{-6}$	$1x10^{-5}$
Asset Damage	$1x10^{-4}$	NA	$1x10^{-5}$

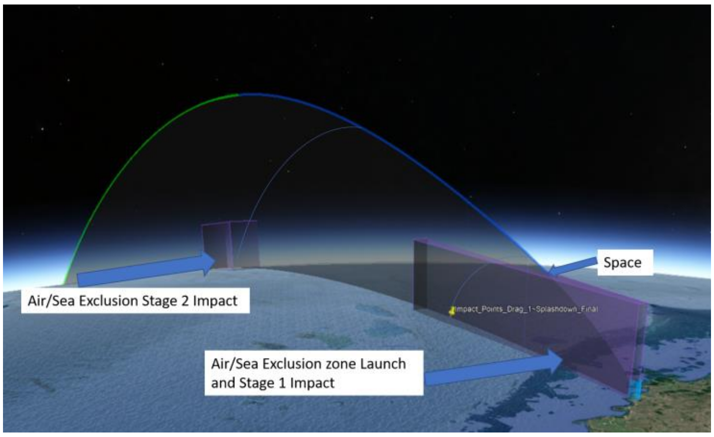

Figure 11 - Air / Sea Exclusion Zones

Figure 12 - Terrestrial Exclusion Zone

[15] Taken from the Australian Space Agency Flight Safety Code p10

For launch activity, the exclusion zones will be sanitised through remote observation accompanied by published restrictions (Air and Maritime Notices) and regular broadcast of warnings in the downrange environment to reduce the risk to personnel of impacts from inflight failure (or scheduled debris).

Within these exclusion zones, the probability of injury or damage increases with increasing proximity to the planned ground track of the launch vehicle and its scheduled debris.

5.4.1 Orbital Failure

Failure of the stage 3 of the vehicle to achieve nominal orbital insertion and de-orbit burn could arise from any of the potential failure modes above. Off-nominal insertion could lead to risk of collision with objects already in orbit (satellites or spacecraft) and generation of debris clouds in the LEO environment.

The NASA Range Commanders Council[16] recommends protection of objects in orbit by ensuring (through launch window timing) an ellipsoidal miss-distance of 200km in-track and 50 km cross track and radially for manned spacecraft. Or 25 km in-track and 7km cross track and radially for other than manned spacecraft. When implemented, this control limits the exposure of other spacecraft in the LEO to any deleterious effect from a stage 3 failure.

[16] Common Risk Criteria Standards for National Test Ranges – RCC Standard 321-16

6 Summary of Residual Risks and Regulatory Requirements

This hazard analysis and risk assessment indicates residual risks exist for the BOS construction and launch activities. The regulatory requirements of the Space, EBPC, EP Acts and SPP require that Gilmour Space control or mitigate these risks to meet certain standards. The residual risks and treatments are described in the sections below.

6.1 EPBC Act, EP Act and SPP

The federal and state level environmental protection and planning legislation require that activities be controlled such that they represent no significant impact to the environment where it concerns matters of national or state environmental significance. Given that the flight path traverses both the Great Barrier Reef Marine Park and the Coral Sea Marine Park, both world heritage sites and matters of National Environmental Significance, Gilmour Space have sought advice on the significance of ecological impact of an inflight failure and the impact of scheduled debris through the planned flight path.

SMEC have prepared an ecological assessment review that indicates that the construction and operation of the BOS is not likely to meet any definitions of a significant impact under the EBPC Act or SPP and that of an Environmentally Relevant Activity under the EP Act.

SMEC have recommended a referral of the BOS development approval to the federal Department of the Environment for confirmation that the proposed development does not exceed the threshold of significant impacts.

6.2 Space Act

Gilmour Space will be required, after the approval for development, to apply for a Launch Facility Licence, and further, a Launch Permit for each launch activity. The Code requires the nomination of controlled areas for launch vehicle scheduled debris which has been calculated where the act requires that a launch vehicle be fitted with a compliant Flight Safety System (FSS) for flight termination (for a fully autonomous system) with a reliability of 99.9% which will be fitted to Eris for launch.

