Enduring Atmospheric Platforms

PROGRAMME THESIS

v 2.0

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CONTEXT

This document presents the core thesis underpinning a programme that is currently in development at ARIA. We share an early formulation and invite you to provide feedback to help us refine our thinking.

This is not a funding opportunity, but in most cases will lead to one — sign up **here** to learn about any funding opportunities derived or adapted from this programme formulation.

An ARIA programme seeks to unlock a scientific or technical capability that

+ changes the perception of what's possible or valuable
+ has the potential to catalyse massive social and economic returns
+ is unlikely to be achieved without ARIA's intervention.

We aim to launch the programme funding call in late 2025, pending approval.

UPDATE: OUR THINKING, EVOLVED

A summary capturing the evolution of our thinking since first publication.

Since publishing this thesis in August 2025 under the name 'Perpetual Flight', we have invited public feedback on our ideas and engaged with experts to challenge and refine our thinking. We've made the following changes as a result:

+ Focus on the needs of communication: Instead of drawing specifications from the wide field of potential applications for long-endurance platforms, our focus is strictly on the requirements of communication. By successfully delivering a solution that meets these communication needs, we will establish a foundation from which we anticipate numerous other applications to evolve.

+ The integrated worldwide telecommunications industry is a trillion-plus market. Rapid growth is anticipated to support £13 trillion to £20 trillion annual economic benefits of AI [1]. This programme's principal goal is to provide a path to low cost, regionally scalable, high performance infrastructure to enable this development.
+ We are explicitly expanding our focus beyond harvesting of atmospheric sources of energy as a means to solving the problem of how to suspend and power communications hardware in the atmosphere.

We've changed the name of the thesis to reflect the programme's evolution.

PROGRAMME THESIS, SIMPLY STATED

In 1957, Sputnik marked the beginning of a new kind of infrastructure, one that operated above the Earth. Since then, satellites have transformed the modern world, enabling global communication, positioning, and Earth observation. But space-based infrastructure carries deep limitations: putting new hardware into orbit typically takes five years or more, and once launched, it is immutable and follows a trajectory that cannot easily be changed. The distance to Low Earth Orbit imposes hard physical constraints — on latency, resolution, power, and persistence — that no amount of engineering can fully overcome.

A new layer of infrastructure, operating persistently within the atmosphere, would overcome these constraints. For an atmospheric alternative to viably integrate with or replace satellites, we need a way to reliably suspend and power communications hardware in the atmosphere. We will use the term High Altitude Pseudo Satellites (HAPS) to describe them. Existing HAPS approaches — using fossil fuels, solar power, or lighter-than-air vehicles — have so far proven too limited, fragile, costly, or impractical to deliver a scalable solution.

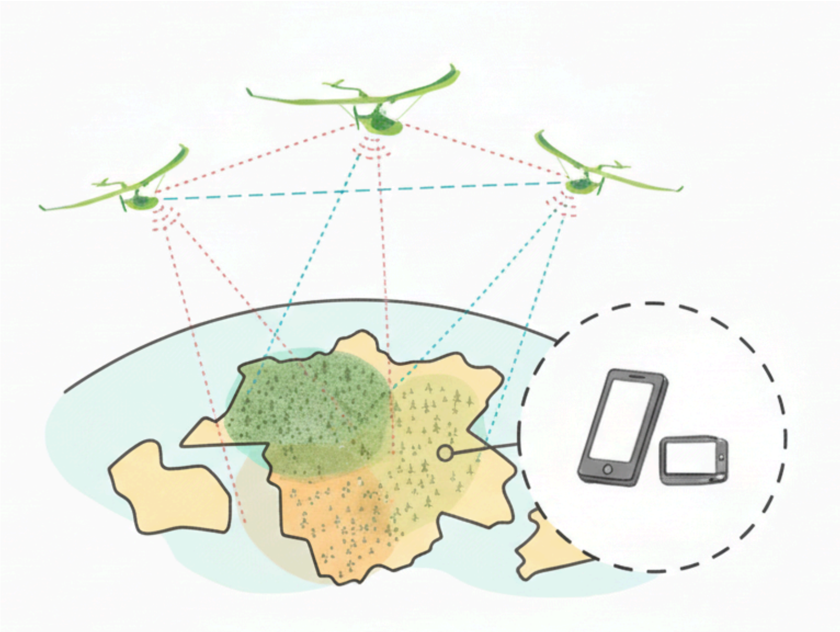

Fig. 1: Artist's vision of airborne communication infrastructure.

If successful, the technology developed in this programme will stimulate massive downstream investment, creating a more competitive, resilient, sovereign, and sustainable digital infrastructure layer between the Earth and space.

This programme is derived from the ARIA Opportunity Space: [Scoping Our Planet](#).

PROGRAMME THESIS, EXPLAINED

A detailed description of the programme thesis, presented for constructive feedback.

Why it's worth shooting for

Communications has been an engine that has driven the space industry since the late 50's. Satellite services have meanwhile become indispensable to modern life, underpinning navigation, global communications, weather forecasting, disaster response, and scientific discovery. The ability to place sensing, communications, and positioning systems in orbit has created tens of trillions of pounds in value and transformed how we live and work.

This programme builds on the thinking of a community that envisions persistent, high-altitude platforms as the enabler of more capable, more resilient, more sustainable, and lower cost sovereign digital infrastructure.

