Air Emissions Protocol for the Arnhem Space Centre

Prepared for:

Equatorial Launch Australia

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Final

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Glossary

Term	Definition
$\mu g/m^3$	micrograms per cubic metre
°C	degrees Celsius
K	Kelvin
g/s	grams per second
kg	kilograms
kg/s	kilograms per second
m	metres
m/s	metres per second
Nomenclature	**Definition**
Al_2O_3	aluminium oxide
CO	carbon monoxide
HCl	hydrogen chloride
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
PM_{10}	particulate matter with a diameter less than 10 micrometres
Abbreviations	**Definition**
AGL	Above ground level
ASC	Arnhem Space Centre
Air NEPM	National Environmental Protection (Ambient Air Quality) Measure
BoM	Bureau of Meteorology
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
EA	Environmental Authority
ELA	Equatorial Launch Australia
EP Act	*Environmental Protection Act 1994*
EPA	Environment Protection Authority
NEPC	National Environment Protection Council
NSW	New South Wales
NT	Northern Territory
SA	South Australia
TAPM	The Air Pollution Model

EXECUTIVE SUMMARY

Katestone Environmental Pty Ltd (Katestone) was commissioned by Equatorial Launch Australia (ELA) to develop an Air Emissions Protocol (the Protocol) for the Arnhem Space Centre (the Project).

ELA is seeking to amend its Environmental Approval (EA) to allow for the Stage 2 expansion of the Project. To do so, ELA will make a referral to the Northern Territory Environmental Protection Authority (NT EPA) under the *Environment Protection Act 2019* (EP Act). Under the EP Act referral process, the NT Government expects a proponent to show:

> *How it will protect air quality and minimise emissions and their impact so that environmental values are maintained.*

The Arnhem Space Centre is a multiuser commercial spaceport that provides launch companies with launch services allowing them to access all orbits and inclinations. Launch companies use a range of rocket engine technologies of different sizes that may contain proprietary components and mixtures. It is difficult, at this stage, to quantify the likely emissions from the facility. Consequently, Katestone has developed this Protocol that sets allowable emission rates for rockets to ensure air quality is not negatively impacted during launches or static tests.

The Protocol has been developed considering the following:

- Legislative framework for air quality
- Existing air quality in the region surrounding the Arnhem Space Centre
- Meteorological conditions in the region based on measurements and meteorological modelling
- Characterisation of emissions of air pollutants as rockets ascend and during static tests
- Dispersion modelling of air pollutant emissions and assessment at sensitive receptors.

The Protocol is comprised of an emissions envelope that defines maximum emission rates rockets can have so that ground-level concentrations of relevant air pollutants do not exceed air quality criteria. The Protocol covers both emissions generated by launches as well as those by static tests, which involves firing rockets on the ground for testing purposes. As the launch parameters of rockets are unknown and will vary significantly, several examples of launches were considered in the Protocol to ensure a wide range of launches are covered.

The potential pollutants from each launch will depend upon fuel type and the amount of fuel used. Those identified that could make up exhaust fumes include:

- Carbon monoxide
- Hydrogen chloride
- Oxides of nitrogen and
- Aluminium oxide (as particulate matter less than 10 micrometres in diameter).

The Protocol has assigned emission rates to each of these pollutants for three example launches and for a static test. If rockets meet these thresholds, then air quality criteria at all sensitive receptors are expected to be met.

1. INTRODUCTION

Katestone Environmental Pty Ltd (Katestone) was commissioned by Equatorial Launch Australia (ELA) to develop an Air Emissions Protocol (the Protocol) for the Arnhem Space Centre (the Project).

ELA is seeking to amend its Environmental Approval (EA) to allow for the Stage 2 expansion of the Project. To do so, ELA will make a referral to the Northern Territory Environmental Protection Authority (NT EPA) under the Environment Protection Act 2019 (EP Act). The existing EA was assessed under the previous Environmental Assessment Act 1982 where the decision was made that the "potential environmental impacts and risks of the proposed action are not so significant as to warrant environmental impact assessment by the NT EPA under provisions of the EA Act at the level of a Public Environmental Report or Environmental Impact Statement".

Proposals that have the potential to have a significant impact on the environment now require referral to the NT EPA in accordance with s48 of the EP Act and the Environment Protection Regulations 2020 (EP Regulations) (DEPWS, 2021). Under the EP Act referral process, the NT Government expect a proponent to show:

> *How it will protect air quality and minimise emissions and their impact so that environmental values are maintained.*

The Arnhem Space Centre is a multiuser commercial spaceport that provides launch companies with launch services allowing them to access all orbits and inclinations. Launch companies use a range of rocket engine technologies of different sizes that may contain proprietary components and mixtures. It is difficult, at this stage, to quantify the likely emissions from the facility. Consequently, Katestone has developed this Protocol that sets allowable emission rates for rockets to ensure air quality is not negatively impacted during launches or static tests.

The Protocol development is described in the following parts of this report:

- Legislative framework for air quality (Section 2)
- Existing air quality in the region surrounding the Arnhem Space Centre (Section 3)
- Detailed description of the assessment methodology (Section 4)
- Meteorological conditions in the region based on measurements and meteorological modelling (Section 5)
- Characterisation of emissions of air pollutants as rockets ascend and during static tests (Section 6)
- Dispersion modelling of air pollutant emissions and assessment at sensitive receptors (Section 7).

