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1. General Idea

The market demand for satellite launches in Southeast Asia is increasing. Earth observation satellites, which mostly consist of micro to small payloads, comes out to be the fastest growing sector in the region[1]. However, currently no platform for such payload is available locally for commercial launch.

We want to expand the market by providing access to a convenient and economical satellite launch. Our plan is to be first and most economically friendly option launch platform in Southeast Asia. To achieve this, we will use the method of an air launch platform design.

2. History and Case Studies

Air launches have been here for decades and listed below are difference case studies of companies using that same concept.

- **Pegasus**

Pegasus is an air launched multistage rocket, initially developed by Orbital Sciences Corporation (OSC) and it was launched from a NASA directed airplane[2]. It is the world's first orbital launch vehicle developed by a private organization. It has a maximum altitude of a LEO and has small payloads up to 453 kg[3]. It first flew in 1990, and still remained active as of 2021. From its flexibility to operate from anywhere with minimal ground equipment, Pegasus has been a standard for launching small vehicles in affordable prices. It has conducted around 45 missions, launching nearly 100 satellites.

- **LauncherOne and Cosmic Girl (Virgin Orbit)**

Virgin orbit was a US-based private commercial small satellite launch

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[1] https://www.deloitte.com/southeast-asia/en/services/consulting/perspectives/sea-space-industry-report.html

[2] https://ntrs.nasa.gov/api/citations/20170007919/downloads/20170007919.pdf (page 17)

[3] https://www.northropgrumman.com/what-we-do/space/launch-vehicles/pegasus

provided operated by Virgin Group. It’s air launch system consists of 2 separate systems: LauncherOne, a rocket, and Cosmic Girl, a modified Boeing 747-400 commercial plane[4]. The process starts as Cosmic Girl carrying LauncherOne, and jettisoned it after reaching a desired altitude.

As of January 2023, it has carried out a total of 6 missions, only 4 being successful. The company filed for bankruptcy due to lack of funding. It sold $35 million worth of assets to Stratolaunch, Rocket Lab, and Launcher.

- **Stratolaunch/Roc (Scaled Composites)**

The Stratolaunch or Roc is a large twin-fuselage aircraft built to carry rockets for air-launch[5]. It is intended to carry a payload of around 250,000 kg and has a speed of 5 mach. In one of its missions, it carried a Talon, a liquid-fueled rocked engine, on the center of its wing and jettisoned it off the coast of California.

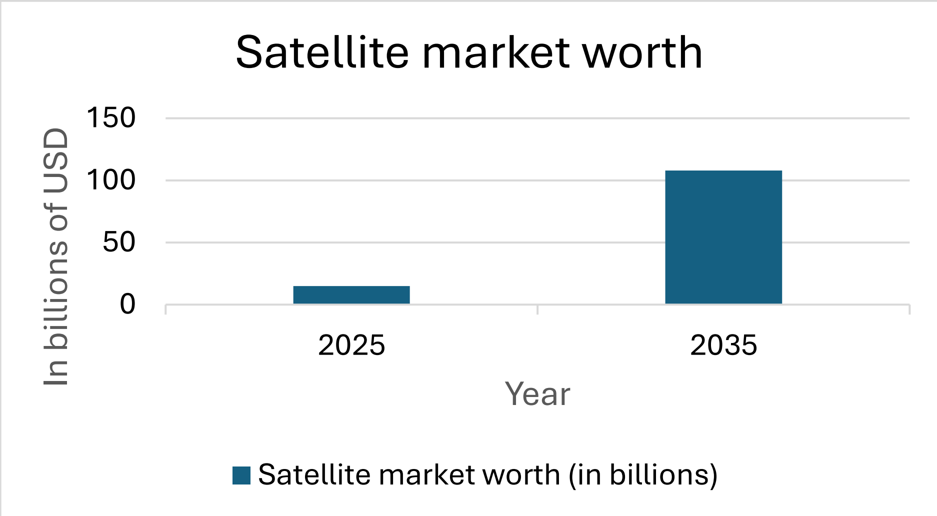
It was originally intended to carry aircrafts for space launches; however, it is now used for launches for reusable hypersonic research vehicles.

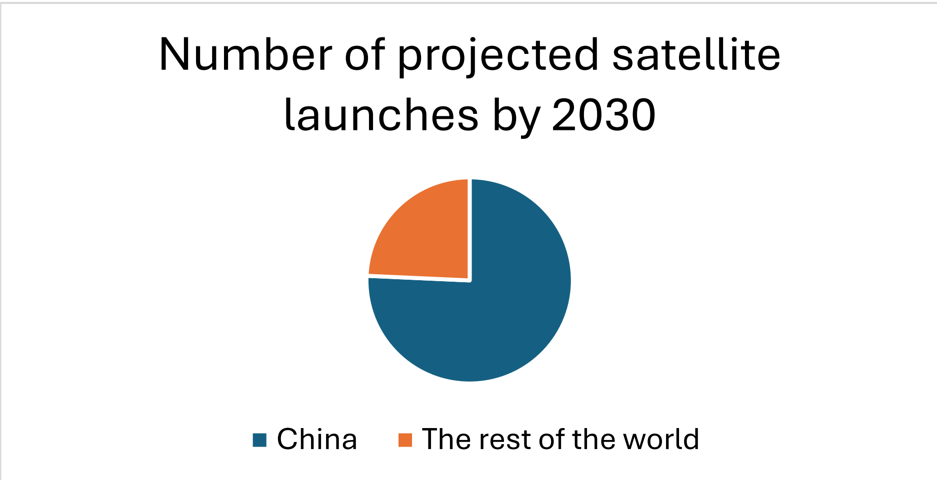
[4] https://www.space.com/42975-virgin-orbit.html

[5] https://apnews.com/article/stratolaunch-hypersonic-flight-test-37aafcd56883a4e0885a5861b30a197e

3. Findings

As of right now, the global satellite market is worth about $15 billion. And by 2035, it is projected to grow to $108 billion. Plus, forecast of satellite launches by 2030 is 70,000. And 53,000 of them would possibly be from China[6].