Performance

Much of the utility of satellites comes from their line-of-sight access to large areas of the Earth's surface, something terrestrial assets like cell towers cannot achieve. Yet the vast distances involved mean that signals to and from satellites are subject to a fundamental power penalty that scales with the square of the distance, demanding much higher required Effective Isotropic Radiated Power (EIRP[1]) for equivalent link margins. Furthermore, the closest satellites (in Low Earth Orbit or LEO), orbit so swiftly they can maintain a ground link for mere minutes. Distance further imposes an irreducible latency as signals travel to outer space and back. Signals get distorted by the atmosphere, in particular in the ionosphere. As the demand for real-time data and ubiquitous connectivity grows, the current approach faces a performance ceiling.

Surpassing the hard limits of space infrastructure

Persistent aircraft operating within the atmosphere could offer an opportunity to outperform orbital systems in multiple dimensions. The list below gives a non-exhaustive overview of some of the constraints that atmospheric platforms could overcome.

+ Link Budget, Power, Bandwidth & Hardware: Orders-of-magnitude lower free-space path loss (shorter slant range) from stratospheric platforms reduces the required EIRP to deliver a given service, enabling higher-throughput direct-to-device links, lower device power, and lower antenna gain [8]. For equal quality of service, required EIRP scales with the square of range ($\propto r^2$). Taking ~500 km (LEO) vs ~20 km (stratosphere) gives $\approx(500/20)^2 \approx 600\times$ higher required EIRP from LEO than from a stratospheric node[2]. Beyond path loss, capacity scales with spatial reuse. For a given beam divergence, ground cell area grows $\propto r^2$, so the number of simultaneously reusable beams[3] per region grows $\propto 1/r^2$.
+ Latency: The time required for a signal to travel at the speed of light to outer space and back is a significant barrier for time-critical applications. This delay is a fundamental impediment to real-time robotic control, high-frequency trading, and certain distributed computing architectures. An atmospheric platform reduces this travel time by more than an order of magnitude compared to LEO.

[1] EIRP: A way to express how much power a transmitter effectively 'radiates' once you factor in its antenna's focusing ability (directivity).

[2] This distance-only comparison assumes comparable antenna apertures; in practice, larger antennas (higher directivity) can reduce the electrical power needed.

[3] This reuse advantage assumes comparable apertures and beamwidths. Satellites can deploy larger apertures to narrow beams and reduce footprint.

- Design: Unlike satellites, atmospheric platforms experience less exposure to cosmic radiation and avoid the thermal management challenges of operating in a vacuum [7]. This could make it easier to use robust, commercially available electronics. New challenges arise at high altitudes in the atmosphere, where designs must account for extreme temperatures, low pressure, and high UV levels.
- Persistence, Rapid Deployment: Atmospheric platforms can loiter to persistently serve a target region, unlike low earth orbit satellites that must hand off connections every few minutes. Their persistence over a fixed region also makes spectrum management and network coordination simpler than for fast-moving satellites. Atmospheric platforms could further avoid the 5-year lead times and immutability of space hardware.

Constraints atmospheric platforms could overcome relative to satellites.

Resilience and sovereignty

LEO mega-constellations have strong 'winner-take-all' dynamics, arising not only from cost scaling, but also from spectrum licensing. This leads to heavy dependence on a very small number of (often foreign) 3rd party providers for critical infrastructure. Furthermore, satellite services are becoming increasingly vulnerable to both malicious disruption (through space or hybrid warfare) and inadvertent disruption (from the growing risk of space debris). HAPS based infrastructure has the potential to offer a sovereign and more resilient alternative.

Such infrastructure also offers advantages for security and governance. Because it can be operated entirely within national jurisdiction, it becomes far easier to apply regulatory measures such as mandated routing, lawful intercept, and data protection requirements. This same control enables alignment between civilian, governmental, and commercial services — for example, through prioritisation or 'network slicing' to support emergency communications.

Regional scaling and cost

The cost of regional deployment of HAPS could be 1-2 orders of magnitude lower than the installation of terrestrial (e.g. fibres & cell towers) or satellite (LEO constellations) infrastructure, see Table 2. This is directly or indirectly enabled by the persistent location in the middle atmosphere. HAPS uniquely have a persistent line-of-sight view of ten thousands of square kilometers of the earth, while being orders of magnitude better able to connect directly with terrestrial devices (e.g. phones, IoT devices) than satellites. For illustration, a Starlink user terminal has two orders of magnitude larger size, weight, and power draw than the transmitter and receiver hardware of a phone[4].

HAPS platforms can be deployed incrementally, enabling fine-grained regional scaling and spectrum reuse approaching that of terrestrial networks. This may require larger or more directive payload antennas. Because these platforms are pseudo-stationary relative to the ground, spectrum coordination and integration with existing terrestrial networks are also more straightforward, making regulatory approval and coexistence easier.

Table 3 compares the cost of HAPS based connectivity for a hypothetical developing country as a percentage of GDP. Low operational costs are a prerequisite to commercial sustainability.

[Rough orders of magnitude]	**Terrestrial infrastructure**	**HAPS infrastructure**	**LEO infrastructure**
Transmission radius of a node	1-10 km	100 km	1,000 km
Cost to add a node	£0.1 million (incl. permitting & real estate)	£1-10 million (incl. aircraft and ground station)	£1 million* (In existing constellations, incl. sat, launch, & ground station) *Prohibitive for new constellations (spectrum not available)
Investment to increase *regional* coverage (e.g. England)	£10 billion (+100,000 nodes)	£100 million (+10-100 HAPS)	£1 billion (+1,000 sats)

Table 2: HAPS based communications infrastructure scales regionally at costs significantly lower than terrestrial or satellite solutions. Values give rough order of magnitude indications.