2. LEGISLATIVE FRAMEWORK FOR AIR QUALITY

2.1 Air quality criteria

The NT EPA has not enacted legislation that specifies air quality criteria or guidelines to be applied to industrial facilities; however, the Northern Territory Ambient Air Quality Monitoring Reports summarise air quality in terms of compliance with the *National Environmental Protection (Ambient Air Quality) Measure* (Air NEPM) standards. This report has therefore nominated assessment criteria for the proposed facility based on the standards specified in the Air NEPM. Where air pollutants are emitted that are not addressed by the Air NEPM, assessment criteria have been adopted from the legislation in force in other Australian states or other countries.

Based on consideration of the key components of rocket fuels and similar combustion processes, the key air pollutants likely to be generated by the proposed activity have been identified to be carbon monoxide, hydrogen chloride, aluminium oxide, and nitrogen dioxide. Aluminium oxide has been assumed to all be in the form of particulate matter with a diameter less than 10 micrometres (PM_{10}). Air quality criteria for these substances have been adopted from the Air NEPM as well as legislation in New South Wales and the United States. The relevant legislation and authority issued information is as follows:

- National Environmental Protection (Ambient Air Quality) Measure (Air NEPM) standards
- Approved methods for the modelling and assessment of air pollutants in NSW (NSW EPA, 2016) (Approved Methods)
- Exposure Standards as defined in the Hazardous Chemical Information System, Safe Work Australia (Safe Work Australia, 2021)
- Integrated Risk Information System, United States Environmental Protection Agency (IRIS, 1995).

The relevant air quality criteria for the assessment are provided in Table 1. Due to the very short-term nature of the static tests and the intermittent use of the facility, only the short-time average standards have been considered in this assessment (i.e., criteria with annual average concentrations have been omitted).

Table 1 Air quality criteria adopted for the Protocol

Pollutant	Averaging Period	Guideline	Units	Source
Carbon monoxide	1-hour	30000	µg/m³	NSW Approved Methods
		25	ppm	
	8-hour	11000	µg/m³	NSW Approved Methods
		9	ppm	
Hydrogen chloride	15-minute	7500	µg/m³	Safe Work Australia
		5	ppm	
	1-hour	140	µg/m³	NSW Approved Methods
		0.09	ppm	
	24-hour	20	µg/m³	IRIS, US EPA
		0.012	ppm	
Nitrogen dioxide	1-hour	164	µg/m³	Air NEPM
		0.08	ppm	
Aluminium oxide (as PM_{10})	24-hour	50	µg/m³	Air NEPM

3. EXISTING ENVIRONMENT

3.1 Local terrain and land-use

The spaceport is located on the Gove peninsula in East Arnhem Land, the Northern Territory. The proposed spaceport is approximately 10 km from the coast. The region is generally flat, although the site and surrounding area are characterised by some small ridgelines. The land-use in the area is predominantly natural scrubland, however there is bauxite mining in the region.

3.2 Sensitive receptors

The region is relatively remote and sparsely populated. The nearest population centres are the township of Yirrkala, which has a population of approximately 800, and Nhulunbuy, which has a population of approximately 3,350.

The closest potential sensitive receptor is the Gulkula festival site that, once a year, hosts up to 2,000 people over a long weekend in July/August. No other sensitive receptors have been identified within five kilometres of the proposed spaceport. Table 2 and Figure 1 present the locations considered within this assessment. Note that the nearest point of State Route 24 has been included, but this is not considered a sensitive receptor location.

Table 2 Receptors and locations within the area of the Project considered in the Protocol

Description	Easting (km)	Northing (km)	Distance and direction from the Project
Gulkula festival site	697.820	8630.950	2.8 km NE
Nhulunbuy	693.700	8652.737	23 km N
Gove Airport	698.225	8642.944	13 km N
Yirrlaka	705.720	8644.538	18 km NE
Yalaŋbara	696.370	8617.602	12 km S
Guluruŋa	694.987	8616.343	13 km S
Bawaka	693.067	8614.543	16 km S
Dhanaya	688.637	8613.207	18 km SSW
State Route 24	694.726	8631.969	2 km N

3.3 Existing air quality

Due to the remote location of the activity, the local air quality is likely to be relatively unaffected by anthropogenic air pollutants. The bauxite mining in the region may contribute to ambient levels of particulate matter, including aluminium oxide. There will also be natural sources of dust including salt spray from the coast and windblown dust from exposed ground. However, there is not expected to be significant sources of hydrogen chloride or carbon monoxide in the area. All pollutants have been assessed in isolation.