Initial costs of ground launches can be expensive. SpaceX's Smallsat Rideshare Program, it will roughly cost around $6,600/kg of payload[7]. While still under developments, Space Engine Systems HELLO-1, is expecting to offer $950/kg[8].

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[6] https://www.goldmansachs.com/insights/articles/the-global-satellite-market-is-forecast-to-become-seven-times-bigger

[7] https://www.spacex.com/rideshare

[8] https://www.researchgate.net/publication/374557499_Small_Launchers_-_2023_Industry_Survey_and_Market_Analysis (page 8)

The **History and Case Studies** section projects ends in different ways. One was successful in the industry, one turned bankrupt, and the last changed to a different business direction. Virgin Orbit failed to secure funds because of a failed reach orbit due to a malfunction in its multistage rocket's fuel filter, causing investors to lose confidence in the company[9]. With knowledge from others' history, we believe to we can steer through the obstacles, and that commercializing a sustainable air launch system is attainable.

4. Process

We do this by reusing decommissioned military planes, and modifying them to fit the requirements of being able to carry rockets to fit client's payloads. This gives a second chance to planes that might be scrapped for parts at a junkyard. Less materials would be needed compared to building one from scratch, this helps the environment in reducing the need to farm from a finite natural resource. The planes that can be acquired within a shorter time frame would be the Hercules C-130B, as they have been decommissioned on April 2025[10]. As Indonesia is currently in the process of obtaining new military planes for its fleet, future decommissioned planes would include the F-16 Fighting Falcon, and the Sukhoi 27 and Sukhoi 30.

Secondly, we will be using a locally manufactured rocket RX-450. It is a single-stage, solid-propellant rocket. This is a more economical choice as solid fuel is cheaper, and can be stored for a longer period of time compared to liquid fuel. Our audience will be clients looking to launch small payloads to Low Earth Orbit, which is suitable for soil fuel. Plus, the single-stage rocket is

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9 https://www.newscientist.com/article/2375306-why-has-virgin-orbit-shut-down-and-what-will-happen-to-uk-spaceports/#:~:text=The%20firm's%20troubles%20began%20with,a%20valuation%20of%20$3.7%20billion

10 https://www.tni-au.mil.id/berita/detail/tiga-pesawat-c-130-hercules-tni-au-dinyatakan-berhenti-operasi#:~:text=Tiga%20Pesawat%20C%2D130%20Hercules%20TNI%20AU%20Dinyatakan%20Berhenti%20Operasi,-Oleh:%20Kohanudnas&text=TNI%20AU.,di%20dalam%20maupun%20luar%20negeri.

smaller and less heavy. This is perfect to maximize carrying capacity, and to equip on to the plane; as some planes that we are considering to use are on the smaller side, such as the F-16.

Furthermore, we can use our location to our advantage. This first point being that we are located on the equator. This means that we can use less fuel to reach orbital velocity, because using the Earth's rotation provides a huge initial boost. Next, we chose Frans Kaisiepo Airport in Papua to be the location of our hangar and ground activities. This is strategical because it is surrounded by ocean. The orbital debris will be safely deposited to the ocean.

5. Calculations

1. Ideal rocket equation

$$\Delta v = v_e \times \ln\left(\frac{m_0}{m_f}\right)$$

Δv = change in velocity (ms^{-1})
v_e = exhaust velocity (ms^{-1})
$\ln$ = natural logarithm
m_0, m_f = initial and final mass respectively (kg)

This equation describes the motion of a rocket during its flight and tells us the change of velocity required. The rocket needs an initial mass (rocket mass + fuel) to launch, and as it flies, fuel is constantly ejected, thus the total mass is constantly decreasing.

2. Rocket thrust equation

$$F = \dot{m}v_e + (p_e - p_a)A_e$$

F = thrust (N)
$\dot{m}$ = mass flow rate ($kg\ s^{-1}$)
v_e = exhaust velocity (ms^{-1})
$p_e,\ p_a$ = nozzle exit and ambient pressure respectively (P_a)
A_e = nozzle exit area (m^2)

This equation shows the trust being performed by a rocket.

3. Orbital velocity

$$v_{circ} = \sqrt{\frac{\mu}{r}}$$

v_{circ} = orbital velocity (ms^{-1})

μ = $GM_{earth}(3.983 \times 10^{14} m^3 s^{-2})$
r = distance from center of planet to desired orbit (m)

This equation tells the orbital velocity required for a satellite to orbit around a planet. Orbital velocity is the minimum velocity required by a satellite to maintain a stable orbit around a celestial body.