The Space Act, through the flight safety code requires assessment and control of risks of individual casualties, collective casualties, and asset damage, as well as assessment of annualised risk of casualties and asset damage. These safety standards are listed in table 5 and are controlled by using exclusion zones designed to the methodology of those displayed in figures 12 and 13 that represent suitable controls to meet the safety requirements and reduce the risk to personnel to as low as reasonably practicable. These risks will continue to be treated as the vehicle matures.

Risk Number	Phase	Risk Hazard	Risk Hazard Description (The Hazard leading to an Event)	Impacts (What does the event impact)	Risk Category	Likelihood	Consequence	Inherent Risk	Existing Barrier or Mitigation Controls to reduce risk	Control Validity	Likelihood	Consequence	Residual Risk
0.01	Construction	Vehicular Traffic	Vehicle traffic leads to introduction of weeds / pests.	Weed / Pest species introduces to the site and disturbed soils altering species composition through competition with native species.	Environment	Likely	Minor	M	Ensuring all vehicles and equipment are free of contaminants prior to entering and exiting the project area. All removed weeds, weed-affected materials and rubbish should be appropriately disposed of off-site. No dumping of refuse onsite or into adjacent retained vegetation or gullies. Minimise the disturbance footprint. Undertaking rigorous weed management of temporarily disturbed areas (including edges of tracks) until a suitable ground cover is established.	Fully Valid	Unlikely	Minor	L
0.02	Construction	Vehicular Traffic	Vehicle traffic leads to contact injury / mortality of flora / fauna.	Destruction / death of individual animals / plants.	Environment	Unlikely	Insignificant	L	Speed limits on construction site reduced to 20km/hr.	Partially Valid	Unlikely	Insignificant	L
0.03	Construction	Vehicular Traffic	Vehicular traffic causes congestion at Bruce Highway Intersection potentially leading to vehicular accident.	Potential Traffic injury to general public (GP).	Safety	Unlikely	Moderate	M	Evidence of 5 accidents at Bruce highway intersection over previous 20 years based on DTMR Data. No Fatalities recorded. Heavy vehicle movements deconflicted with major traffic periods. Car Pooling / Bussing of workers to avoid congestion Awareness training will specifically cover the risks of this intersection and alternate options if congested. TAP in Place.	Partially Valid	Rare	Moderate	L
0.04	Construction	Disturbing Soils and removing vegetation	Earthmoving exposes soils that may contain high Acid Sulphate levels.	Exposure of soils leading to site contamination with acid sulphates.	Environment	Possible	Moderate	M	soil testing in advance of construction activity will inform excavation process. If detected soils will be sequestered and treated on site.	Fully Valid	Unlikely	Minor	L
0.05	Construction	Disturbing Soils and removing vegetation	Earthmoving or clearance leading to disturbance of Culturally Sensitive site.	Destruction or damage to culturally sensitive site degrading cultural heritage value.	Environment	Rare	Moderate	L	Pre-works survey and engagement with traditional owners to confirm the absence of identified sensitive sites	Fully Valid	Rare	Minor	L
0.06	Construction	Disturbing Soils and removing vegetation	Soil / vegetation disruption leading to habitat loss / fragmentation.	Habitat loss and fragmentation leading to species population decline or extinction.	Environment	Unlikely	Minor	L	Clearly demarcate the development footprint on site plans and on the ground to prevent vegetation clearing and disturbance outside of the development footprint. Where possible retain significant microhabitat features by slightly moving the project area. Where microhabitats cannot be avoided (e.g. rockpiles, woody debris etc.) attempt to relocate the feature into adjacent habitat. Prioritise the retention of trees with hollows, trees without hollows, shrubs, grasses and herbs in that order. Rehabilitate temporarily disturbed areas with locally sourced native plants that occur in adjacent vegetation communities.	Fully Valid	Rare	Insignificant	L
0.07	Construction	Disturbing Soils and removing vegetation	Leading to contact mortality of flora fauna	Earthmoving and clearance activity leading to contact injury or death of individual animals or plants.	Environment	Unlikely	Insignificant	L	Engage a qualified spotter-catcher to inspect critical habitats prior to clearing and preferably be present onsite during clearing to relocate any animals exposed during clearing. Relocate exposed animals into suitable adjacent microhabitats where present.	Fully Valid	Rare	Insignificant	L