[4] According to the Shannon–Hartley theorem, any nonzero signal-to-noise ratio (SNR) implies a nonzero theoretical data capacity. This underpins recent demonstrations of direct-to-device satellite links, which operate in a severely power-constrained regime. Moving such links out of this regime would require disproportionate increases in satellite transmit power or antenna size, driving up mass and cost. By contrast, high-altitude platforms (HAPS) at ~20 km enjoy roughly a 29 dB path-loss advantage over 500 km LEO satellites at the same frequency, enabling far higher SNR for comparable power.

Example Country 250 m population, 50% unconnected, £300 billion GDP	**[Investment as % of GDP]**	**Terrestrial**	**3rd party satcom provider**	**HAPS**
Up-front investment	Comms infrastructure	12%	0	0.3%
	End user devices	1%	5%	1%
	Digital skills	0.8%	0.8%	0.8%
Annually recurring cost	OPEX	8%	10%	0.1%

Table 3: Estimated cost as percentage of GDP for the rollout and operation of terrestrial, satellite, and HAPS-based communications infrastructure for a hypothetical developing country. Hybrid solutions not shown for clarity's sake. Reflecting the challenges of bandwidth allocation for the creation of new LEO constellations, the values for a sovereign satellite constellation are crossed out and replaced by costs describing a 3rd party solution. High operational costs (OPEX) are a blocker for commercial sustainability

Global LEO constellations such as Starlink and Kuiper benefit from substantial economies of scale arising from mass production of thousands of satellites. However, the manufacturing learning curve for satellites is comparatively shallow: each doubling of cumulative output typically reduces cost by only 5–10%, reflecting the one-shot reliability and high test overhead of space hardware. By contrast, aircraft-like systems such as HAPS can achieve steeper learning rates of 10–20 % per doubling, enabled by shorter iteration cycles, reuse, and more standardised production.

At these rates, a fleet of roughly 1,000 HAPS (corresponding to full European coverage) could achieve cost reductions similar to those realised by 10,000 Starlink-class satellites, despite an order of magnitude fewer units.

Environment

This programme, if successful, could offer a cleaner and more sustainable complement to the rapid growth of Low Earth Orbit satellite constellations.

+ Already today, the carbon footprint of a Starlink subscription amounts to a value reaching 5% of UK per capita CO_2 output

- Aside from the dangers of debris falling to Earth, the exponential rise in rocket launches and growing impacts of space debris on atmospheric chemistry are not well understood
    - The release of black carbon and reactive gases from launch has long been recognised as a concern, spurring research into alternative fuel solutions;
    - Conversely, the continual burn-up of de-orbiting satellites releasing a range of debris has been assumed to be harmless, however, recent evidence surprised the community by showing the accumulation of ozone-destroying compounds far above natural background, the effects of which are as yet unknown [15, 16 ,17]

<u>Benefit to the UK</u>
With success in this programme the UK could
- Become the 1st country to build intra-atmospheric digital infrastructure, uniquely allowing low-cost, low-power persistent connection
    - This could unlock new industries of considerable size [9] (e.g. precision agriculture) in which the UK could become a technology leader
- Have more resilient infrastructure
- Rapidly deploy future technologies with the potential to upend the global strategic balance like quantum sensing or quantum communications
- Reduce reliance on foreign 3rd parties and save hundreds of millions per year in purchases of foreign-owned satellite services
- Move from the current position (leader in solar HAPS with limited application) to leading enabler of regional digital infrastructure, creating high-skilled jobs exporting this technology to the world
- Grow the demand base for global digital services by connecting 3 billion new individuals to the internet and increasing their prosperity

<u>Benefit to the world: reducing digital exclusion</u>
If successful, this programme could enable low cost, low energy connectivity to the unconnected 2.6 billion of the world, bringing together the following aspects
- Requiring 600x less power than a satellite connection, High-Altitude Pseudosatellites (HAPS) enable the use of low power, low-cost communications technologies. This enables overcoming significant adoption barriers:
    - <u>Direct to device</u>: No need for additional hardware (unlike Starlink[5] terminals)
    - <u>Cost of end user device</u>: A device capable of direct-to-HAPS connection[6] could possibly be produced by the million at costs of the order of £1/unit.
    - <u>Cost of subscription</u>: Connectivity at a price point of £1/month appears

[5] While Starlink has demonstrated direct to device capability under highly specific conditions, industry experts remain skeptical of this being a commercially viable offering.
[6] This could enable a diverse range of sensors, monitoring remote and not so remote areas that could enable advances in areas like environmental forecasting and real-time logistics.

        + commercially viable for service providers
        + a worthwhile investment for the extreme poor (7% of monthly income)
    + <u>Access to electricity</u>: The envisioned communications technologies require low power, reducing dependence on the grid
+ Voice-to-chat AI allows overcoming the barrier of <u>digital literacy</u>

The impact could be a significant reduction of global poverty:

+ Mobile banking typically delivers the equivalent of 5–15% of income per year in value by reduction of losses
+ Analogous arguments can be made for access to microinsurance and access to the knowledge of large language models

At the same time, the GDP of the poorest countries could experience significant growth, as a 1% increase in adoption of digital payments corresponds to 6 - 8% GDP increase. The integration of the remaining 2.6 billion unconnected would increase the global market for services by 10%.