4. Aerodynamic drag

$$D = \frac{1}{2}\rho v^2 C_D A$$

D = drag (N)
ρ = density of fluid ($kg\ m^{-3}$)
v = flow velocity relative to object (ms^{-1})
C_D = drag coefficient
A = reference area (m^2)

This equation tells us the drag force exerted on a body by a fluid. The drag coefficient is a dimensionless coefficient.

5. Δv budget

$$\Delta v \approx v_{orbit} + \Delta v_{gravity\ losses} + \Delta v_{drag} + \Delta v_{guidance} + \Delta v_{marg}$$

This equation tells us the total change in velocity, taking everything into consideration

6. Orbital Mechanics Technicality

- Launch altitude

  We will be launching the rocket from a height of 7,000m. That would be loaded ceiling of the C-130B. Although the logistics are more difficult to operate than a ground launch, there are a lot of advantages to it. Firstly, the thinner atmosphere creates less drag and friction, saving the plane and rocket fuel. And, it also avoids any issues that the weather might cause, such as lightning and strong winds.

- Launch latitude

  The location of the hangar is at Frans Kaisiepo Airport with it location in Biak, Papua. It is 1.19˚ south, very near to the equator. And launching the rocket from the equator itself will not take much time or fuel because of its proximity. An equatorial launch is preferred due to maximizing the use of the Earth’s rotation, leading to less need for fuel and increasing the plane’s payload capacity.

- Launch speed
  Launching the rocket with initial speed saves rocket fuel and it makes it easier to reach orbital velocity. We will be jettisoning the rocket from the plane at the speed of 520km/h. This is conservatively under the maximum cruising speed of a C-130B, taking the payload of the plane into consideration.

7. Cost Modelling

<table>
<tr><th colspan="2">Cost structure</th></tr>
<tr>
<td valign="top">Initial Capital:
• Fleet
• Modification on fleet
• Renovations/furnishings</td>
<td valign="top">Operational:
• Manpower
• Reparations resources
• Utilities
  ▪ Electricity
  ▪ Water
  ▪ Internet access
• Rent
  ▪ Office
  ▪ Hangar
  ▪ Runway
• Fuel (plane)
• Rockets (single-use)
• Fuel (rocket)</td>
</tr>
</table>

Revenue streams	
Services offered: • Micro-satellite launch • Premium/tiered services • Loans of planes • Loans of crew service	Partnership/sponsorship: • Fuel provider • Academic institutions • Investors • Government funding • PT Dirgantara Indonesia → Local airplane manufacturer* • mu Space Corp → First dedicated satellite factory in Southeast Asia*
*Future possible partnerships	

The estimated cost to operate a C-130B would be at $15,000/hour at its highest, with the lowest being $10,000[11]. And the fuel capacity for the RX-450 is 757 kg[12], with the fuel being at approximately $6/kg. It totals to an amount of $4,542 for a full tank, however with fluctuating cost of HTPB solid propellant, the total propellant cost could go as high as $20,000 to $40,000 per launch. Other costs that would contribute to monthly operations include manpower, maintenance, utilities, hangar, and airport fees, with satellite insurance being a possible addition.

Cost: C-130B	Prices in USD					
Vehicle	Unit cost	Need at launch	Total cost at max capacity			
C-130 fuel and maintenance/hour	15000	1	15000			
Rocket fuel/hour	20000	6	120000			
RX-450	100000	6	600000			
		Total cost	735000			
Load/rocket (kg)	50	Price/kg	2450			
Blue highlighted portion is a variable based on cilents' need						

Youth Orbit would mainly focus on micro-satellite launch in Southeast Asia as

[11] https://ig.space/commslink/c-130-hercules-lockheeds-do-everything-transport

[12] https://www.kompas.id/baca/ilmu-pengetahuan-teknologi/2017/12/11/lapan-pun-merintis-roket-pengorbit-satelit/

its primary revenue streams. Once established, premium or tiered services (such as private rockets instead of ridesharing) could be offered, and further branching into loaning planes and crew service to neighboring nations. To finance the initial capital, investment schemes, and partnerships would be beneficial, especially with the constant use of fuel both for the plane and rocket. Future collaborations with manufacturers of planes and satellites could mean a more cost-efficient option for both Youth Orbit and our clients. Partnership with academic institutions could also be beneficial for both parties since many micro-satellite are launched for research purposes.

8. Comparison with Competitors

Cost of launching satellites per kilogram varies widely between launch providers, with many current launchers set prices above $10000/kg[13]. Many of these launchers offer rideshare services, launching the client's satellites from the same rocket as larger satellites. Some notable exceptions are United Frontiers Discovery-2 which sets a price $2000/kg, SpinLaunch which sets a price of $5000/kg, and Space Engine Systems which sets a price of $950/kg. Space Engine Systems by utilizing their HELLO-1, a reusable spacecraft, sets the lowest price available in 2023, however this UK and Canada-based company is still in developmental stage. Most of these launchers offer not just LEO but also Sun-synchronous orbit (SSO) launch, which despite being the more popular and preferable choice, notably costs more than LEO launch. These launchers also mostly offer services for payloads above 100 kg, and over 70% of these launchers are ground-based.