0.08	Construction	Hazardous and Dangerous Goods Management	Spills of industrial fluids (hydrocarbons / solvents etc) through operation and maintenance of construction equipment.	Leading to contamination of soils or if not contained – waterways.	Environment	Unlikely	Minor	L	Minimise the area of soil disturbance and stage the development to manageable phases. Stabilise earth batters and other steep areas to control runoff. Maximise the retention of vegetation along and adjacent to watercourses which slow and filter runoff. Utilise bunds or sediment basins to capture runoff during the construction phase of the project. Mulch cleared vegetation and place in a thick layer of exposed surfaces. Attempt to undertake works during drier months to reduce the risk of erosion. Regularly water excavated materials to reduce the potential for erosion. Ensure the safe storage and handling of contaminants in accordance with Australian Standards (e.g., AS1940 and AS3833) and the requirements of the EP Act. Ensure that any materials coming in contact with liquid oxygen are cleaned of organic materials that could combust. Ensure that materials that come into contact with liquid oxygen are suitable for purpose. Transfer contaminated deluge water in bunded areas into drums for disposal at an authorised landfill. Temporary fuel storages used for excavation and other equipment should utilise temporary bunding. Employees and contractors to be trained in the use of spill kits and the removal of contaminated soils. Ensure the safe storage and handling of contaminants in accordance with Australian Standards (e.g. AS1940 and AS3833) and the requirements of the EP Act. Major vehicle services to be undertaken off site.	Fully Valid	Rare	Minor	L
0.09	Construction	Noise, Air Quality and Light	Operation of heavy plant, tools and machinery generating acoustic effects.	Noise generated by construction causes physical damage, stress or behavioural change for endemic species.	Environment	Possible	Minor	M	Avoid early morning and night works. Ensure that there are periods during the day when activities cease, even for a short period (e.g. lunch, morning tea, afternoon tea). Where possible minimise vehicle movements and localise noise impacts by phasing construction activities to the smallest area feasible at any given time. Apply onsite speed restriction and avoid excessive revving of vehicles. Time the major noise producing activities to coincide with periods of low animal activity (i.e. early afternoon). Maintain and operate plant and machinery in accordance with Australian Design Rules and manufacturers specifications to ensure efficient operation.	Fully Valid	Possible	Insignificant	L
0.1	Construction	Noise, Air Quality and Light	Operation of heavy plant, tools and machinery generating particulate matter.	Particulate matter from construction related activity degrades local air quality.	Environment	Likely	Insignificant	L	20km/hr speed limit on site. Minimise vehicle movements, especially heavy vehicle movements. Restrict vehicle movements to specifically defined areas. Dust suppression using water trucks to douse access tracks. Cover loads on trucks when transporting materials that would be dispersed under normal driving conditions. Undertake visual monitoring for fugitive dust during construction and implement controls as required. Ensure that all plant and equipment are maintained and operated in accordance with Australian Design Rules and manufacturers specifications. Generators used for power supply will produce exhaust emissions. Over the course of delivery the emissions of water vapour will total 20t and carbon dioxide will total 8t. The wetland bird community is at most risk of these impacts during construction.	Fully Valid	Possible	Insignificant	L
0.11	Construction	Noise, Air Quality and Light	Operation of heavy plant, tools and machinery generating artificial light.	Artificial Light levels during natural periods of darkness leading to circadian disturbances, avoidance behaviour and roost abandonment by endemic species.	Environment	Unlikely	Insignificant	L	Clearing and construction activities to be undertaken only during daylight hours. Directing artificial light only to where it is required (i.e., areas critical for security and safety). Utilise artificial light only during necessary periods. Avoid the use of ultraviolet light emitting outdoor lighting. Deploy artificial lighting at the lowest intensity required for the purpose.	Fully Valid	Rare	Insignificant	L