STATE OF THE ART (see also footnotes in 'What we aim to fund')

The pull for such a solution has driven major advances in High-Altitude Pseudo-Satellites (HAPS). Lighter-than-air platforms like Google Loon connected hundreds of thousands of users worldwide [2]. Solar-powered fixed-wing aircraft such as Airbus Zephyr have set endurance records of several weeks [3, 4], evidence that long-endurance atmospheric platforms are technically feasible, even if they still face major blockers preventing their commercial viability.

Existing HAPS platforms have significant limitations. They tend to

+ have excessively high costs, driven by aircraft amortization and low aircraft reuse rates
+ need to avoid turbulence as this puts the aircraft at risk
+ have difficulty operating outside the tropics

Lighter-than-air vehicles struggle to hold station, making consistent coverage difficult and leading to low utilisation [2]. Solar-powered HALE (high altitude, long endurance) aircraft require vast photovoltaic surface areas, have extremely low wing loading and ultra-light structures, leaving them vulnerable to structural failure except in the calmest conditions [3]. Even the most advanced solar HALE platforms are constrained by the availability of sunlight at higher latitudes [5] and by the limited specific energy of batteries, which forces deep daily discharge cycles that shorten battery life, capping mission length [3]. Aircraft amortisation dominates operational costs, with 1 in 4 missions ending with aircraft loss [6].

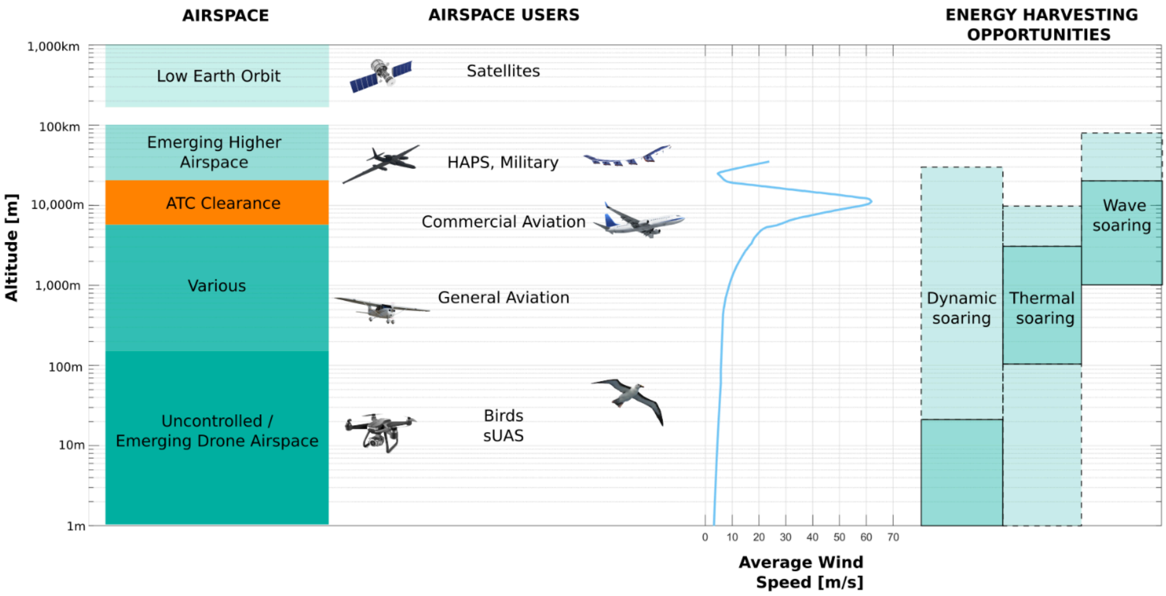

Figure 2: Chart showing atmospheric layers, the aircraft that frequent them, and typical windspeeds. Right hand side: The atmosphere itself contains sources of energy that could potentially be harvested.

WHY NOW

Emergence of enabling technology

A number of technologies are emerging that could make atmospheric communication platforms not only feasible, but commercially lucrative. These include

+ Advances in battery specific energy density[7]
+ Novel radio communications technologies like switch-mode direct-polar radio circuits[8] require 5-10x less power and weigh 2-3x less than state of the art systems. Similarly, free-space optical (FSO) terminals are also making rapid progress.
+ Rapid advances in drone autonomy, accompanied by progress in regulatory acceptance [11]
+ Demonstration of power beaming[9]

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[7] For example, ~450Wh/kg solid state lithium batteries from Amprius. https://rmi.org/the-rise-of-batteries-in-six-charts-and-not-too-many-numbers/#

[8] See for example https://eridan.io/

[9] Beamed Laser Power For UAVs, NASA Dryden Flight Research Center, 2003 link

+ A new generation of AI-driven models can forecast weather at unprecedented resolution and update in minutes. They are approaching the ability to predict the location and strength of wind shear and lift, atmospheric energy sources this programme could exploit.
+ Multifunctional materials and manufacturing techniques that have promise to reduce aerobody size and weight, e.g. load bearing energy storage mechanisms.