To calculate running cost of each launch, an estimate of hourly operational cost of C-130B is used, with an estimate of $15,000 per hour, which is inferred from the operational cost of other C-130 planes[14]. This aircraft is expected to be able to carry 6 rockets at full payload. As for the RX-450 rocket, no current

[13] https://www.researchgate.net/publication/374557499_Small_Launchers_-_2023_Industry_Survey_and_Market_Analysis

[14] https://comptroller.defense.gov/Portals/45/documents/rates/fy2022/2022_b_c.pdf

unit price is available, however by referencing other rockets of similar capabilities and capacity an estimate of $100,000 per rocket[15] is achieved. Each rocket is estimated to operate at a full payload capacity of 50 kg, which would result at a running cost of $2450/kg. This is a competitive price within the small satellite market. In addition, our concept of air-launch adds the advantage of a higher rate of payload delivery by utilizing the relative convenience and simplicity of using a plane rather than a ground-launch rocket.

Within Southeast Asia, there currently exist no launching platforms for small satellite. Thus, our presence would benefit the region by providing a more convenient option to launch closer to home. Our usage of decommissioned military plane also means a possibility business model diversification in the future, such as allowing rental fleet, crew, and technician to be flown from each Southeast Asian country locally, not just from Biak, Indonesia.

9. Safety

To make sure our operation runs safely, several standards need to be met. The pilots flying the military aircraft needs to be experienced because of the unstable nature of a C-130 propeller plane. The is no “military pilot license”, so all pilots must be of military personnel that took the training of that respective plane model[16].

Safety in runways requires the need for a monthly payment for a runway service. This includes communication to the air traffic control, ground personnels, and vehicles. The airport crew maintains the gaps and cracks on the runway, making sure it is suitable for flight.

Furthermore, checklists to be completed by the crew regarding the plane, rockets and personnels.

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[15] https://www.newspace.im/launchers/rocket-lab

[16] https://terra-drone.co.id/wp-content/uploads/2020/04/CASR-Part-061.pdf

Our project ensures our flights follows a structured three-phased checklist before flight, during flight, after flight, and post-launch. Plus, we also have procedures on how to respond in the event of an emergency. And it goes as follows:

Pre-flight checklist	
Area	Preparation
Personnels • Pilot • Engineers • Ground engineers	• Safety and mission briefing • Health check
Aircraft	• Fuel check • Load distribution • Systems operating • Confirm no damage
Rocket	• Fuel check • Payload check • Confirm no damage

During-flight checklist	
Area	Preparation
Personnels • Pilot • Engineers • Ground engineers	• Monitor aircraft and rocket
Aircraft	• Check if fuel is depleting normally • Load still strapped in • Systems operating • Confirm no damage
Rocket	• No leakage in fuel • Payload still stable • Confirm no damage

Post-launch checklist	
Area	Preparation
Personnels • Pilot • Engineers • Ground engineers	• Headcount • Track both rocket and payload after separation
Aircraft	• Fuel check • Empty cargo load distribution • Systems operating set for descent • Confirm no damage
Rocket	• Fuel check • Track in orbit • Check last known position
Rocket's Payload	• Check projection into orbit

Post-flight checklist	
Area	Preparation
Personnels • Pilot • Engineers • Ground engineers	• Health check • Final check of systems
Aircraft	• Fuel check • Load distribution • Systems operating • Confirm no damage • Turn off vehicle
Rocket	N/A
Rocket's Payload	• Check arrival to orbit • Check connection to ground system

10. Government Regulations

Law No. 21 of 2013 on Space Activities

Pasal 21:

(1) Instansi Pemerintah Penyelenggara Keantariksaan wajib

menyerahkan metadata dan duplikat data penginderaan jauh kepada Lembaga, kecuali ditentukan lain berdasarkan perjanjian lisensi.
(2) Penyelenggara Keantariksaan, selain Lembaga dan Instansi Pemerintah, wajib menyerahkan metadata penginderaan jauh kepada Lembaga, kecuali ditentukan lain berdasarkan perjanjian lisensi[17].

https://translate.google.com translates this as follows:
Article 21:
(1) Government agencies organizing space activities are required to submit metadata and duplicate remote sensing data to the Agency, unless otherwise specified in the license agreement.
(2) Space operators, other than agencies and government agencies, are required to submit remote sensing metadata to the Agency, unless otherwise specifies in the license agreement.

<u>Government Regulation No. 11 of 2018 on Remote Sensing</u>
Pasal 11:
Sensor adalah bagian dari sistem Penginderaan Jauh bumi berbasis antariksa, yang merekam gelombang elektromagnetik dari semua rentang spektral atau bidang gravimetrik, dan terdiri atas sensor pasif dan sensor aktif[18].

https://translate.google.com translates this as follows:
Article 11:
Sensors are part of a space-based Earth Remote Sensing system, which records electromagnetic waves from all spectral ranges or gravimetric fields, and consist of passive sensors and active sensors.

This shows the government's expectation towards agencies on space activities. Since our clients will be international, and we highly value

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[17] https://www.unoosa.org/documents/pdf/spacelaw/national/UU_Nomor_21_Tahun_2013.pdf

[18] https://www.hukumonline.com/pusatdata/detail/lt5af167cf67dbb/peraturan-pemerintah-nomor-11-tahun-2018/

individual's privacy, we will have to have to tailor the license agreement to meet each clients' plan.

11. Future Prospects and Innovations

Comparison Between a Single Rocket and an Airplane

Falcon 9 has high frequency of launches and long-term viability for transportation of payload in space.