0.12	Construction	Disturbing Soils and Removing vegetation	Disturbance of soils and local waterways leads to erosion and sediment transportation.	Sedimentation of local watercourses leading to reduced water quality on site and flowing into regional waterways.	Environment	Unlikely	Minor	L	Minimise the area of soil disturbance and stage the development to manageable phases. Stabilise earth batters and other steep areas to control runoff Maximise the retention of vegetation along and adjacent to watercourses which slow and filter runoff. Utilise bunds or sediment basins to capture runoff during the construction phase of the project. Mulch cleared areas and place in a thick layer over exposed surfaces. Attempt to undertake works during drier months to reduce the risk of erosion. Regularly water excavated materials to reduce the potential for erosion.	Fully Valid	Unlikely	Insignificant	L
0.13	Construction	Hazardous and Dangerous Goods Management	Commissioning testing of new ground support distribution and storage facility fails to contain fluids.	Fluid spill in vicinity of launch pad / storage areas.	Environment	Likely	Minor	M	Bunded construction of storage area and spill troughs for containment. Ensure bulk water is available for dilution.	Fully Valid	Unlikely	Insignificant	L
1.01	Pre-Launch	Hazardous and Dangerous Goods Management	General upkeep activities result in spills of industrial fluids.	Hydrocarbons or solvents contaminate local area.	Environment	Possible	Insignificant	L	Staff trained in spill management and dangerous goods management. Ensure the safe storage and handling of contaminants in accordance with Australian Standards (e.g., AS1940 and AS3833) and the requirements of the EP Act. Major vehicle services to be undertaken off site	Partially Valid	Unlikely	Insignificant	L
1.02	Pre-Launch	Ground Integration System Failure	Ground Integration System Failure leading to propellant / oxidiser spill which impacts personnel.	Propellant / oxidiser spill causes harm to personnel.	Safety	Possible	Minor	M	Bunded construction of storage area and spill troughs for containment. Bulk water available for dilution. Full PPE available and mandated for use by response teams.	Fully Valid	Unlikely	Insignificant	L
1.03	Pre-Launch	Ground Integration System Failure	Ground Integration System Failure leading to propellant / oxidiser spill.	Propellant / oxidiser spill causes harm to BOS environment.	Environment	Possible	Minor	M	Bunded construction of storage area and spill troughs for containment. Bulk water available for dilution. Contracted removal of waste chemicals in bunding and spill trough available to reduce time for H_2O_2 dissipation.	Partially Valid	Unlikely	Minor	L
1.04	Pre-Launch	ERIS System Failure	Integrated and Full ERIS Vehicle suffers catastrophic Failure creating blast effects, chemical hazards, and debris risk for personnel.	Full Eris Vehicle converts to explosive event causing over pressure effects, flame, debris, and chemical hazards to personnel.	Safety	Possible	Severe	H	Earthen berms and remote construction of BOS deflect / control blast, debris, and chemicals. Exclusion zones established for GP, COP, and MEP. Pre-Launch DFO hazard threshold established. Broadcast during launch activities to deter transgression of exclusion zones. RSO establish surveillance of downrange areas before launch.	Fully Valid	Rare	Moderate	L