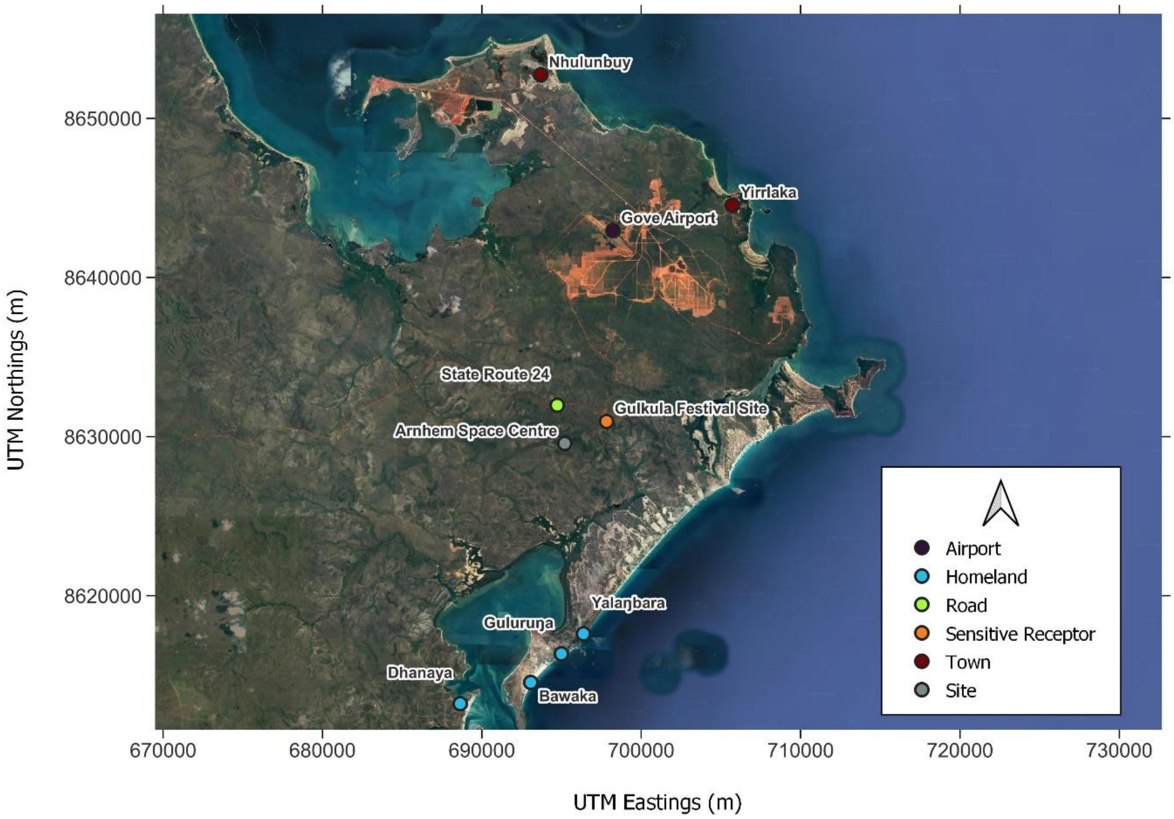

Figure 1 Location of sensitive receptors

4. AIR EMISSIONS PROTOCOL METHODOLOGY

4.1 Overview

The following presents the methodology that has been used to develop the Protocol. The Protocol defines an emissions envelope that has been developed from three simulated rocket launches. These three launches are indicative of the types of launches that will occur at ASC and will span the lower and upper limits of potential emissions from rockets.

Upper limits of emission rates have been defined using dispersion modelling to characterise the emissions from rockets and their transport to sensitive receptors. Predicted air pollutant concentrations have been evaluated against the air quality criteria detailed above.

The Protocol defines maximum emission rates of air pollutants that rockets can produce such that air quality criteria at all sensitive receptors are met.

4.2 Rocket launch modelling

To model emissions from the rocket, the height of the rocket at any time must be known. Both the upwards thrust of the rocket and the downward force due to gravity are considered, whereas resistance due to air is neglected. Taking these factors into account, the height of the rocket over time is modelled via the following equations:

$$z = t\tau + (\mu\tau - t\tau)\, ln\left(1 - \frac{t}{\tau}\right) - \frac{gt^2}{2},$$

$$\tau = T/b,$$

$$\mu = m_i/b.$$

Where:

z is the height of the rocket at time t,

g is the acceleration due to gravity - 9.8 m/s^2

T is the constant thrust of the rocket

b is the burn rate of the fuel and

m_i is the initial total mass of the rocket (mass of the rocket alone with the mass of the fuel).

For static tests, the rockets are continuously fired for a fixed period on the ground.

4.3 Meteorology

Site specific meteorology for input into the dispersion modelling assessment has been generated by TAPM, a prognostic meteorological model developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

TAPM is predicts the flows important to regional and local scale meteorology, such as sea breezes and terrain-induced flows from the larger-scale meteorology provided by synoptic analyses. TAPM solves the fundamental fluid dynamics equations to predict meteorology at a mesoscale (20 km to 200 km) and at a local scale (down to a few hundred metres). TAPM includes parameterisations for cloud/rain micro-physical processes, urban/vegetation canopy and soil, and radiative fluxes.

TAPM (version 4.0.5) was configured as follows:

- Modelling period for one year from 1 January 2018 to 31 December 2018
- 30 x 30 grid point domain with an outer grid of 30 km and nesting grids of 10 km, 3 km and 1 km
- 25 vertical levels
- Grid centred at the site (latitude –12.383°, longitude 136.800°)
- Grid centre point (695695 m E, 8630398 m S)
- Geoscience Australia 9 second DEM terrain data
- Land cover data default
- Default options selected for advanced meteorological inputs.