Emissions from Falcon-9 (Zaremba 2017):
The Falcon 9B uses 29,600 gallons of fuel, equivalent to 112,184 Kg, of kerosene per launch (8 Billion Trees 2023) For each kilogram of kerosene burned, 3 Kg of CO2 goes into the air (8 Billion Trees 2023). Manufacturing Kerosene further produces carbon emissions. As 1 kg of kerosene produces 2.7 kg of CO2,
112,184 Kg x (3 + 2.7) = 639448 Kg~ 640 metric tons of CO2 emissions.
That means 640,000 kilograms of CO2 goes into the atmosphere every time Falcon 9 is launched. While that is just an approximation, it paints a picture of what multiple launches would due to the environment.

Zaremba, Haley. 2017. "HuffPost." HuffPost. 8 August.
https://www.huffpost.com/entry/how-much-fuel-does-it-take-to-get-to-the-moon_b_598a35b5e4b030f0e267c83d
2023. 8 Billion Trees. 30 March.
https://8billiontrees.com/carbon-offsets-credits/carbon-footprint-of-space-travel/#:~:text=The%20Falcon%209%20B%20uses,Kg%20of%20kerosene%20per%20launch.&text=For%20each%20kilogram%20of%20kerosene,2%20goes%20into%20the%20air.&text=That%20means%20336%2C552

Boeing 737- The Boeing 737 was used as a model for commercial flights as it is one of the most commonly used airplanes for passenger flights.
Emissions from Boeing 737: (Science Focus)
Boeing 747 uses 7840 kgs of fuel pe5r 250 kms, with 10.1 kg for additional 1 km. Considering that the average flight distance globally is about 981 km, the calculation gives: (Science Focus)
250 + 731 kms= 7840 + 7383.1= 15223~ 15250 kgs of fuel used.

Jet A-1 fuel CO_2 emission rate: 1 kg of fuel produces 3.16 kgs of CO_2
Jet fuels produce about 0.5 kg of carbon emissions from 1 kg of fuel manufactured: (ICAO)
Hence, 15223 x (3.16+0.5) = 55,716 kg~ 55.7 metric tons of CO_2

Pearce, Carla. n.d. Science Focus. https://www.sciencefocus.com/future-technology/how-many-cars-equal-the-co2-emissions-of-one-plane

The contrasts above indicate that rockets generate roughly 11.5 times more carbon emissions during launch compared to airplanes. It's important to note that these numbers can differ based on various factors like model types, duration, objectives, and fuel varieties. However, precise quantitative data on these aspects is absent from the industries' reports, which is why they are not subjected to a comparative analysis in the context of this study.

How Reusable Rockets Impact the Environment

A case study was conducted comparing a non-reusable Falcon 9 and a reusable Falcon Heavy. The two rockets were analyzed using a sustainability assessment that evaluated the environmental, economic, and societal impact of the two rockets. The environmental portion of the study was conducted on a per unit mass basis where the non-reusable Falcon 9 was the baseline. The study demonstrated that the reusable Falcon Heavy reduced costs by 65% and global warming potential by 64%. Global warming potential is an important metric by which different pollution emitters are standardized and used to be compared to one another. A large contribution to Global warming is from the manufacture of a rocket, which is eliminated from reusing the rocket again and again, thus reducing the impacts contributing to global warming (A. Torres 2020)

Torres. 2020. “Reusable Rockets and the Environment.” eScholarship. https://escholarship.org/uc/item/1v52510j.

One of the main factors driving down the cost of space launches is the industry's focus on sustainability and competitiveness. Often, making a product more sustainable also leads to improvements in cost and overall performance.

Fuel Innovation

Kerosene (RP-1) vs. Liquid Methane (LCH4)

https://ntrs.nasa.gov/api/citations/20000065620/downloads/20000065620.pdf

Kerosene, also known as RP-1 (Rocket Propellant-1) or Refined Petroleum-1 is a highly refined form of kerosene, similar to jet fuel. It is a well-established industrial commodity. Its production is integrated into existing, massive oil refinery operations.

Methane (Liquid Methane / LCH4): This is the primary component of natural gas. It must be purified and cryogenically cooled to -162°C (-260°F) to become a liquid.

Chemical & Physical Properties

https://cn.airliquide.com/sites/al_cn/files/2022-08/sds-078a-clp_methane_0.pdf

https://www.researchgate.net/publication/228696033_Comparative_Study_of_Kerosene_and_Methane_Propellant_Engines_for_Reusable_Liquid_Booster_Stages

"Fuel Properties Comparison," U.S. Office of Energy Efficiency and Renewable Energy, DOE/GO-102021-549B, January 2002.

"Handbook of Products," Air BP, 2000.

https://link.springer.com/article/10.1007/s12567-024-00564-w#:~:text=Different%20liquid%20propellant%20combinations%20are,hydrogen%20and%20staged%20combustion%20cycle.