1.05	Pre-Launch	ERIS System Failure	Integrated and Full ERIS Vehicle suffers catastrophic Failure.	Full Eris Vehicle converts to explosive event causing over pressure effects, flame, debris, and chemical hazards to BOS environment.	Environment	Possible	Minor	M	Earthen berms and remote construction of BOS deflect / control blast, debris, and chemicals.	Partially Valid	Rare	Minor	L
1.06	Pre-Launch	Environmental Hazard (Fire / Electrical Storm)	Integrated and Full ERIS Vehicle exposed to environmental hazard like fire or lightning leading to catastrophic failure creating blast effects, chemical hazards, and debris risk for personnel.	Full Eris Vehicle converts to explosive event causing over pressure effects, flame, debris, and chemical hazards to personnel.	Safety	Possible	Severe	H	BOS operational procedures will limit chance of vehicle exposure to environmental dangers through forecasting and land management. Exclusion zones established for GP,COP, and MEP. Earthen berms and remote construction of BOS deflect / control blast, debris, and chemicals.	Fully Valid	Rare	Moderate	L
1.07	Pre-Launch	Environmental Hazard (Fire / Electrical Storm)	Integrated and Full ERIS Vehicle exposed to environmental hazard like fire or lightning leading to catastrophic failure creating blast effects, chemical hazards, and debris field.	Full Eris Vehicle converts to explosive event causing over pressure effects, flame, debris, and chemical hazards to BOS environment.	Environment	Possible	Minor	M	BOS operational procedures will limit chance of vehicle exposure to environmental dangers through forecasting and land management. Earthen berms and remote construction of BOS deflect / control blast, debris, and chemicals.	Fully Valid	Rare	Insignificant	L
2.01	Launch	Ground Integration System Failure	Hold downs or Tower malfunction leading to catastrophic Failure creating blast effects, chemical hazards, and debris risk for personnel	Full Eris Vehicle converts to explosive event causing over pressure effects, flame, debris, and chemical hazards to personnel.	Safety	Unlikely	Severe	M	Exclusion zones established for GP, COP, and MEP. Pre-Launch DFO hazard threshold established exclusion zones established for GP, COP, and MEP. Earthen berms and remote construction of BOS deflect / control blast, debris, and chemicals.	Fully Valid	Rare	Moderate	L
2.02	Launch	Ground Integration System Failure	Hold downs or Tower malfunction leading to catastrophic Failure creating blast effects, chemical hazards, and debris risk for personnel	Full Eris Vehicle converts to explosive event causing over pressure effects, flame, debris, and chemical hazards to BOS environment.	Environment	Unlikely	Minor	L	Earthen berms and remote construction of BOS deflect / control blast, debris and chemicals. Broadcast during launch activities to deter transgression of exclusion zones. RSO establish surveillance of downrange areas before launch.	Fully Valid	Rare	Minor	L
2.03	Launch	Ground Integration System Failure	Ground Integration System Failure leading to propellant / oxidiser spill post launch impacting personnel.	Propellant / oxidiser spill causes harm to personnel.	Safety	Possible	Minor	M	Bunded construction of storage area and spill troughs for containment. Bulk water available for dilution. Full PPE available and mandated for use. Contracted removal of waste chemicals in bunding and spill trough available to reduce time for H_2O_2 dissipation.	Fully Valid	Unlikely	Insignificant	L