Acute need

+ AI is making connectivity even more valuable, while driving up data rates. Future networks will need to deliver data at multiple orders of magnitude higher rates and at a fraction of today's cost per bit. Meeting both requirements simultaneously appears beyond the economics of terrestrial and orbital infrastructure.
+ Satellite services are increasingly subject to jamming, spoofing, and unintentional interference [10]
+ The deployment rate of LEO mega constellations is rapidly accelerating. An atmospheric alternative could allow
    + an environmentally more sustainable future
    + escaping digital feudalism arising from the 'winner takes all' dynamics intrinsic to LEO mega constellations

WHAT WE AIM TO FUND

This programme is open to a broad range of approaches to satisfy the programme's goal of persistent, low cost atmospheric platforms that can hold station while carrying and powering a payload.

Pathways that could suspend and power a 20 kg payload drawing 300 W, while maintaining a line-of -sight connection to a fixed point on the ground could include

+ Harvesting of atmospheric sources of energy[10],
+ Tethered atmospheric platforms [12]
+ Lighter than air vehicles [13]
+ Variable buoyancy driven gliders,

[10] See "Perpetual Flight", ARIA Programme Thesis version 1.0 (https://www.aria.org.uk/media/2g2ayg3u/perpetual-flight-_-programme-thesis-v10.pdf), also SAWES (https://www.scmp.com/news/china/science/article/3326920/worlds-most-powerful-flying-wind-turbine-launched-western-china)

+ Solar powered aircraft[11],
+ Ground powered aircraft rotations, possibly including automated refuelling/recharging,
+ power beaming[12],
+ ballistically launched systems[13],
+ Aircraft exploiting unconventional approaches to remaining aloft, including membranes, aircraft comprised of an aggregation of smaller aircraft, aircraft exploiting the earth's electro-magnetic field, and aircraft exploiting photophoretic effects [14]
+ Well thought-through schemes to exploit 3rd party platforms of opportunity
+ Hybrid approaches combining two or more approaches

In order to be considered, proposals need to show radical differentiation from state of the art and a path to fulfil the programme success metrics.

WHAT WE HOPE TO ACHIEVE: GOALS & METRICS

This programme aims to drop the hourly operating cost of long endurance aircraft by an order of magnitude with respect to the state of the art. It aims to solve the primary blocker of commercial viability of atmospheric communications infrastructure.

Requirements for communications applications

This thesis builds on the assumption that HAPS could uniquely offer significant data rates (10 Mbps or more) direct-to-device connectivity across a region. This programme further aims to do so at costs orders of magnitude lower than existing infrastructure layers. This thesis assumes that satellites' ability to deliver commercially viable direct-to-device connectivity will remain very limited (<100 kbps in realistic scenarios) for the foreseeable future.

The target specifications for a minimum viable, but impactful HAPS connectivity solution appear to be

+ The ability to carry a 20 kg payload drawing 300 W
+ Low cost regional scalability (CAPEX)
+ Low cost regional operation (OPEX)

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[11] State of the art: Airbus AALTO Zephyr, Softbank/Aerovironment Sunglider, BAE/Prismatic Phasa-35, Skydweller Aero

[12] HAPS and Laser Power Beaming: A Marriage Made in the Stratosphere https://powerlighttech.com/haps-and-laser-power-beaming-a-marriage-made-in-the-stratosphere/

[13] State of the art: https://www.longshotspace.com/ and https://www.spinlaunch.com/

- >99.9% reliability

We assume operation at an altitude above general & commercial aviation.

Derived Metrics for Programme Success

The progress of this programme will be measured using the **primary metric**. As the programme progresses, downselects will occur, informed by the **secondary and tertiary metrics** as determined by the programme team who will make use **panels of experts and red teaming** workshops.

Primary metric: Power

Distilled down to a single metric, this programme aims to demonstrate the delivery of 300 W to a payload within a region of interest in the sky (see *Operating Altitude* and *Stationkeeping* below).

Applicants to the central programme effort (TA2) must present a plan to continuously do so for a full week, while maintaining station within line of sight of a fixed point on the ground. Progress throughout the programme will be measured in Wh delivered continuously in pursuit of the goal to deliver 300 W over one week (50.4 kWh), and a plausible plan to achieve delivery of 3 kW over one week (0.5 MWh) in the future. Fractionalized solutions (where the power is not supplied to a single monolithic payload, but rather to multiple of payloads on multiple platforms) are not a priori excluded, provided their techno-economics are competitive.

Secondary metric: Proxies for cost

For many historical efforts of HAPS platforms, costs were dominated by aircraft amortisation. This term, spread over limited endurance, typically significantly exceeded other operational costs. This suggests that the goal of low cost operations can be broken down into a solution that

- Maximizes endurance within range T_{WR}. High endurance can be achieved by a single or a constellation of aircraft, keeping in mind that the off-station fraction of a constellation will also drive cost.
  - Programme Target $T_{WR} > 1$ week
- Minimises the redeployment cost by maximising the reuse rate $R_{redeployment}$ = (recovered missions / total missions) .
  - Programme Target: $R_{redeployment} > 0.95$

+ Maximizes payload fraction $F_{payload}$ =(weight of payload / total weight of platform)
+ Maximizes the utilisation fraction of a constellation $F_{utilisation}$= (# of platforms within range / # of platforms deployed)
+ Minimises customization, such that manufacturing drives rapid progression on the learning curve, lowering costs

In their proposals, TA2 Creator teams must present a techno-economic analysis of their solution tracking these parameters, with a plan to achieve an gross hourly operating (including for aircraft amortization, maintenance, monitoring, and external power/fuel costs) cost below

Programme Target: C_{Gross}< £500 / hour

within the duration of the programme. As they progress in the programme, TA2 Creator teams must update their models and show a compelling extrapolation to achieving C_{Gross}< £100/h in the future.