4.4 Dispersion modelling

Dispersion modelling was conducted using the US EPA regulatory model AERMOD. AERMOD is a steady state gaussian dispersion model that is widely used in Australia. Non-steady state puff models, such as CALPUFF, were considered for use but determined to be not necessary in this instance. The main reasons for choosing AERMOD were the relatively small primary study domain, lack of significant terrain features and intermittent release of emissions associated with a launch event. One of the most significant advantages of a non-steady state model like CALPUFF is its ability to more accurately deal with the potential recirculation or build-up of pollutants over multiple time-steps; however, the very short timeframes for launches mean that this feature is not required.

AERMOD was configured as follows:

- Site specific surface and profile meteorological files extracted from TAPM at the location of the spaceport
- Predictions of ground-level concentrations were modelled without depletion
- Deposition was modelled with depletion.

4.5 Short term averaging

AERMOD models 1-hour average concentrations. Short term averaging periods have been calculated using the following peak to mean ratio (*k*):

$$k = \left(\frac{t_1}{t_2}\right)^{0.2}$$

Where:

t_1 is the averaging period of the model output (60 minutes)

t_2 is the short-term averaging period (15 minutes).

Additionally, to account for emissions being released over a time period much shorter than the 60-minute model averaging time, the following additional peak to mean ratio has been applied:

$$k' = \frac{t_1}{t_2}$$

The composite peak to mean ratio is, therefore:

$$k'' = \left(\frac{t_1}{t_2}\right)^{1.2}$$

The following equation is used to calculate the peak (15-minute average) concentration (C_2) as a function of the predicted 1-hour average concentration (C_1):

$$C_2 = C_1 \times \left(\frac{t_1}{t_2}\right)^{1.2}$$

4.6 Deriving emission rate thresholds

All pollutants are modelled with an emission rate of 1000 g/s and then scaled to derive the final upper emission rates that will define the Protocol. As emission rates are directly proportional to ground-level concentrations, the results of the modelling can be scaled to generate an emission rate that would produce ground-level concentration that match the air quality criteria. This is done via the following equation:

$$ER_{\text{max}} = \frac{GLC_{\text{max}}}{GLC_{\text{model}}} ER_{\text{model}},$$

Where:

ER_{max} is the maximum emission rate allowed to not exceed the maximum ground-level concentration as guided by the air quality criteria (GLC_{max})

GLC_{model} is the ground-level concentration output from the model

ER_{model} is the modelled emission rate.

The maximum allowable ground-level concentration (GLC_{max}) is chosen to be half of the relevant air quality criteria to ensure exceedances never occur. For PM_{10}, a background concentration is also added. This background value represents the existing ambient air quality of the site. The closest monitoring stations to the ASC are in Darwin, where three stations exist. Analysis of 2022 data measuring hourly levels of PM_{10} from all three stations results in a 24-hour average background of 18.8 µg/m^3. While more industrial activities occur in the Darwin region, the close proximity of the bauxite mine is likely to increase levels of PM_{10} to potentially similar concentrations. To be conservative, a background value of 20 µg/m^3 was chosen. The maximum allowable ground-level concentrations are shown in Table 3. Where multiple criteria exist for a single pollutant (e.g., hydrogen chloride), maximum emissions rates for all are calculated and the lowest is chosen to define the emissions envelope for that pollutant.

Table 3 Maximum allowable ground-level concentrations of air pollutants

Pollutant	Averaging Period	GLC_{max} (µg/m^3)
Carbon monoxide	1-hour	15000
	8-hour	5500
Hydrogen chloride	15-minute	3750
	1-hour	70
	24-hour	10
Nitrogen dioxide	1-hour	82
Aluminium oxide (as PM10)	24-hour	15[a]
Table notes: [a]Background concentration of 20 µg/m^3 has been considered in deriving max GLC.		

4.7 Limitations and uncertainty

This study relies on the accuracy of a number of data sets that feed into the dispersion model, all of which will have uncertainties associated with them. The input data sets include:

- Meteorological monitoring observations from the Bureau of Meteorology

- Air quality monitoring observations from the Department of Environment and Science (DES)
- Synoptic and surface information datasets from CSIRO.

It is also important to note that numerical models are based on an approximation of governing equations and will inherently be associated with some degree of uncertainty. The more complex the physical model, the greater the number of physical processes that must be included. There will be physical processes that are not explicitly accounted for in the model and, in general, these approximations tend to lead to an over prediction of air pollutant levels.

The dispersion model has been configured with conservative assumptions and, therefore, the assessment is likely to overpredict potential impacts of the Project.

5. METEOROLOGY

5.1 BoM Gove Airport

The nearest Bureau of Meteorology (BoM) meteorological station is located at the Gove Airport, approximately 12 km to the north-northeast of ASC.

The distribution of winds measured by the weather station is shown as a wind rose in Figure 2. The wind rose shows that winds occur predominantly from the southeast.

The Gove Airport meteorological monitoring station is nearer to the coast than the subject site and, whilst indicative of regional conditions, is not like to be considered representative of the ASC site. Consequently, meteorological modelling has been conducted to produce a site-specific meteorological dataset.