2.04	Launch	Ground Integration System Failure	Ground Integration System Failure leading to propellant / oxidiser spill post launch.	Propellant / oxidiser spill causes harm to BOS environment.	Environment	Possible	Minor	M	Bunded construction of storage area and spill troughs for containment. Bulk water available for dilution. Contracted removal of waste chemicals in bunding and spill trough available to reduce time for H_2O_2 dissipation.	Fully Valid	Unlikely	Insignificant	L
2.05	Launch	ERIS System Failure	Full Eris Vehicle suffers catastrophic failure proximate to ground creating blast effects, chemical hazards, and debris risk for personnel.	Full Eris Vehicle converts to explosive event causing over pressure effects, flame, debris, and chemical hazards to personnel.	Safety	Possible	Severe	H	Exclusion zones established for GP, COP, and MEP. Pre-Launch DFO hazard threshold established broadcast during launch activities to deter transgression of exclusion zones. RSO establish surveillance of downrange areas before launch. To address the specific threat of liquid H_2O_2 falling - RSO will include a go/no go based on possible H_2O_2 liquid threat based on launch day wind conditions. Use of "GUARDIAN" SMS warning system in the event of wind change after launch carrying H_2O_2 droplets near port / rail / road.	Partially Valid	Rare	Minor	L
2.06	Launch	ERIS System Failure	Full Eris Vehicle suffers catastrophic failure proximate to ground creating blast effects, chemical hazards, and debris field.	Full Eris Vehicle converts to explosive event causing over pressure effects, flame, debris, and chemical hazards to BOS environment.	Environment	Possible	Minor	M		Not controlled	Possible	Minor	M
2.07	Launch	Acoustic effects of launch	ERIS Launch activity generates substantial albeit short-lived acoustic effects.	Eris Vehicle acoustic effects cause physical harm to MEP, COP, or GP.	Safety	Possible	Minor	M	Exclusion zones established on land for GP, COP, and MEP. Maritime exclusion Zones and Airspace restrictions in place for launch. Pre-launch DFO hazard threshold established broadcast during launch activities to deter transgression of exclusion zones. RSO establish surveillance of downrange areas before launch.	Fully Valid	Rare	Minor	L
2.08	Launch	Acoustic effects of launch	ERIS Launch activity generates substantial albeit short lived acoustic effects.	Eris Vehicle acoustic effects cause damage or distress to endemic species.	Environment	Possible	Insignificant	L		Not controlled	Possible	Insignificant	L
3.01	Stage 1 Flight	ERIS System failure	Full Eris Vehicle suffers catastrophic failure during first stage flight creating blast effects, chemical hazards, and debris risk for personnel.	Full Eris Vehicle converts to explosive event causing over pressure effects, flame, debris, and chemical hazards to personnel.	Safety	Possible	Severe	H	Exclusion zones established on land for GP, COP, and MEP. Maritime exclusion Zones and Airspace restrictions in place for launch. Pre-launch DFO hazard threshold established broadcast during launch activities to deter transgression of exclusion zones. RSO establish surveillance of downrange areas before launch.	Partially Valid	Rare	Moderate	L
3.02	Stage 1 Flight	ERIS System failure	Full Eris Vehicle suffers catastrophic failure during first stage flight creating blast effects, chemical hazards, and debris field.	Full Eris Vehicle converts to explosive event causing over pressure effects, flame, debris, and chemical hazards to marine environment.	Environment	Possible	Insignificant	L	Flight plan Selected to minimise overflight of sensitive marine areas.	Not controlled	Possible	Insignificant	L
3.03	Stage 1 Flight	ERIS System failure	Eris Vehicle flight termination by FSS, creating chemical and debris risk for personnel.	Eris Vehicle thrust loss and subsequent ballistic path to impact.	Safety	Possible	Severe	H	Exclusion zones established on land for GP, COP, and MEP. Maritime exclusion Zones and Airspace restrictions in place for launch. Pre-launch DFO hazard threshold established broadcast during launch activities to deter transgression of exclusion zones. RSO establish surveillance of downrange areas before launch.	Partially Valid	Rare	Moderate	L
3.04	Stage 1 Flight	ERIS System failure	Eris Vehicle flight termination by FSS creating chemical and debris field.	Eris Vehicle thrust loss and subsequent ballistic path to impact.	Environment	Possible	Insignificant	L	Flight plan Selected to minimise overflight of sensitive marine areas.	Partially Valid	Possible	Insignificant	L
3.05	Stage 1 Separation	Nominal Scheduled Debris	Eris Vehicle stage 1 achieves nominal separation, completes ballistic path to impact.	Stage 1 ballistic path to impact collides with aircraft or vessel.	Safety	Rare	Severe	M	Flight plan selected to ensure scheduled debris impacts in remote location. Danger / advisory areas declared and broadcast to Airmen and Mariners for avoidance.	Fully Valid	Rare	Moderate	L
3.06	Stage 1 Separation	Nominal Scheduled Debris	Eris Vehicle stage 1 achieves nominal separation, completes ballistic path to impact.	Stage 1 ballistic path to impact in marine environment causing harm to endemic species.	Environment	Rare	Insignificant	L	Flight plan selected to ensure scheduled debris impacts in remote location (CSMP). Residual propellant / oxidiser amount minimised and designed to rapidly sink. Design of vehicle minimises use of non-inert material consideration for sea dumping act permissions sought.	Fully Valid	Rare	Insignificant	L
3.07	Stage 1 Separation	Separation Failure	Eris Vehicle Stage 1 fails to separate leading to FSS activation creating chemical hazards and debris field risk for personnel.	Eris Vehicle thrust loss and subsequent ballistic path to impact.	Safety	Possible	Major	H	Flight plan selected for scheduled debris. Maritime exclusion zones and airspace restrictions in place for launch. Broadcast during launch activities to deter transgression of exclusion zones. RSO establish surveillance of downrange areas before launch.	Fully Valid	Rare	Moderate	L
3.08	Stage 1 Separation	Separation Failure	Eris Vehicle Stage 1 fails to separate leading to FSS activation creating chemical hazards and debris field.	Eris Vehicle thrust loss and subsequent ballistic path to impact.	Environment	Possible	Minor	M	Flight plan selected for scheduled debris.	Partially Valid	Rare	Minor	L