Aircraft costs are often driven by

+ Regulation & certification
+ Low production volumes, and
+ High reliability requirements

Applicants should understand how their approach bipasses these cost drivers, or at least mitigates their cost impact.

Estimated cost per hour for existing fossil fuel UAVs, existing high altitude long endurance (HALE) platforms, and satellites, in relation to the programme threshold and goal[14].

+ **Fossil-fuel long-endurance UAVs** (e.g., ScanEagle, fully burdened): ~£1,000/hr
  - ~20% of cost is hardware amortization
+ **Solar HALE** (e.g. Zephyr): ~£7,000/hr
  - ~85% of cost is aircraft amortization; 1 in 4 aircraft lost on ascent/descent
  - ~70% of aircraft cost is battery & PV array
  - Battery degradation primary limiting factor capping endurance to 2 months
+ **Enduring Atmospheric Platforms** Threshold: ~£500/hr
  - <25% of cost will be aircraft amortization; loss rate improved to 1 in 20
  - Battery degradation removed as primary blocker to endurance
+ **Enduring Atmospheric Platforms** Goal: ~£100/hr
  - <20% of cost will be aircraft amortization; loss rate improved to 1 in 200
  - Learning curve further drops aircraft cost
  - Regulation enables multiple autonomous aircraft per operator

[14] Rough order of magnitude estimates by programme team and industry experts.

For reference, the estimated hourly costs for satellites (on a per satellite basis) are listed below. Direct 1:1 comparison with the programme's cost threshold and target values is difficult as these values do not account for the (mission specific) precision or quality of the services rendered, or the (mission specific) required number of aircraft/satellites in a constellation.

+ **Basic LEO satellites:** ~£100-500/hr
    - ~20-60% of cost is hardware amortization
+ **Basic MEO satellites:** ~£2,000-5,000/hr
    - ~50-80% of cost is hardware amortization
+ **GNSS satellites (critical infrastructure in MEO):** ~£13,000-18,000/hr
    - ~30-50% of cost is hardware amortization

Tertiary metric: payload weight

TA2 Creators must present a plan to be able to support a payload weighing 20 kg.

Operating altitude

We assume the operating altitude to be above general aviation, yet within the atmosphere. Lower altitude solutions can be accepted provided they

+ Provide a compelling rationale as to how they will integrate with air traffic, and
+ Make economic sense accounting for their reduced slant range.

VLEO and other orbits are excluded.

Stationkeeping

We assume a system must fulfill a stationkeeping requirement of

+ Maintaining line of sight connection to a fixed point on the ground; as individual aircraft (preferred) or as a constellation,
+ Not violate the boundaries of the segregated airspace made available for testing, and
+ Doing so in the geographic vicinity of the UK regardless of season, dealing with the weather conditions that may prevail.

Applicants whose solution does not comply with these requirements must present a compelling rationale explaining why their solution is worth pursuing.

Airspace Integration Strategy

TA2 Creators must include a brief safety strategy explaining how, in a commercially deployed environment i.e. after the programme, integration with commercial and general aviation will be safely achieved considering all elements of their solution (e.g. tethers, laser beams) and all phases of operation (e.g. climb phase, station keeping, likely fault cases on station, and descent/recovery). This should highlight areas where regulation is lacking or immature. This will inform cooperation with TA3 Creators.

Programme Structure: How we aim to fund

The programme's Technical Area (TA) efforts run in parallel, and their numbering (TA1, TA2, TA3) roughly reflects technology maturity levels. TA1 will focus on developing game-changing enabling technologies as components for TA2. TA2 will form the core of the programme with the main efforts of system development, integration, and testing. TA3 will focus on applications and their deployment. Proposers can apply for a single or several TAs.

Collaboration between TAs will be fostered by programme design (see down-select requirements further down), all-hands Creator workshops, and other community building measures.

Applicants to both TA1 and TA2 must present a path to achieving the programme's goals, identify the key technical blockers and bottlenecks to do so, and propose a workplan that solves the most difficult blocker first.

TA1: Enabling Technologies

TA1 applicants will typically be small teams that have the skills and resources to solve the one (or more) most difficult blocker(s). Examples could be a TA1 applicant making the case for

+ Harvesting of energy from gravity waves being the biggest blocker, and proposing an effort to verify the existence, predictability and exploitability of gravity waves
+ Power beaming being the biggest blocker, that if solved makes the rest of the solution comparatively easy. This TA1 Applicant might propose an effort to fully solve the challenges of power beaming relevant to this application
+ A novel, low-cost Lighter-Than-Air airframe or material that solves the key reliability and station-keeping challenges, which have been the primary blockers for past LTA efforts.

TA1 Applicants must make a strong case that once these blockers are solved, the development of the full system will be comparatively low risk. With respect to these blockers, TA1 Creators must propose a suitable metric to measure their progress. Relative to the state of the art, Creators must use this metric to explain how they will achieve a 10x capability improvement within 2 years of project kickoff, with further improvement to a factor 20x.

To be selected for funding, TA1 proposals will ideally have identified and received strong buy-in from the organisations capable of developing the full system once the blockers have been removed. TA1 Creators not able to demonstrate such buy-in and path to a full system will likely be eliminated by DS1.