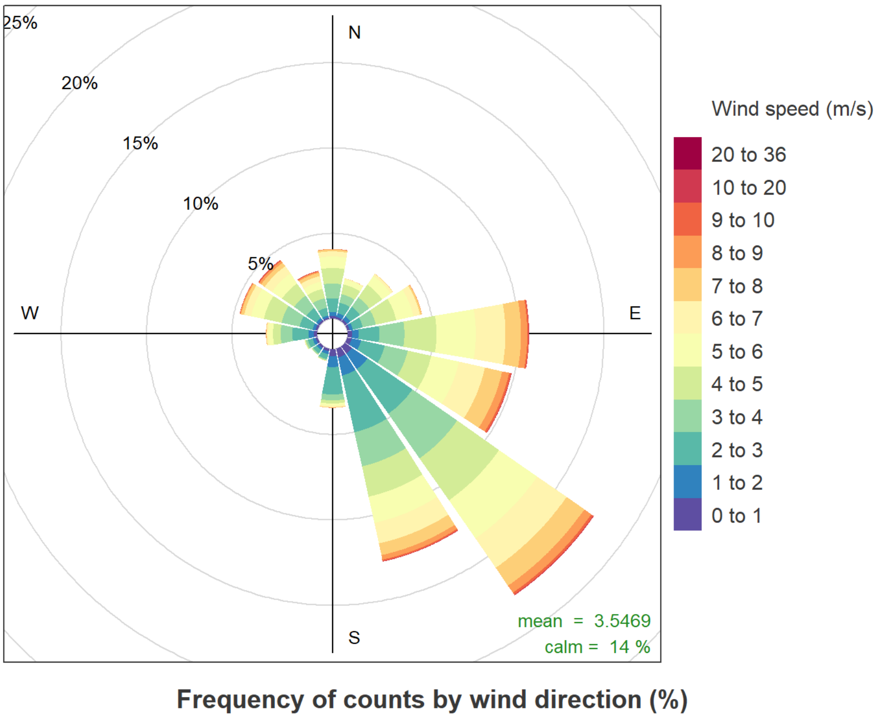

Figure 2 Distribution of winds measured at the BoM Gove AWS between 1991 and 2010

5.2 Model Meteorology

This section provides a description of the meteorology of the Project site using the TAPM meteorological modelling, focusing on parameters that are important for the dispersion of pollutants including wind speed and wind direction, temperature, and mixing height.

5.2.1 Wind speed and wind direction

Wind speed and wind direction are important meteorological parameters that will influence the dispersion of air pollutants from the site. Figure 3 illustrates the annual wind speed distribution at the Project site. Consistent with the long-term winds observed at the BoM Gove Airport weather station (Figure 2), winds occur predominantly from the southeast. Remaining winds are predominantly from the northwest and northeast sectors, with minimal winds from the southwest sector.

The diurnal profile of winds in Figure 4 illustrates minimal diurnal variability in the direction of winds at the site, with the greatest variation being the strength of the winds. Winds during the evening and night (6pm to 6am) are predominantly light and less than 2 to 3 m/s, while the greatest wind speeds are between 4 and 8 m/s and occur during the afternoon period (midday to 6pm). The early morning winds show the transition between the calmer night-time winds and the stronger winds during the afternoon.

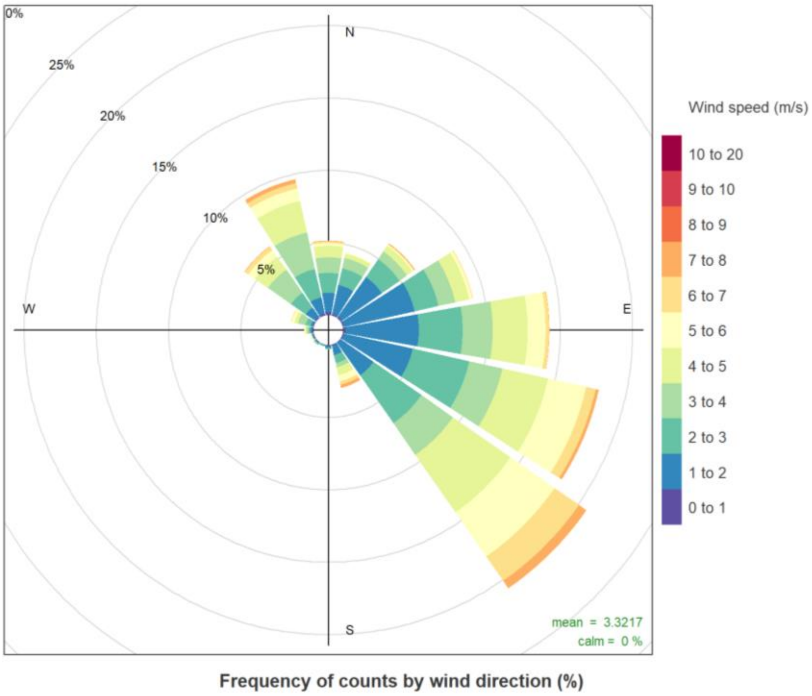

Figure 3 Annual distribution of winds at the Project site (from TAPM)