4.01	Stage 2 Flight	ERIS System Failure	Eris vehicle stage 2 & 3 suffers catastrophic failure during second stage flight causing debris field risk for personnel.	Stage 2 & 3 of Eris Vehicle converts to explosive event causing debris field and possible chemical hazards to personnel.	Safety	Possible	Major	H	Maritime exclusion zones and airspace restrictions in place for launch. Broadcast during launch activities to deter transgression of exclusion zones. RSO establish surveillance of downrange areas before launch.	Fully Valid	Rare	Moderate	L
4.02	Stage 2 Flight	ERIS System Failure	Eris vehicle stage 2 & 3 suffers catastrophic failure during second stage flight causing debris field.	Stage 2 & 3 of Eris Vehicle converts to explosive event causing debris field and possible chemical hazards to personnel.	Environment	Possible	Minor	M	Flight plan selected to minimise overflight of sensitive marine areas.	Partially Valid	Unlikely	Minor	L
4.03	Stage 2 Separation	Nominal Scheduled Debris	Eris vehicle stage 2 achieves nominal separation, completes ballistic path to impact.	Stage 2 ballistic path to impact collides with aircraft or vessel.	Safety	Rare	Severe	M	Flight plan selected to ensure scheduled debris impacts in remote location. Danger / advisory areas declared and broadcast to airmen and mariners for avoidance.	Fully Valid	Rare	Moderate	L
4.04	Stage 2 Separation	Nominal Scheduled Debris	Eris vehicle stage 2 achieves nominal separation, completes ballistic path to impact.	Stage 2 ballistic path to impact in marine environment causing harm to endemic species.	Environment	Rare	Insignificant	L	Flight plan selected to ensure scheduled debris impacts in remote location. Residual propellant / oxidiser amount minimised and designed to rapidly sink. Design of vehicle minimises use of non-inert material.	Fully Valid	Rare	Insignificant	L
4.05	Stage 2 Separation	Separation Failure	Eris Vehicle Stage 2 fails to separate leading to FSS activation creating chemical and debris field risk to personnel.	Eris Vehicle thrust loss and subsequent ballistic path to impact.	Safety	Possible	Severe	H	Flight plan selected for scheduled debris. Maritime exclusion zones and airspace restrictions in place for launch. Broadcast during launch activities to deter transgression of exclusion zones. RSO establish surveillance of downrange areas before launch.	Fully Valid	Rare	Moderate	L
4.06	Stage 2 Separation	Separation Failure	Eris Vehicle Stage 2 fails to separate leading to FSS activation creating chemical and debris field.	Eris Vehicle thrust loss and subsequent ballistic path to impact.	Environment	Possible	Minor	M	Flight plan selected to minimise overflight of sensitive marine areas.	Partially Valid	Unlikely	Minor	L
5.01	Stage 3 Flight	ERIS System Failure	Eris Vehicle Stage 3 suffers catastrophic failure causing debris field risk to personnel.	Stage 3 of Eris vehicle converts to explosive event causing debris field hazards to personnel or orbital craft.	Safety	Possible	Major	H	Maritime exclusion zones and airspace restrictions in place for launch. Orbital insertion path clear for spherical 50km from objects or manned space vehicles.	Fully Valid	Rare	Moderate	L
5.02	Stage 3 Flight	ERIS System Failure	Eris Vehicle Stage 3 suffers catastrophic failure causing debris field descending to earth or remaining in orbit.	Stage 3 of Eris vehicle converts to explosive event causing debris field hazards to orbital environment.	Environment	Possible	Minor	M	Intended orbital insertion clear or manned spacecraft by ellipsoidal distance of 200km in-track and 50km radially / cross track and other than manned spacecraft by ellipsoidal distance of 25km in-track and 7km radially / cross track.	Partially Valid	Unlikely	Minor	L
5.03	Payload Deploy	Payload Deploy Failure	Eris Vehicle payload fails to deploy leading to off nominal de-orbit burn by stage 3.	Payload Fails to deploy leading to Stage 3 deorbit burn off - nominal causing debris field hazards to personnel.	Safety	Possible	Moderate	M	Eris stage 3 designed for atmospheric burn up rather than re-entry.	Fully Valid	Rare	Minor	L
5.04	Payload Deploy	Payload Deploy Failure	Eris Vehicle payload fails to deploy leading to off nominal de-orbit burn by stage 3.	Payload Fails to deploy leading to Stage 3 deorbit burn off - nominal causing debris field hazards to the LEO Environment.	Environment	Possible	Minor	M	Eris stage 3 designed for atmospheric burn up rather than re-entry.	Fully Valid	Unlikely	Insignificant	L
5.05	Stage 3 de-orbit	ERIS System Failure	Eris Vehicle suffers catastrophic failure leading to space debris.	Stage 3 of Eris vehicle converts to explosive event causing debris field hazards to personnel or orbital craft in LEO.	Safety	Possible	Major	H	Intended orbital insertion clear or manned spacecraft by ellipsoidal distance of 200km in-track and 50km radially / cross track and other than manned spacecraft by ellipsoidal distance of 25km in-track and 7km radially / cross track.	Fully Valid	Unlikely	Minor	L
5.06	Stage 3 de-orbit	ERIS System Failure	Eris Vehicle suffers catastrophic failure.	Stage 3 of Eris vehicle converts to explosive event causing debris field hazards to LEO environment.	Environment	Possible	Moderate	M	Intended orbital insertion clear or manned spacecraft by ellipsoidal distance of 200km in-track and 50km radially / cross track and other than manned spacecraft by ellipsoidal distance of 25km in-track and 7km radially / cross track.	Fully Valid	Unlikely	Minor	L