TA1 Creators must create and maintain a document describing their proposed technologies. This document should target an integration date 26 months after kickoff. It should document the target capabilities, interface requirements, and anticipated COGS (Cost of Goods Sold) at the integration date, as well as 3.5 years after kickoff. This table will form a part of proposals to TA1. TA1 Creators are expected to update and share the table with TA2 & TA3 Creators on a 6-monthly basis. This helps TA2 plan for adoption and integration.
Traction with TA2 Creators will impact down-selection of TA1 Projects: TA1 Creators whose technologies are experiencing 'pull' from TA2 Creators interested in integrating their enabling technology have a lower probability of being eliminated in the down-selects. Strong 'pull' would be evidenced by TA2 Creators updating their planning (as part of their milestone package) to include time and resources for the integration of a TA1 technology, with the TA1 Creator focusing its resources on facilitating the integrating TA2 Creator's success.

TA1 Structure & Down-selection

TA1 is a set of risky bets, of which 1 - 3 are expected to mature into impactful technologies that can be integrated into TA2 to radically improve endurance. TA1 will have decision points at which down-selects will reduce the number of funded teams to the most promising. This will occur in an

+ evaluation starting Month 10 leading to down-selection by Month 12, followed by an
+ evaluation starting Month 24 leading to down-selection by Month 26.

Down-selection will be based on potential impact, success likelihood, and traction with TA2 Creators for integration in their platforms.

TA2: Integration and Testing

TA2 Applicants will typically be larger teams with the skills and resources to develop a system fulfilling the programme metrics and goals. In their proposal they shall identify which is the largest blocker to their success.

TA2 proposals must provide a phased development plan that solves the biggest technical risks early in the programme, and tracks progress against the primary and secondary metrics described above. Within the duration of the programme, Creators are expected to achieve the

+ Primary metric: Demonstrate delivery of 300 W power to a payload in the sky, within line of sight of a fixed point on the ground, over the duration of one week (50.4 kWh), and a plausible plan to achieve delivery of 3 kW over one week (840 kWh) in the future.
+ Secondary and tertiary metrics: TA2 Creator teams must develop a techno-economic analysis, and refine it throughout the programme. This analysis should track the proxy for cost variables listed in Goals & Metrics, and present a path to achieving a gross hourly operating cost of C_{Gross}< £500 / hour within the duration of the programme, and a plan to achieve C_{Gross}< £100 / hour beyond. TA2 Creator teams must also present a plan to achieve a 20 kg payload weight. A panel of experts and red-teaming efforts will use the secondary & tertiary metrics to inform downselect decisions.

TA2 teams are directed to plan for integration of novel technologies or tools developed under TA1 in later phases of the programme. TA2 will also have decision points at which downselects will reduce the number of funded teams to the most promising. Creator teams that do not pass downselect may be considered for continued funding under TA1, providing they have a key technology that they are willing to license to other TA2 Creator teams.

Driven by the assumption that making a newly designed uncrewed aerial vehicle (UAV) airworthy, and establishing efficient flight testing operations takes years, we are recommending that to the extent possible, TA2 teams plan to leverage an existing, proven airframe they can modify, along with access to suitable testing infrastructure and established processes for rapid flight testing. This approach appears better suited for achieving disruptive breakthroughs given the short, four-year timeline of the programme. Exceptions may be considered if the described concerns are addressed in a compelling manner: Such teams should clearly demonstrate they have the expertise to design aircraft and bring them to airworthiness, including establishing suitable flight testing and improvement campaigns. They should present a compelling plan that aligns with the programme's goals and timing.

The 'adapt existing' rather than 'design from scratch' approach above applies also to modelling and simulation tools. A possible approach could be to pair adapted models of aircraft control and weather prediction. Such integrated models could be validated using the results of the measurement-based feasibility milestone, and model outputs then used to demonstrate the abundance and predictability of atmospheric energy. Such a model could further accompany the project's development plans, increasing energy extraction capabilities up to achievement of the programme goals and beyond.

Teams are welcome to propose testing and demonstration environments of their choice, keeping in mind that test & evaluation protocols will be based on conditions typically encountered in the UK's geographic vicinity.

Smaller teams lacking some capabilities are encouraged to collaborate to bridge these gaps. The programme team is open to helping facilitate such collaborations.

This thesis lays out the goals of the programme for operations in the middle atmosphere. The programme is open to other altitude ranges, but Creators must argue a compelling case that programme metrics can still be achieved

The maturity at the end of the programme is expected to be sufficiently high for further pursuit without ARIA funding (be that through commercial viability, the ability to raise venture capital or other forms of funding, or a maturity sufficiently high to become a government-funded programme).

TA2 Structure & Down-selection

TA2 Creator teams must conduct a Proof of Concept demonstration within the first 12 months from kickoff, addressing their project's largest technical risk.

A further milestone at Month 24 will lead to down-selection by Month 26, trimming down the portfolio to a target size of 1-3 TA2 Creators by the end of the programme. Down-selection will be based on Creators' progress against and likelihood to achieve the programme's metrics. TA2 Creators are expected to improve their outlook on success by planning the integration of enabling technologies developed by TA1 Creators. As part of the Month 26 Milestone, TA2 Creators are expected to update their forward looking planning to integrate compelling TA1 technologies, or make a strong case against doing so.

The final testing campaign in Month 37 will allow the TA2 Creators to demonstrate their systems' ability to achieve the target of delivering 300 W (or a distributed equivalent) to a payload while keeping station. This demonstration will gauge the programme's success and position the Creators for third party funding beyond the programme.