Properties	Kerosene (RP-1)	Liquid Methane (LCH4)	Significance for Propulsion
Chemical Formula	Paraffin and naphthene mixture (~C12H24)	CH4	Methane's simple molecule leads to cleaner, more predictable combustion.
Molecular Weight	172 g/mol	16.043 g/mol	Lighter exhaust products from CH4 contribute to higher efficiency (Isp).
State at Room Temp.	Liquid	Gas (must be stored as a cryogenic liquid)	RP-1 is storable, simplifying ground operations. LCH4 requires complex insulated tanks.
Density (liquid)	0.81 g/cm³	0.42 g/cm³	RP-1 is much denser. For the same mass, LCH4 needs ~92% larger tank volume, impacting vehicle size and mass.
Boiling Point	150-300 °C	-161 °C	LCH4 is a cryogen, leading to boil-off losses and thermal management challenges. RP-1 has no boil-off.
Freezing Point	-40 °C	-182 °C	Both can be used in space, but LCH4 poses greater thermal control challenges.
Specific Impulse (Isp) with LOX	300.1 - 358.2 s	309.6 - 368.9 s	LCH4 provides higher efficiency, meaning more thrust from the same propellant mass.
Heat of Combustion	35 MJ/L	22.2 MJ/L	Although the energy density of Kerosene is slightly higher, most of the advantage that it harbors could

			potentially be later offset due to the fact that the difference in boiling points between Methane and Oxygen is smaller than the difference in boiling points between Kerosene and Oxygen (which has implications on the construction of the rocket body) http://large.stanford.edu/courses/2023/ph240/wu1/
Stoichiometric Mixture Ratio (MR) with LOX	2.6	3.25	An LCH4 engine consumes more oxidizer by mass for ideal combustion, affecting tank size ratios.
Adiabatic Flame Temperature (AFT) with LOX	3,500 K (3,230°C)	3,050 K (2,780°C).	RP-1 burns hotter, creating greater thermal stress on the combustion chamber and nozzle.
Soot (Carbon) Formation	High (Coking)	Very Low / Negligible	This is the critical difference. RP-1 coking requires extensive engine cleaning; LCH4 enables rapid turnaround.
Specific Heat Capacity (Cp)	2.01 kJ/kg·K	2.232 kJ/kg·K	LCH4 is a superior coolant, absorbing more heat per unit mass before vaporizing in the engine cooling channels.

Combustion reaction Kerosene

$C_{12}H_{24} + 18\ O_2 \rightarrow 12\ CO_2 + 12\ H_2O$

Combustion reaction Methane

$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

Environmental Impact

Combustion Byproducts

Emission	Kerosene (RP-1)	Methane (LCH4)	Environmental Winner & Why
Carbon Dioxide (CO_2)	Produces more CO2 per unit of thrust.	Produces less CO2 per unit of thrust.	Methane. While both produce CO2, methane's higher efficiency means less CO2 is emitted for the same mission.
Soot / Black Carbon	High. Incomplete combustion produces significant amounts of black carbon particles.	Very Low. Cleaner, more complete combustion results in negligible soot.	Methane (Massively). This is the most significant differentiator. Soot particles emitted directly into the stratosphere are a potent climate forcer. They absorb sunlight, heat the surrounding air, and can contribute to ozone depletion.
Water Vapor (H_2O)	Produces some water vapor.	Produces more water vapor.	Tie / Complex. Water vapor is a greenhouse gas, but its impact in the stratosphere is complex and shorter-lived. For rockets, its overall climate impact is considered less than that of soot.
Sulfur Oxides & Other Aerosols	Can produce sulfates and other particulates.	Produces virtually none.	Methane. Leads to cleaner exhaust with fewer secondary aerosol effects.

Production & Lifecycle

Kerosene (RP-1)

Source: Crude oil.

Process: Energy-intensive refining, which is a major source of industrial CO_2 emissions and other pollutants. There is no "green" version of kerosene. It is inherently a fossil fuel. While some bio-derived alternatives are being researched for aviation, they are not yet viable or scalable for rocketry.

Methane (LCH4)

Source: Primarily natural gas (fossil fuel), but also biogas from landfills, and wastewater treatment.

Process: Purification and liquefaction, which requires energy but is generally less carbon-intensive than oil refining. Methane can be synthesized using renewable electricity (solar, wind), to split water (H_2O) to get Hydrogen (H_2). Then, combine this H_2 with CO_2 captured directly from the atmosphere to create methane (CH_4). This process is carbon-neutral. The CO_2 released upon combustion is the same CO_2 that was captured from the atmosphere to create the fuel. This creates a closed loop with no net new greenhouse gas emissions.

Sabatier Reaction

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

http://large.stanford.edu/courses/2023/ph240/wu1/

Total Cost of Ownership (TCO)

Factor	Kerosene (RP-1)	Methane (Liquid CH_4)	Cost Impact Winner
Fuel Cost	~$3.29/liter. https://www.dla.mil/Portals/104/Documents/Ene	$1.27/Liter https://www.globalpetrolprices.com/methane	Methane

	rgy/Standard%20Prices/Aerospace%20Prices/E_2023Oct1AerospaceStandardPrices_231019.pdf?ver=MxFp2P7QThfFoanPm84gDA%3D%3D	_prices/#:~:text=Methane%20prices%2C%20liter%2C%2029%2DSep%2D2025%20Methane%20prices%2C%2029%2DSep%2D2025:,substantial%20difference%20in%20these%20prices%20among%20countries.	
Handling & Storage	Stable at room temp. Stores for long periods.	Requires cryogenic tanks & insulation. Boils off over time.	Kerosene
Engine Coking	Leaves sooty carbon deposits in the engine, especially in complex cycles like full-flow staged combustion. Requires extensive cleaning between flights.	Clean combustion. Minimal coking. Drastically reduces maintenance for reusable engines.	Methane (Massively)
Performance (Isp)	Good. Specific impulse (~350 s) is lower than methane.	Better. Higher specific impulse (~380 s). You get more "push" from the same mass of fuel.	Methane
System Density	More energy-dense, allowing for smaller fuel tanks.	Requires larger, heavier, and more complex insulated tanks.	Kerosene