Abbreviations

Abbreviation	Definition
1080	Sodium Fluoroacetate
ACH	Aboriginal Cultural Heritage
ADG Code	Australian Code for the Transport of Dangerous Goods by Road and Rail
APSDA	Abbot Point State Development Area
ASA	Australian Space Agency
BOS	Bowen Orbital Spaceport
CSMP	Coral Sea Marine Park
DA	Development Application
DFO	Distant Focusing Overpressure
DGR	Dangerous Goods Regulations
ECSS	European Cooperation for Space Standardization
EDQ	Economic Development Queensland
EMP	Environmental Management Plan
EP Act	Environmental Protection Act
ERA	Environmentally Relevant Activity
ESC	Erosion and Sediment Control
ESCP	Erosion and Sediment Management Plan
FMECA	Failure Modes, Effects, and Criticality Analysis
FMP	Facilities Management Plan
FSS	Flight Safety System
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GP	General Public
GST	Gilmour Space Technologies
H_2O	Water
H_2O_2	Hydrogen Peroxide
HDGMP	Hazardous and Dangerous Goods Management Plan
IAASS	International Association for the Advancement of Space Safety
IATA	International Air Transport Association
IMDGC	International Maritime Dangerous Goods Code
Kero	Kerosene
LCC	Launch Control Centre
LEO	Low Earth Orbit
LMP	Land Management Plan
LOx	Liquid Oxygen
LPAD	Launch Pad
MCU	Material Change of Use
MEDQ	Minister for Economic Development of Queensland
NASA	National Aeronautics and Space Administration
NEW	Net Explosive Weight
NQBP	North Queensland Bulk Ports
O_2	Oxygen
PCBU	Person Conducting a Business or Undertaking
PPE	Personal Protective Equipment
RHD	Rabbit Haemorrhagic Disease
SDA	State Development Area
SDS	Safety Data Sheet
SPP	State Planning Policy
SSP	Site Security Plan
TAP	Transport and Access Plan
TBC	To be Confirmed
TNT	Trinitrotoluene
UN	United Nations
VAB	Vehicle Assembly Building
WHS	Workplace Health and Safety
WMP	Waste Management Plan
WRC	Whitsunday Regional Council

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