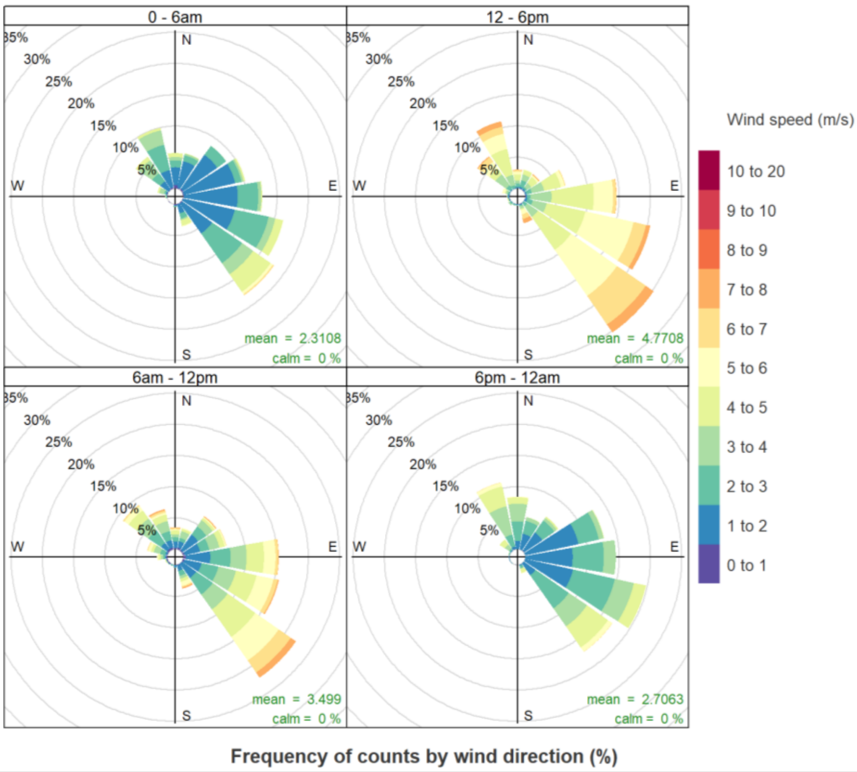

Figure 4 Diurnal distribution of winds at the Project site (from TAPM)

5.2.2 Temperature

Figure 5 and Figure 6 provide the hourly and monthly distributions of temperature at the Project site. Over the 12-month meteorological simulation, the temperature at the Project site was predicted to range between 21.6°C and 33.8°C (average 26.4°C). During winter, the temperature was predicted to range between 21.6°C and 28.4°C (average 24.3°C), and between 24.6°C and 33.8°C (average of 27.9°C) during the summer.