Reusability	Possible, but high maintenance due to coking.	Ideal. The clean-burning nature is a primary driver for its selection in next-gen reusable rockets.	Methane
Future-Proofing	Earth-only fuel.	Can be produced on Mars via In-Situ Resource Utilization (ISRU).	Methane

Reusability and Maintenance

In a complex rocket engine, kerosene can thermally decompose in the pre-burners and cooling channels, leaving behind hard carbon deposits ("coke"). This coking can clog injectors, reduce cooling efficiency, and damage turbopumps. After each flight, a reusable kerosene engine like the SpaceX Merlin requires significant inspection and potentially cleaning.

Methane's clean combustion virtually eliminates coking. This means an engine like the SpaceX Raptor or Blue Origin BE-4 can be designed for rapid turnaround with minimal maintenance between flights. This eliminates the need for harsh chemical cleaning processes, reducing the ground operation's environmental hazard footprint. The reduction in labor, time, and replacement parts is a game-changing economic advantage that far outweighs any minor difference in fuel cost.

Conclusion

For a simple, expendable rocket, kerosene might have a slight overall cost advantage due to simpler vehicle design and handling. For a reusable launch system—which is the key to affordable LEO commercialization—methane is the cheaper option. For any new launch system being designed today, methane is the environmentally responsible choice. It is the only propellant that offers a credible path to a sustainable, high-tempo launch future, making it the winner from an ecological standpoint.

Expansion of Air Launch Fleet (PTDI & Regional Collaboration)

To scale operations sustainably and cost-effectively, we plan to expand its air-launch fleet through a combination of domestic production, regional partnerships, and strategic acquisition of suitable airframes.

PTDI provides a solid foundation for launch-ready aircraft through existing platforms:

- **CN-235** — Medium-range twin-turboprop capable of carrying light suborbital or microsatellite launchers. Ideal for test flights and early operational launches.
- **N-219 Nurtanio** — Lightweight utility aircraft suitable for atmospheric research, payload integration tests, and suborbital missions.

As domestic aerospace capabilities mature, new PTDI-built variants or custom-modified aircraft can enter the fleet to improve payload capacity, fuel efficiency, and operational flexibility.

We aim to establish regional cooperation with institutions such as GISTDA (Thailand), MYSA (Malaysia), VAST (Vietnam) and etc. We can have joint R&D in materials science, avionics, and sustainable aircraft modification. Additionally, we can share design and testing of airframes optimized for air-launch operations, reducing duplication of development costs.

This approach creates a self-sustaining, regionally integrated ecosystem, where Southeast Asian-built aircraft can launch Southeast Asian-developed rockets, strengthening the region’s autonomy.

To maximize operational flexibility and payload diversity, we could explore other feasible airframes, balancing availability, cost, and payload capacity:

1. Medium-lift turboprops

   ATR 72 / Embraer EMB 120 Brasilia — Available second-hand, moderate payload capability (~5–8 tons), useful for smaller rockets or multiple suborbital launches.

2. Jet airliners (narrow-body)

   Boeing 737 / Airbus A320 — Large cabin and wing-loading capacity allow multiple small rocket mounts or larger single payloads. Retired units are relatively affordable for conversion.

3. Military transports

   Lockheed Martin C-130J Super Hercules or CASA/IPTN CN-235/295 variants — Already used globally for air-launch tests, suitable for heavier experimental rockets.

   An-32 / Il-76 (second-hand markets) — Larger options for future multi-rocket or orbital prototype launches.

4. Futuristic / long-term concepts

   Blended-wing or hybrid-electric aircraft — Future sustainable designs capable of carrying multiple methane-fueled rockets.

   Autonomous cargo aircraft — Could allow unmanned high-altitude launches for microsatellites, reducing operational costs.

Each proposed airframe is evaluated based on:

- Payload mass & volume capacity
- Operational altitude and range
- Modifiability for rocket integration
- Cost-effectiveness and availability in Southeast Asia

Next Steps for Fleet Expansion

1. Conduct feasibility studies for each airframe in terms of structural modifications, wing-load analysis, and safe rocket separation.
2. Develop modular launch pods compatible with multiple aircraft types to reduce development cycles.
3. Begin joint regional R&D projects for avionics integration, fuel compatibility, and high-altitude operations.
4. Plan phased fleet deployment: start with existing decommissioned aircraft, integrate PTDI-built planes, and gradually add regional or alternative airframes as capacity increases.

<u>Partnership with BRIN and Regional Institutions for Orbital and Suborbital Research</u>

We aim to strengthen cooperation with BRIN's Rocket Technology Division, which is renowned for the RX-series rockets and experimental sounding vehicles. By combining BRIN's launch expertise with our innovative air-launch platform, this partnership has the potential to accelerate Indonesia's presence in both suborbital and orbital research.

1. Suborbital and Microgravity Research

The collaboration enables suborbital missions that support:

- Atmospheric research: High-altitude measurements of temperature, pressure, ozone levels, and other environmental data.
- Microgravity experiments: Short-duration microgravity conditions for materials science, fluid dynamics, and biological research.
- Reentry and aerothermal testing: Validation of heat shield designs, reentry vehicle performance, and sensor durability under high-G conditions.