TA3: Deployment planning

Viewing this programme's target capability as impactful as satellite technology, TA3 will plan the deployment of enabled communications applications for the world of 2030 and beyond.

TA3 Creators are expected to design the architecture of a solution that exploits the developments of this programme to deliver transformational capability. To do so, they must understand the emerging capabilities of TA2, understand potential customers' and their needs, evaluate what communications and backhaul hardware could be deployed on the platforms to deliver a valuable service, understand the challenges of integrating the hardware on the platforms, determine constellation sizes and deployment concepts, and work out the economics of operations.

TA3 Creators are expected to anticipate the intercept of the outcomes of this programme with the trajectories of novel emerging technologies that could be combined in a disruptively valuable manner.

Over the course of the programme, they are expected to study the technical and commercial viability of their vision, and work with TA2 Creators to understand the gaps and blockers standing in the way of achievement. Over the course of the programme, TA3 will also have decision points at which downselects will reduce the number of funded teams to the most promising.

TA3 Creators will serve as translation partners. Unlike TA1 and TA2 efforts, which involve hardware and software development, TA3 is a desktop exercise in technology foresight, impact determination, and business strategy. TA3 Creators will establish target product profiles, define constellation sizes for the foreseen missions, and explore the legal and regulatory framework required to translate the technology developments and scientific understanding unlocked in TA1 and TA2 into practical deployment. They will coordinate with regulators like the CAA and Ofcom to do so.

TA3 Creators may be large or small organizations or even individuals, possibly enlisting the support of subject matter experts to fill critical skill gaps. Creators could include technology developers, service providers or industry experts with experience in relevant applications such as communications solutions, aerial imagery, PNT or other advanced sensor or photonics solutions.

TA2 Creators should feel a strong incentive to collaborate with TA3 Creators, as a successful TA3 Creator could unlock a new and untapped future market for the technology developed by this programme.

TA3 Structure & Down-selection

TA3 will start with a portfolio of ~5 Creators. TA3 will have decision points at which down-selects will reduce the number of funded teams to the most promising. This will occur in an

+ evaluation starting Month 10 leading to down-selection by Month 12, followed by an
+ evaluation starting Month 24 leading to down-selection by Month 26.

The target portfolio size at the end of the programme is 2-3.

Teaming and collaboration

We expect Creators to be very open to collaboration with other Creators. During the course of the programme, successful Creators in TA2 are expected to increase their potential by collaborating with Creators from TA1 (integrating emerging enabling technologies to increase capability) and TA3 (increasing the commercial value of the platform technology).

TAs: Note applicable to academic institutions

For academic institutions, the process of elimination by down-selection across the TAs will nevertheless operate in line with ARIA policy on funding academics (including PhD students). The programme team will work with those academics to ensure knowledge transfer and value to other Creators.

Programme Partners

In parallel with the creator funding above, we will contract with 1-3 partners who will act as critical enablers for the programme. These partners will provide Creators (in particular TA2 Creators) with essential support services, such as access to UK flight test sites and regulatory expertise, proactively derisking one of the programme's biggest operational challenges.

ASPECTS STILL TO FIGURE OUT

Communications architecture

This thesis presumes that the developed capability leaves space for a broad range of communications solutions, and has avoided solutioneering the individual aspects such as constellation size, technology selection, backhaul planning, and integration with existing infrastructure and regulation. Doing so will be the task of TA3.

What about fossil-fueled, long-endurance aircraft?

~20 hour endurance can be achieved with fossil fuels, yet such platforms have not unlocked fundamentally game-changing applications, perhaps with the exception of warfare. Does this mean long-endurance flight serves little benefit?
Why would the outcomes of this programme be more useful - does increasing endurance from days to weeks, and reducing the cost to below £500/hour make a big enough difference?

Could the atmosphere serve as a reliable energy source to suspend and power payloads?

Answering the question of the abundance (not to mention predictability) of favorable atmospheric conditions has been a challenge. This is in part due to the lack of established metrics to quantify such conditions in a satisfactory way. More surprisingly, it appears that the necessary data is unavailable due to lack of study.

a. How abundant are conditions enabling sustained flight (e.g. gravity waves and wind shear) near the tropopause and above?
b. How much energy needs to be harvested and stored to reliably sustain an aircraft through the times when favorable conditions are absent? How is that best performed?

Airspace integration

The integration of autonomous aircraft with existing air traffic presents two main challenges. The first pertains to development and testing, the latter to adoption into service once mature. TA2 (and potentially TA1) will be faced with the former, probably conducting testing in segregated airspace. TA3 will consider the latter, taking into account potential future regulatory developments.

Spectrum integration

Communications provision from the stratosphere introduces challenges associated with the large ground footprint, variable position, and dynamics associated with handover events between aircraft. Under the TA2 program there is no requirement for spectrum integration other than that necessary for control and monitoring during the test events. This is expected to take place on dedicated frequencies under the advice of the test service provider. TA3 will consider the spectrum integration in service, considering the evolving technical and regulatory environment.

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ENGAGE

Our next step is to launch a funding opportunity derived or adapted from this programme formulation. Click [here]() to register your interest, or to provide feedback that can help improve this programme thesis.

Success in the programme requires multidisciplinary teams. For groups or individuals needing assistance in building these teams, you can register your capabilities and missing expertise to ARIA's teaming tool via the feedback form linked above, allowing us to support matching with other registered teams.