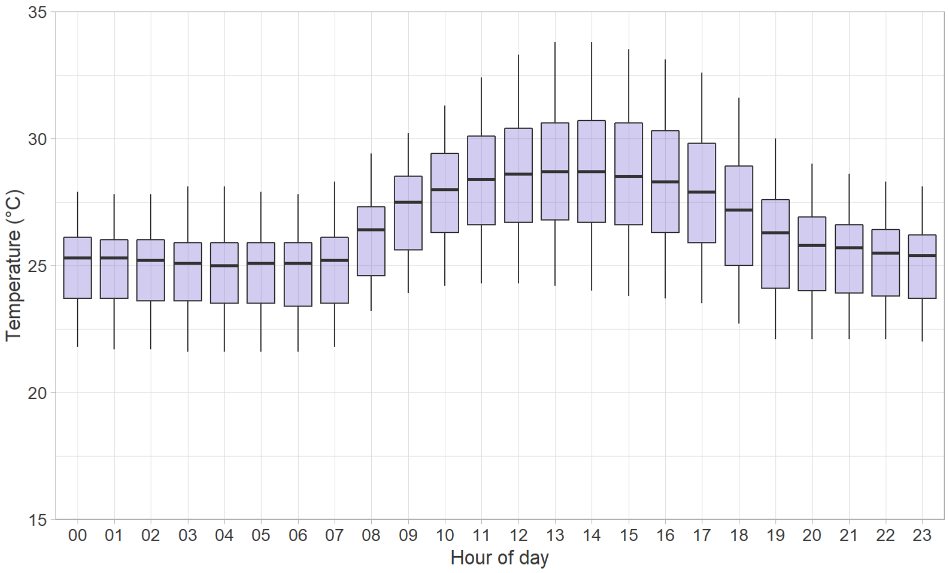

Figure 5 Hourly distribution of TAPM predicted temperature at the site

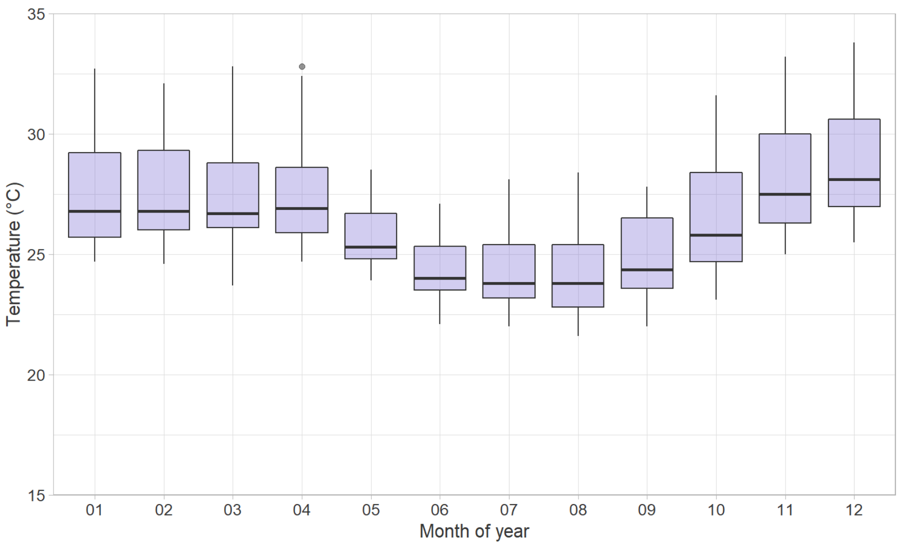

Figure 6 Monthly distribution of TAPM predicted temperature at the site

5.2.3 Mixing height

The mixing height refers to the maximum predicted height above ground within which the air pollutants released at or near ground can mix with the air. During stable atmospheric conditions, the mixing height is often quite low, and dispersion is limited to within this layer (typical night-time conditions). During the day, solar radiation heats the air at ground level and causes the mixing height to rise. The growth of the mixing height is dependent on how well the air can mix with the cooler upper-level air and therefore depends on meteorological factors such as the intensity of solar radiation and wind speed. During strong wind speed conditions, the air will be well mixed, resulting in a high mixing height.

Mixing height information indicative of the Project site has been extracted from the TAPM modelling of the region and is presented in Figure 7. This shows that, on average, the mixing layer begins to develop from a relatively shallow depth overnight at around 8am, reaching a peak height at around 2pm, before decreasing during the late afternoon and evening.

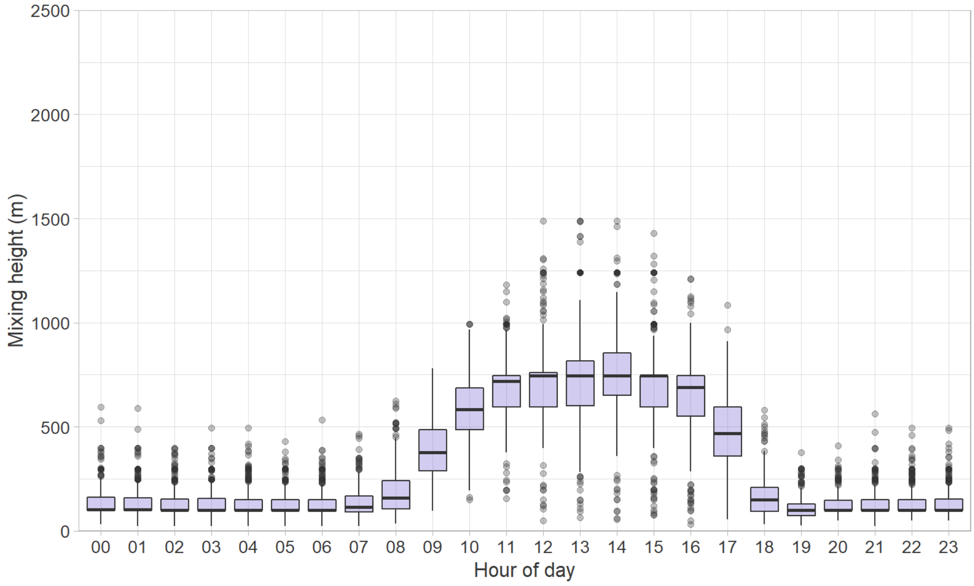

Figure 7 Diurnal profile of mixing height at the Project site (extracted from TAPM)

6. EMISSIONS TO THE ATMOSPHERE

6.1 Launches

The three example rocket launches considered in the Protocol span the potential launch profiles expected at the ASC. To model the rocket as described in Section 4.2, only three parameters need to be specified: the initial mass of the rocket on the launchpad (i.e., rocket and fuel mass), the average thrust during launch and the burn rate of fuel. The parameters for these launches are shown in Table 4 and the height of each example rocket over time is shown in Figure 8 up to a height of 1000m above ground level.

Table 4 Example rockets and their launch characteristics

Parameter	Units	Value	Notes
Example 1			
Total initial vehicle mass	kg	1,189	-
Average thrust	N	65,200	Constant throughout burn period
Propellant rate	kg/s	61	Constant throughout burn period
Burn time (stage 1)	s	13	-
Example 2			
Total initial vehicle mass	kg	36,000	-
Average thrust	N	600,000	Constant throughout burn period
Propellant rate	kg/s	97	Constant throughout burn period
Burn time (stage 1)	s	100	-
Example 3			
Total initial vehicle mass	kg	90,000	-
Average thrust	N	1,100,000	Constant throughout burn period
Propellant rate	kg/s	370	Constant throughout burn period
Burn time (stage 1)	s	200	-

Emissions released above the mixing height will not contribute to ground-level concentrations (i.e., less than approximately 1500m at midday) and hence only stage 1 of the launch needs to be considered (stage 2 typically begins many kilometres above ground).

Modelling emissions from the rocket in AERMOD is done by splitting the launch into many segments. Each segment, defined with a 0.1s timespan[1], is assigned as a volume source emission with an effective height above ground, diameter, emission rate and length (the sigma-z parameter in AERMOD). The effective height of the volume source is defined as the average height of the rocket within the 0.1s timespan and the diameter of the volume source is set to 2m. The Sigma-Z parameter is defined as standard deviation of the equivalent Gaussian envelope that contains the emissions for each trail.

All sources are located at 695,100 m east and 8,629,950 m north (UTM Zone 53S).

[1] The choice of 0.1s was checked to ensure variation of this timespan did not affect the result.