These missions provide universities, research centers, and startups with accessible flight platforms, reducing costs and logistical barriers for experimental payloads.

2. Orbital Launch Capabilities

Our partnership with BRIN can facilitate CubeSat and microsatellite deployments into Low Earth Orbit:

- Leverage RX-series rockets as upper stages integrated with our air-launch platform.
- Enable flexible orbital insertion for educational, scientific, and commercial payloads serve as a stepping stone for future multi-stage launchers capable of heavier payloads.

This approach empowers Indonesian researchers and startups to participate in space missions independently, reducing reliance on foreign launch providers.

3. University and Startup Support

The collaboration will lower barriers to space access for academic and entrepreneurial initiatives:

- Offer flight opportunities for experimental payloads, allowing universities to test prototypes and technology demonstrators.
- Provide mentorship and technical support, including payload integration, avionics, and telemetry systems.
- Enable technology incubation, turning experimental designs into commercially viable products or services.

We position ourself as a launch facilitator, enabling small-scale organizations to participate in space missions without heavy upfront investments in infrastructure.

4. Regional and International Partnerships

Beyond Indonesia, we seek to establish strategic collaborations across Southeast Asia and globally, including:

- Regional research centers (e.g., Equatorial Space Systems in Singapore) for joint payload testing, orbital experiments, and data collection.
- Private companies and emerging academic consortia, fostering technology exchange and innovation in satellite systems, launch mechanics, and ground support operations.
- International knowledge transfer, including flight-proven payload integration techniques, telemetry solutions, and mission planning expertise.

These partnerships accelerate joint R&D projects, creating a robust ecosystem for space innovation in the region.

5. Commercial Applications and Market Integration

The BRIN-Youth Orbit collaboration also enables commercial opportunities:

- Research institutions, universities, and startups can access affordable launch services without investing in full-scale launch infrastructure.
- Support for commercial payload demonstrations opens potential revenue streams and encourages private sector engagement in Indonesia’s space economy.
- Integration with regional aerospace initiatives positions Southeast Asia as a competitive and sustainable hub for small satellite launches.

6. Strategic Impact

Through these collaborations, we become a bridge between government research, private industry, and academia, achieving multiple objectives:

- Strengthen Southeast Asia’s competitive position in space operations.
- Promote innovative, sustainable, and commercially viable aerospace solutions.
- Build regional expertise in orbital and suborbital missions, paving the way for larger-scale space projects.
- Ensure that knowledge, skills, and technology remain localized, supporting long-term autonomy in space access.

Global Collaboration and Market Integration

Our operational model is designed to integrate seamlessly with global space initiatives, positioning Southeast Asia as an active participant in the international space ecosystem. By leveraging both governmental and commercial partnerships, we can enhance technological capability, access to space, and market opportunities.

1. Collaboration with NASA and ESA

We align our operations with major international space programs, including:

- NASA’s Small Satellite Launch Initiative (SSLI): Provides universities and startups worldwide with opportunities for CubeSat and microsatellite deployments. We can serve as a regional launch partner, facilitating Southeast Asian payloads’ integration into NASA missions.
- ESA’s Future Launchers Preparatory Program: Supports the development of innovative launcher technologies, propulsion systems, and modular payload architectures. We can collaborate on technology exchange, testing, and demonstration flights, contributing to ESA’s preparatory objectives while gaining access to cutting-edge propulsion research.

Participation in these programs allows us to benchmark standards, safety protocols, and mission planning, ensuring its air-launch platform meets international requirements.

2. Commercial Launch-on-Demand Services

We aim to develop flexible, cost-effective launch solutions for international academic institutions, research labs, and private operators by:

- Offering air-launch and small-rocket services tailored to microsatellites, CubeSats, and experimental payloads.
- Providing rapid integration and deployment options, reducing turnaround times compared to traditional ground-based launches.
- Supporting emerging space startups with affordable access to LEO, creating a new commercial pathway for Southeast Asia.

By facilitating commercial payloads, we strengthen the region's role in the global small-satellite market and encourages private investment in aerospace technology.

3. Linking Regional and Global Players

Our model bridges Southeast Asian aerospace capabilities with global networks:

- Connects universities, research centers, and startups in Southeast Asia with international programs and launch services.
- Promotes cross-border R&D, including collaborative satellite missions, propulsion testing, and payload development.
- Enhances knowledge transfer, allowing domestic aerospace teams to adopt international best practices while contributing regional innovations.

This network effect ensures that Southeast Asia actively participates in shaping international space standards, rather than solely consuming external capabilities.

4. Strategic Impact

Through global collaboration and market integration, we position Indonesia and the wider region as competent, sustainable, and competitive space players:

- Equitable access to LEO: Lowers barriers for academic, research, and commercial payloads to reach orbit.
- Capacity-building: Develops regional expertise in launch operations, mission planning, and payload integration.
- Sustainability and commercialization: Encourages environmentally responsible launch operations and supports commercially viable small-satellite services.
- Regional autonomy and influence: Ensures Southeast Asia contributes actively to global aerospace initiatives and standards.

By combining strategic international partnerships with a robust regional ecosystem, we facilitate the growth of a resilient and self-sufficient Southeast Asian aerospace sector, capable of supporting scientific, commercial, and environmental missions globally.