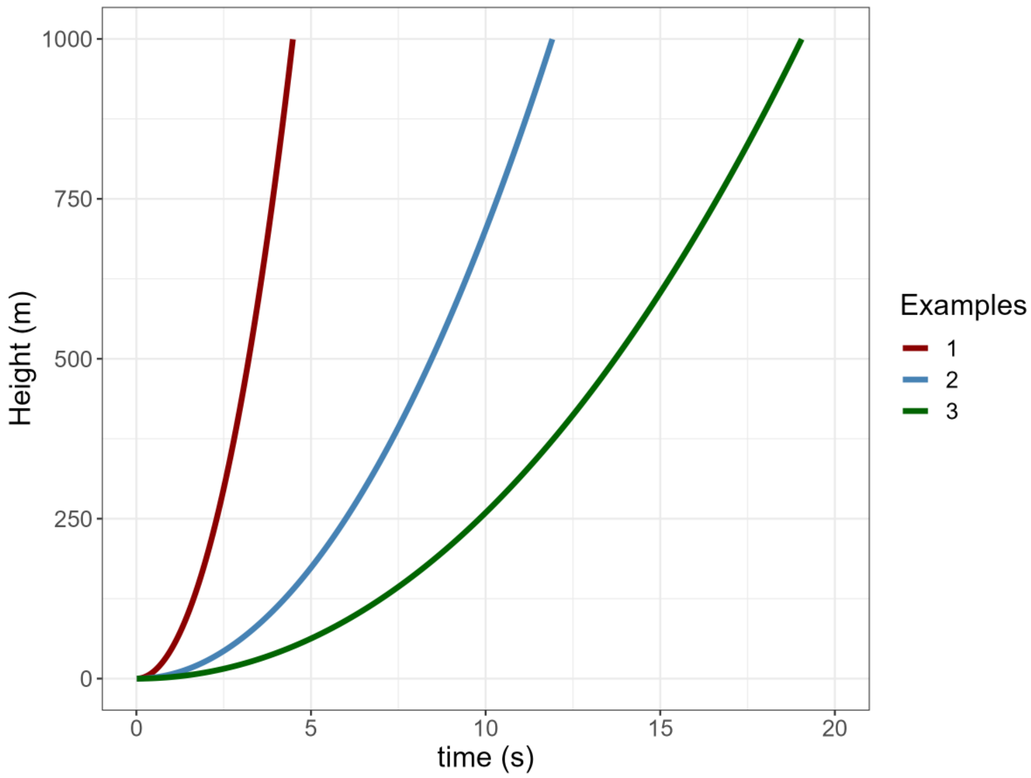

Figure 8 Height of the three example launches over time to an elevation of 1000 metres AGL

6.2 Static tests

Static tests will be a frequent occurrence at ASC. Rockets will be fired at ground-level continuously for a given period. The static test was modelled as a single point source at 20 metres above ground level to account for the buoyancy of the plume with the characteristics shown in Table 5.

Table 5 Static test model source characteristics

Parameter	Units	Value
Height	m	20
Temperature above ambient	K	9
Initial velocity [1]	m/s	6.7
Diameter	m	20
Table note: [1] Modelled as POINTCAP source; initial velocity is input only to determine initial volume flow		

7. RESULTS

7.1 Launches

The emissions envelope for launches is presented in Table 6. For both carbon monoxide and hydrogen chloride, the 1-hour criterion (c.f. Table 1) is the strictest and limits the emission rates most significantly.

The results presented are derived from the maximum ground-level concentration measured over the entire modelled year (i.e., at any time of day in any month of the year). In some jurisdictions and for some pollutants, the 99.9th percentile of measured concentrations is taken as the result, not the maximum. If this were to be case, allowable emission rates increase by over 600%.

Table 6 Emissions envelope for launches

Parameter	Example 1	Example 2	Example 3
Rocket parameters			
Initial Mass (kg)	1,189	36,000	90,000
Thrust (N)	65,200	600,000	1,100,000
Burn Rate (kg/s)	61	97	370
Maximum allowable pollutant emission rates			
CO (kg/s)	472.9	183.3	109.2
HCl (kg/s)	2.2	0.9	0.5
NO_X (kg/s)	2.6	1.0	0.6
Al_2O_3 (as PM_{10}) (kg/s)	11.4	4.4	2.6

7.2 Static tests

The emissions envelope for static tests is presented in Table 7. The results represent the total amount of pollutant allowed to be emitted from a static test within one hour to ensure air quality criteria are achieved. The rate at which the pollutant is emitted does not impact the result.

Table 7 Emissions envelope for static tests

	CO (kg)	HCl (kg)	NO_X (kg)	Al_2O_3 (as PM_{10}) (kg)
Maximum emission in 1 hour	59,778	279	327	1,435

8. CONCLUSIONS

Katestone Environmental Pty Ltd (Katestone) was commissioned by Equatorial Launch Australia (ELA) to develop an Air Emissions Protocol (the Protocol) for the Arnhem Space Centre (the Project).

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The potential pollutants from each launch will depend upon fuel type and the amount of fuel used. Those identified that could make up exhaust fumes include:

- Carbon monoxide
- Hydrogen chloride
- Oxides of nitrogen and
- Aluminium oxide (as particulate matter less than 10 micrometres in diameter).

The Protocol has assigned emission rates to each of these pollutants for three example launches and for a static test. If rockets meet these thresholds, then air quality criteria at all sensitive receptors are expected to be met.

9. REFERENCES

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